Computational Risk Management

Desheng Dash Wu *Editor*

Quantitative Financial Risk Management

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Computational Risk Management

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Quantitative Financial Risk Management

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Preface

The past financial disasters have led to a great deal of emphasis on various forms of risk management such as market risk, credit risk and operational risk management. Financial institutions such as banks and insurance companies are further motivated by the need to meet various regulatory tendency toward an integrated or holistic view of risks.

In USA, the Global Association of Risk Professionals (GARP), and the Professional Risk Managers' International Association (PRMIA) were established since 1996 and 2002 respectively. In Canada, the Government of Canada, the Government of Ontario and financial sector leaders recently launched the Global Risk Institute in Financial Services (GRi) in Toronto, with the aim of T building on Canada's growing reputation in financial risk management.

Enterprise risk management (ERM) is an integrated approach to achieving the enterprise's strategic, programmatic, and financial objectives with acceptable risk. ERM generalizes these concepts beyond financial risks to include all kinds of risks. Enterprise risk management has been deemed as an effective risk management philosophy. We have tried to discuss different aspects of risk, to include finance, information systems, disaster management, and supply chain perspectives (Olson and Wu 2008a, b, 2010).

The bulk of this volume is devoted to address four main aspects of risk management: market risk, credit risk, risk management from both in macro-economy and enterprises. It presents a number of modeling approaches and case studies that have been (or could be) applied to achieve risk management in various enterprises. We include traditional market and credit risk management models such as Black–Scholes Option Pricing Model, Vasicek Model, Factor models, CAPM models, GARCH models, KMV models and credit scoring models; We also include advanced mathematical techniques such as regime-Switching models to address systematic risk, H-P Filtration techniques to manage energy risks. New enterprise risks such as supply chain risk management are also well studied by a few authors in this volume. We hope that this book provides some view of how models can be applied by more readers aiming to achieve quantitative financial risk management.

Toronto ON Canada
November 2010

Desheng Dash Wu

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Part I
Market Risk Management

Empirical Analysis of Risk Measurement of Chinese Mutual Funds

Ju Yang

Abstract Investment funds in China started in 1991. After 20 years of development, the mutual fund industry is now offering a rich product line for investors. At present, individual investors hold about 90% of the mutual fund with more than 90,000,000 fund accounts. Mutual fund purchasing has become the preferred way of managing money for urban residents in China. This paper study on risk assessment methods of investment fund. An empirical analysis of the selected 15 mutual funds in China is performed with testing models of VaR, Semi-Parameter VaR and GARCH-VaR. After testing of these models, these selected funds demonstrated some of characteristics of China funds. As to risk assessment methods, we find that Semi-Parameter VaR is relatively simple in calculation but the resulting confidence interval is too wide for practical application. Comparatively GARCH-VaR is found to be more rational and precise. GARCH-VaR method has better precision than conventional performance index.

Keywords Mutual funds · Risk management · Semi-Parameter VaR model · GARCH-VaR

1 Introduction

Investment funds in China started in 1991, with the mark as promulgation and implementation of in "Interim Measures for the Administration of Securities Investment Funds" in October 1997. In March 1998 Guotai and Kaiyuan Securities Investment Fund was set up, marking the beginning of securities investment fund and its dominant direction in the industry in China. In 2001, Hua An Innovative Investment Fund started the first open-end fund, marking another stage in China's fund industry development.

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On 29 April 2005, the China Securities Regulatory Commission (CSRC) issued a "The share holder structure reform of the listed companies". It proposed a reform of non-tradable shares which was unique in China's stock market then. Consequently Chinese stock market ended nearly 5 years long of downward trend since June 2001. The Shanghai (securities) composite index rose from 1,160 points (6 January 2006) to 5,261 (28 December 2007). It reached the highest point of 6,124 on 19 October 2007 in the history of the China Securities Index.

By the end of 2007, the total number of funds in China has reached 341 with a total net asset value of 1.9 trillion yuan. Besides the 39 closed-end mutual funds, there are 145 Stock funds, 82 Asset Allocation funds, 40 Money Market Funds, 17 General Bond funds, 5 Short-term Debts, 7 Guaranteed funds, and 6 Conservative Allocation funds.

After 20 years of development, the mutual fund industry is now offering a rich product line for investors. The number of individual investors purchasing mutual fund products has been growing rapidly. At present, individual investors hold about 90% of the mutual fund with more than 90,000,000 fund accounts. Mutual fund purchasing has become the preferred way of managing money for urban residents.

As mutual fund industry experiences continuing growth, research on fund's risk management also step up accordingly. Western traditional performance evaluation and risk management methods are being used widely in China, and being considered as the basis for fund selection and the evaluation of fund manager's ability. Fund management companies put more efforts in branding and influence, also give more focus on fund performance and risk evaluation.

It is of great theoretical and practical significance to scrutinize our study on risk management of China open-end mutual funds after China's "share holder structure reform of the listed companies", and a reasonable assessment on China open-end mutual fund's investment ability in 2006 and 2007.

2 Literature Review

Markowitz (1952) finds the Mean-Variance Theory, Sharpe (1964) sets up the Capital Asset Pricing Modal (CAPM) which is a measurement for systematic risk, and Stephen Ross (1976) puts forward the Arbitrage Pricing Theory (APT). Since then it has been widely accepted to measure the investment return with expected return rate. However, the Mean-Variance Theory, the CAPM and the APT all make certain assumptions, like the stock return rate must be normally distributed. Fama (1965) and Benston and Hagerman (1978) find that the stock return rate has characteristics of skewness and excess kurtosis. For a clear reflection of the characteristics of variance, Engle (1982) presents the model of autoregressive conditional heteroskedasticity (ARCH) which is a better approach for measuring the excess kurtosis of financial timing sequence when the kurtosis of the ARCH distribution is over three under certain conditions. On this basis, Bellerslev (1986) inducts the lagged variable of the residual-variance into the variance equation of

ARCH and sets up the generalized model of ARCH, GARCH(p,q) which settles the problem of parameter estimation in ARCH and is easier for operation.

Risk management has become increasingly important and evolved into related fields for practitioners and academic researchers. Value at Risk (VaR) is one of the most important concepts widely used for risk management by banks and financial institutions. In 1993, Group 30 published the report of “the Practice and Rules of Derived Products” as a result of the research on the derived products, in which Value-at-Risk (VaR) was presented. In 1994, this model was used by J.P. Morgan Company to assess the market risk of different exchanges and business departments. Later, it was widely applied in banks and other financial institutions including insurance agent, stockjobber, fund management company and trust company, etc. It becomes one of the most popular international risk management tools. The literature on VaR has become quite extensive, e.g., Hendricks (1995), Beder (1995), Marshall and Siegel (1996), Fung and Hsieh (1997), Liang (1999), Favre and Galeano (2002). Agarwal and Naik (2004) introduce a mean-conditional VaR (CVaR) framework for negative tail risk. Fuss et al. (2007) examine most of the hedge fund style and prove that the GARCH-type VaR outperforms the other VaR tools. Zhou (2006) compares the VaR with the model VaR-GARCH based on normal distribution, t-distribution and generalized difference (GED) distribution respectively, and finds that the VaR based on GED distribution is more effective than the other two in reflecting the fund risk.

3 Empirical Analysis

Substantial fluctuation in China’s securities market is due to lack of mobility, so it is difficult to get excess earnings in the large-cap mutual funds while it is relatively easier in small-cap mutual funds. For example, the over-large mutual funds from the equity funds and the balanced funds that were established before November 2006 have low yields. The yields of mutual funds over ten billion are lower than the average market. They even suffered a loss from the period from January 23, 2007 to March 15, 2007, while the smaller mutual fund’s performance was above the market average. The average yield of equity fund in the size of more than five billion was 0.56% and −3.17% for those more than ten billion, while average yield of less than one billion was 2.74%. In balanced funds, for the funds with size of more than five billion, the average yield was less than 0 and the scale of 10–30 billion was 2.24% (The Economic Observer Online www.eeo.com.cn on 22 March 2007).

Therefore, the criteria for our mutual fund selection are:

- The scale of the mutual funds should be ranged from one to five billion, reflecting the industry average level.
- The mutual fund should maintain the same size in money raised and the same number of recent shareholders (before 16 January 2008) to keep a stable capital flows.

- The mutual fund should be established before the end of December 2004. We use data from 2006 to 2007 to avoid instability during the early stage caused by non-systematic factors.

There are 29 open-end mutual funds that comply with the above standards.

In order to have a good representation of China's open-end mutual funds, we set the screening standards of the mutual funds to comply with the market distribution of funds, and select the sample funds (Table 1).

Table 1 Characteristic values of statistics of daily return of sample mutual funds

Fund name	Mean value	Standard deviation	Skewness	Kurtosis	ADF test (99%)	JB statistics (test of normality)
HUA AN CHINA A FUND	0.003395	0.016433	−0.95137	5.923691	−8.961	244.3816
CHANGSHENG VALUE GROWTH FUND	0.001887	0.009528	0.068109	6.796228	−9.190	289.8005
E FUND STRATEGIC GROWTH FUND	0.003348	0.016057	−0.66549	4.671298	−8.665	91.67512
CHINA SOUTHERN POSITIVE ALLOCATION FUND	0.002484	0.012744	−0.3803	4.633449	−9.114	65.20379
PENGHUA CHINA 50 FUND	0.002775	0.011392	−0.37229	4.144489	−8.184	37.44072
ABN AMRO TEDA SELECTION FUND	0.003644	0.018091	−0.49916	4.67528	−9.235	76.38125
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	0.003476	0.015328	−0.41465	4.145142	−8.854	40.1483
CHINA INTERNATIONAL ADVANCED FUND	0.003712	0.016969	−0.81915	5.023208	−8.619	136.1126
HARVEST GROWTH INCOME FUND	0.002158	0.009265	0.280176	6.525901	−8.325	255.9816
GALAXY SUSTAINING FUND	0.002516	0.010866	−0.50742	5.821657	−8.457	180.5822
BAOYING FRUITFUL INCOME FUND	0.002329	0.010917	−0.17484	5.365925	−8.095	114.8742
BAOKANG COMSUMPTION PRODUCTS FUND	0.00212	0.009468	−0.69135	8.851189	−8.998	725.978
DACHENG BOND FUND	0.000235	0.00126	2.286258	22.8042	−10.430	8296.714
FULLGOAL TIANLI GROWTH	0.000966	0.003389	0.073283	7.968999	−8.569	496.3079
CHINA SOUTHERN BAOYUAN BOND FUND	0.001452	0.007044	−0.35816	13.35047	−9.518	2161.879

Sample period is from 1 January 2006 to 31 December 2007. Reasons for selecting these 2 years are as follows. In 2006, a reform on equity distribution took place. This has not only solved the differences of interests among shareholders caused by the non-tradable shares, e.g. state-owned shares, but has also brought greater circulation to the market. The introduction of institutional investors has also led mutual fund managers to highly regard the value-oriented investment philosophy. The reform on equity distribution may unify interests of all parties, and vigorously develop the institutional investors. In 2007, the implementation of new accounting standards leads to the revaluation of profitability of listed companies. In addition, the central bank raised interest rates several times and adjusted deposits reserve ratio in the year, and gradually pushed out many measures to stabilize the market including issuing high-quality large companies and adjusting macro-economic control. Also a series of risk hedging, the stock index futures and gold futures were launched that year. Both contributed to the rational behavior in the market, promoting a risk-controlling system and management.

There are both opportunities for operations and challenges for investment ability to the growing open-end funds in China.

"Accumulative net value of fund"(that is, rights recovery net value) represents the net value plus dividend since its foundation and reflects the accumulative yield since the foundation of the fund (minus a face value of one Yuan is the actual yield), and it can directly and fully reflect the fund's performance during the operation period. Comparing to the instant performance of 'the latest net asset value', it reflects the importance of dividend in fund's performance. Therefore, this paper adopts the data as daily funds' accumulative net value in trade dates from 1 January 2006 to 31 December 2007. In order to better reflect open-end fund's liquidity requirement of purchase and redemption, we use the daily yields. There are 483 days totally and we have 482 daily yields in our data.

Daily return of the funds is time series data. Results of ADF (Augmented Dickey-Fuller) test show that the null hypothesis is rejected with 99% confidence and the daily return data is stable. Skewness coefficients are not zero and kurtosis coefficients are generally high, presenting a trend of spike. The spike of Dacheng Bond Fund even reaches to 22. Jarque–Bera test statistic is quite big and the null hypothesis is rejected with 95% confidence, which means the return is not normally distributed.

The advantage of Semi-Parametric VaR calculation lies in the upper and lower limits of 95% confidence interval of VaR can be calculated using the skewness, kurtosis, variance, mean value and Equations (Yang and Peng 2006) without knowing the return distribution. The results are shown in Table 2 (X_U and X_L being the upper and lower limits of 95% confidence interval of VaR, and L being the length of confidence interval).

We find that the skewness of the return and the length of VaR confidence interval are inversely proportional, which means that the higher the skewness, the more clustered the return and the smaller volatility range of VaR interval. As seen in Fig. 1 that the skewness of Dacheng Bond Fund is extremely high, showing it is extremely positively skewed; while its VaR confidence interval length is close to

Table 2 VaR in 95% confidence intervals

Fund name	X_U (%)	X_L (%)	L
HUA AN CHINA A FUND	2.54	−10.36	0.129017
CHANGSHENG VALUE GROWTH FUND	82.83	−1.36	0.841947
E FUND STRATEGIC GROWTH FUND	2.55	−10.74	0.132971
CHINA SOUTHERN POSITIVE ALLOCATION FUND	2.15	−13.83	0.159719
PENGHUA CHINA 50 FUND	1.96	−11.02	0.129814
ABN AMRO TEDA SELECTION FUND	2.98	−15.57	0.185491
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	2.58	−13.51	0.160909
CHINA INTERNATIONAL ADVANCED FUND	2.65	−10.24	0.128913
HARVEST GROWTH INCOME FUND	19.94	−1.23	0.211719
GALAXY SUSTAINING FUND	1.86	−11.68	0.135418
BAOYING FRUITFUL INCOME FUND	1.96	−28.76	0.307191
BAOKANG COMSUMPTION PRODUCTS FUND	1.62	−11.95	0.135763
DACHENG BOND FUND	1.40	−0.15	0.015427
FULLGOAL TIANLI GROWTH	32.88	−0.46	0.333345
CHINA SOUTHERN BAOYUAN BOND FUND	1.27	−25.27	0.265391

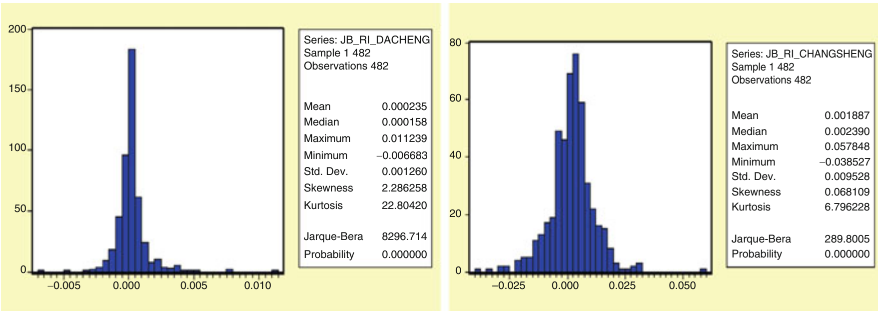

Fig. 1 Diagram of frequency distribution of daily returns of Dacheng and Changsheng

zero and the volatility range is quite small. The skewness of Changsheng Value Growth Fund is almost zero, and its VaR confidence interval length is the longest among all the sample funds.

For each open-end fund, we retest the daily return data to find the number of times (Failure Number) and also the fraction (Failure Rate) of being outside the confidence interval. The results are shown in Table 3.

The failure rate is mainly about 5% and the VaR failure rate of bond funds is relatively lower than stock funds, showing risk return has a high degree of concentration.

In our retest there is always one of the confidence interval limits exceeds the extremum, so we adjust the harmonic value of VaR as in Table 4.

We find that risks and returns of the 15 mutual funds are not directly proportional. Although retest results look good, Semi-Parametric VaR cannot act as an

Table 3 Regression of semi-parametric VaR

Fund name	Failure number	Failure rate
HUA AN CHINA A FUND	23	0.047718
CHANGSHENG VALUE GROWTH FUND	25	0.051867
E FUND STRATEGIC GROWTH FUND	26	0.053942
CHINA SOUTHERN POSITIVE ALLOCATION FUND	28	0.058091
PENGHUA CHINA 50 FUND	27	0.056017
ABN AMRO TEDA SELECTION FUND	30	0.062241
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	32	0.06639
CHINA INTERNATIONAL ADVANCED FUND	26	0.053942
HARVEST GROWTH INCOME FUND	22	0.045643
GALAXY SUSTAINING FUND	22	0.045643
BAOYING FRUITFUL INCOME FUND	23	0.047718
BAOKANG COMSUMPTION PRODUCTS FUND	24	0.049793
DACHENG BOND FUND	18	0.037344
FULLGOAL TIANLI GROWTH	21	0.043568
CHINA SOUTHERN BAOYUAN BOND FUND	21	0.043568

Table 4 Regression value of semi-parametric VaR

Fund name	Standard (%)	Harmonic VaR (%)
HUA AN CHINA A FUND	2.54	−8.16
CHANGSHENG VALUE GROWTH FUND	−1.36	−1.36
E FUND STRATEGIC GROWTH FUND	2.55	−7.47
CHINA SOUTHERN POSITIVE ALLOCATION FUND	2.15	−5.27
PENGHUA CHINA 50 FUND	1.96	−4.08
ABN AMRO TEDA SELECTION FUND	2.98	−8.65
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	2.58	−5.38
CHINA INTERNATIONAL ADVANCED FUND	2.65	−7.13
HARVEST GROWTH INCOME FUND	−1.23	−1.23
GALAXY SUSTAINING FUND	1.86	−5.19
BAOYING FRUITFUL INCOME FUND	1.96	−4.83
BAOKANG COMSUMPTION PRODUCTS FUND	1.62	−6.31
DACHENG BOND FUND	−0.15	−0.15
FULLGOAL TIANLI GROWTH	−0.46	−0.46
CHINA SOUTHERN BAOYUAN BOND FUND	1.27	−4.55

indicator to evaluate risk value because of its no-restriction-on-return-distribution model. So, the results are not acceptable.

Failure rate is satisfactory in the retest as can be seen from the confidence interval of Semi-Parametric VaR, but many VaR confidence interval lower limits of the funds exceed the extremum of the fund returns. This means that they cannot properly reflect the downside risk measures of the funds.

From Table 1 the returns of sample mutual funds do not follow normal distribution. In the distribution of the fund's daily returns, vast majority of kurtosis is 3 and

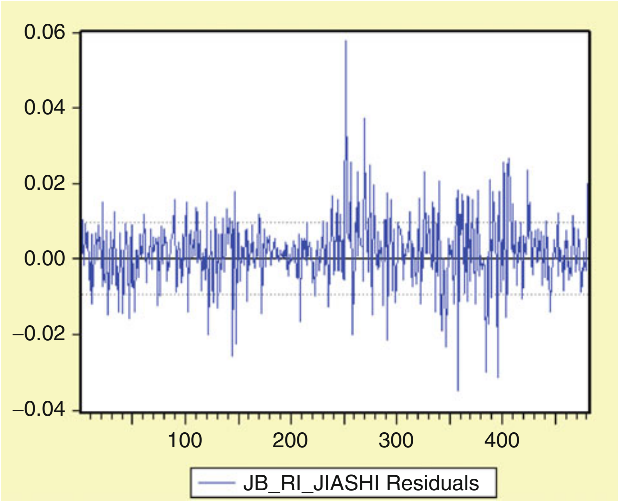

Fig. 2 Diagram of regression residuals of Jiashi Fund

some even reach 22, indicating that the daily return curve presents a shape of "aiguille". Most of the skewness coefficients are non-zero. Furthermore, under the original assumptions (normal distribution of error) Jarque–Bera test statistics should be χ^2 distributed with degree of freedom as 2. Jarque–Bera test statistics of the returns of 15 funds are far greater than the critical value of $\chi^2(2)$ at 5% significance level (that is, the P value of Jarque–Bera test statistics are far less than 5% and close to zero). So we can reject the null hypothesis that returns follow normal distribution, and infer that the distribution of returns has the presence of "fat tail". Therefore the daily returns of the open-end funds appear to be a non-normal "aiguille and fat tail".

In Fig. 2 residuals of fund's returns appear to have the phenomenon of aggregation. Below are the results from the calculation of VaR of the 15 mutual funds through the GARCH(1, 1) model.

According to GARCH(1, 1)'s conditional mean equation and conditional variance equation, we regress on ARCH (residual square lag term ε_{t-1}^2), GARCH (the last variance decomposition σ_{t-1}^2), and conditional variance. The results are shown in Table 5, where α_0 is a constant term, α_1 the coefficient of ARCH (return coefficient), β_1 the coefficient of GARCH (lag variable coefficient), AIC is the criteria for fitness of lag order length, $D - W \approx 2(1 - \rho)$ is the autocorrelation test in regression equation.

GARCH(1,1) model is subject to the assumption that error follows conditional normal distribution, and it is estimated with maximum likelihood method.[1] P value

[1]After the circumstances that sample observation has been obtained, we use the overall distribution parameter of maximum of likelihood function to represent the greatest probability, and this overall parameter is what we require. The method that through maximization of likelihood function we get overall parameter's estimate is known as maximum likelihood method – Gao (2006).

Table 5 Regression coefficients of GARCH conditional variance equation

GARCH-VAR	α_0	α_1	P	β_1	AIC	D-W
HUA AN CHINA A FUND	3.82E-06	0.099047	0	0.891590	−5.470598	2.013669
CHANGSHENG VALUE GROWTH FUND	3.37E-06	0.106762	0.0001	0.861149	−6.569099	1.996649
E FUND STRATEGIC GROWTH FUND	1.07E-05	0.108792	0.0003	0.856017	−5.43977	2.02522
CHINA SOUTHERN POSITIVE ALLOCATION FUND	1.02E-05	0.049182	0.1025	0.889553	−5.881355	1.964589
PENGHUA CHINA 50 FUND	7.99E-06	0.054952	0.0863	0.887043	−6.083192	1.946972
ABN AMRO TEDA SELECTION FUND	8.45E-06	0.111776	0	0.868731	−5.250611	2.038398
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	9.00E-06	0.07478	0.018	0.889795	−5.517308	2.006605
CHINA INTERNATIONAL ADVANCED FUND	1.56E-05	0.090673	0.0009	0.860309	−5.322434	2.003453
HARVEST GROWTH INCOME FUND	1.97E-06	0.088741	0.0006	0.89484	−6.567319	1.932005
GALAXY SUSTAINING FUND	3.41E-06	0.09225	0.0001	0.883013	−6.304452	1.936266
BAOYING FRUITFUL INCOME FUND	4.27E-06	0.076111	0.0018	0.889314	−6.284161	1.963278
BAOKANG COMSUMPTION PRODUCTS FUND	2.78E-06	0.113913	0	0.863038	−6.587039	1.990175
DACHENG BOND FUND	4.56E-07	0.150165	0	0.600431	−10.56455	1.982497
FULLGOAL TIANLI GROWTH	1.87E-06	0.150002	0.1339	0.600000	−8.503482	2.024178
CHINA SOUTHERN BAOYUAN BOND FUND	9.59E-07	0.170944	0	0.831057	−7.336402	2.143479

is the index of statistical significance of regression coefficient. With the exception of China Southern Positive Allocation Fund, Penghua China 50 Fund, and Fullgoal Tianli Growth, majority of the return coefficients and lag coefficients are significant. In addition, lag coefficients β_1's of all funds are bigger than 0.8 except Dacheng Bond Fund, and return coefficients α_1's are less than 0.2. This indicates certain fluctuation exists in daily returns, and that the characteristic of the past fluctuations is inherited in the present time. It will play an important role in all forecasts in the future. Furthermore, funds with $\alpha_1 + \beta_1 < 1$ satisfy the constraints set by parameters of the GARCH(1,1) model, showing its wide stability. Also, funds with AIC value less than -5 reflect the accuracy and simplicity of the GARCH(1,1) model.

Model fitting depends on the existence of autocorrelation and heteroskedasticity phenomenon in the residuals of the model. From the regression all D-W values of the funds are close to 2, so autocorrelation is not present in the residuals. We use

ARCH Test on the residuals for heterokedasticity (using View-Residual Test-ARCH LM Test in GARCH regression), and cannot reject the null hypothesis at significance level of 5%, so we believe there is no heteroskedasticity in residuals (Table 6).

For each fund's GARCH fitting model, we will get the conditional variance sequence using GARCH Variance Series. We then take square root to get conditional standard deviation sequence. In our study we select significance level at 5% and $c_{\alpha} = 1.65$. We can obtain all open-end fund's means and upper and lower limits of the VaR. The test process is the same as mentioned above.

From Table 7 the failure rates remain below 5%, which show good statistical characteristics and accuracy of GARCH-VaR. GARCH-VaR's average is more valuable in referencing than semi-parameter of VaR.

Table 6 ARCH LM test of the return of harvest growth income fund

F-statistic	0.003731	Probability	0.951319
Obs*R-squared	0.003747	Probability	0.951192

Table 7 Risk confidence value of GARCH-VaR

Fund name	Mean value of VaR	Upper limit of VaR	Lower limit of VaR	Failure days	Failure rate
HUA AN CHINA A FUND	0.026968	0.054749	0.014261	24	0.049793
CHANGSHENG VALUE GROWTH FUND	0.015402	0.034924	0.007792	17	0.035270
E FUND STRATEGIC GROWTH FUND	0.026729	0.048500	0.016988	22	0.045643
CHINA SOUTHERN POSITIVE ALLOCATION FUND	0.021092	0.031523	0.014365	15	0.031120
PENGHUA CHINA 50 FUND	0.019060	0.027312	0.013616	21	0.043568
ABN AMRO TEDA SELECTION FUND	0.029790	0.056655	0.016409	19	0.039419
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	0.025492	0.042995	0.017384	20	0.041494
CHINA INTERNATIONAL ADVANCED FUND	0.028232	0.048049	0.019869	23	0.047718
HARVEST GROWTH INCOME FUND	0.015355	0.031437	0.008413	13	0.026971
GALAXY SUSTAINING FUND	0.017636	0.035504	0.008413	18	0.037344
BAOYING FRUITFUL INCOME FUND	0.017581	0.031176	0.008809	21	0.043568
BAOKANG COMSUMPTION PRODUCTS FUND	0.015367	0.039255	0.008558	12	0.024896
DACHENG BOND FUND	0.002106	0.007434	0.001769	8	0.016600
FULLGOAL TIANLI GROWTH	0.004811	0.013586	0.003622	21	0.043568
CHINA SOUTHERN BAOYUAN BOND FUND	0.011179	0.045517	0.004340	15	0.031120

Table 8 Risk return index of GARCH-VaR

Fund name	Risk return index
HUA AN CHINA A FUND	0.122999
CHANGSHENG VALUE GROWTH FUND	0.117452
E FUND STRATEGIC GROWTH FUND	0.122352
CHINA SOUTHERN POSITIVE ALLOCATION FUND	0.114054
PENGHUA CHINA 50 FUND	0.141492
ABN AMRO TEDA SELECTION FUND	0.119697
INVESCO GREAT WALL DOMESTIC DEMAND GROWTH FUND	0.133312
CHINA INTERNATIONAL ADVANCED FUND	0.128722
HARVEST GROWTH INCOME FUND	0.135483
GALAXY SUSTAINING FUND	0.138266
BAOYING FRUITFUL INCOME FUND	0.128062
BAOKANG COMSUMPTION PRODUCTS FUND	0.132899
DACHENG BOND FUND	0.074382
FULLGOAL TIANLI GROWTH	0.184530
CHINA SOUTHERN BAOYUAN BOND FUND	0.122886

As a result it is better for VaR to fit fund's return risk, which is in line with the positive correlation between risks and returns. While GARCH-VaR's fitting of risk better reflects the downside risk measure in actual situation.

From the Table 8 by comparing the risk and returns under GARCH-VaR, we see that FullGoal Tianli Growth, Penghua China 50 Fund and China Galaxy Sustaining Fund have higher profitability, while Dacheng Bond Fund and China Sothern Positive Allocation Fund bear weaker profitability. This conclusion is similar to the Morningstar ratings (http://cn.morningstar.com/main/default.aspx). This shows the feasibility of GARCH-VaR methods in the practical performance evaluation of fund.

4 Conclusion

This paper uses two methods to test VaR on measuring risk and returns of mutual funds. The advantage of the confidence interval of Semi-Parameter VaR is that there is no need to decide the fund return distribution and the calculation is relatively simple (computing the confidence interval based on the statistical characteristics of the risk and returns). However, there is a flaw. Although it has a good result in our retest (with a failure rate about 5, the interval is too wide for practical application. This is evident in the research of Chinese open funds which are more sensitive to the influence of news and policies, and the exact return distribution cannot be concluded in general. Comparatively, GARCH-VaR is more rational and precise. Similar results can be achieved for risk and returns with those from the evaluation of Morningstar (http://cn.morningstar.com).

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Assess the Impact of Asset Price Shocks on the Banking System

Yuan Fang-Ying

Abstract In order to analyze the impact of asset price shocks on the banking system, this paper develops a macro stress-testing framework to assess liquidity risk, credit risk and market risk. Firstly, using the Monte Carlo method to simulate market risk path generated by the financial asset price shocks; secondly, using Morton model to analyze the linkage between market and default risks of banks, while the linkage between default risk and deposit outflows is estimated econometrically; Contagion risk is also incorporated through banks' linkage in the interbank and capital markets. Finally, the framework is applied to a group of banks in China, based on publicly available data as at the end of 2009. Its test results show that: the liquidity risk of the bank system is very low, the probability of no bank default is 99.32%, and the entire bank system is stable.

Keywords Asset price shocks · Credit risk · Liquidity risk · Market risk

1 Introduction

Sub-prime crisis triggered a global financial crisis reflects the interaction of credit risk, market risk and liquidity risk. When U.S. house prices falling, and interest rates rising, the mortgage person burden, default rates increased substantially and thus triggered the value of subprime mortgage-related derivatives (ABS and CDS, etc.) declined, this means credit risk transform to market risk. Then people in the market were of panic. At that time, liquidity had a highly strained, and then caused credit retrench, the vicious cycle of market led eventually the outbreak of the subprime mortgage crisis. After the outbreak of the sub-prime crisis, with the risk of default increased, the interbank lending more difficult, what led the banking system liquidity problems, despite the U.S. government put into a lot of money,

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they could not avoid bankrupt of many financial institutions due to insufficient liquidity.

While the banking systems in most other economies have remained relatively resilient, they are not immune to similar crises because of three common features running through all banking systems. First, banks' balance sheets are inevitably exposed to common market-risk factors, as they generally hold similar financial assets. Thus, significant asset-price declines, even in a single market, could expose many banks to substantial market-risk losses. Secondly, the capital available for banks to serve as a buffer against such losses is limited, as banks usually operate with a relatively high level of financial leverage. This suggests that banking systems in general are vulnerable to multiple default risk during severe market shocks. Thirdly, interbank markets are sensitive to default risk. Significant increases in the default risk of banks could result in tightened interbank markets, creating systemic liquidity shortages.

However, in the literature, stress-testing frameworks capturing the interaction of risks are relatively scant. To fill this gap, this study develops a new stress-testing framework to assess the liquidity risk of banks in this context.

With this framework, daily cash outflows of banks can be simulated given exogenous asset-price shocks. Using the Monte Carlo method, the framework quantifies the liquidity risk of individual banks by estimating the probability of cash shortage and the probability of default due to liquidity problems. In addition, conditional on occurrences of cash shortage and default in the simulations, the first cash shortage time and the default time can be estimated respectively. The corresponding probability of multiple defaults of banks in a banking system can also be estimated, which is an important measure for assessing the systemic risk in the banking system. The framework with two stress scenarios is applied to assess the liquidity risk of a group of 16 listed banks in China with publicly available data.

This study contributes to the literature in three aspects. First, this is among few empirical studies to incorporate interaction of risks in a liquidity risk stress-testing framework. Given that the sub-prime crisis is highly relevant to such interaction of risks, the framework could be useful for policy makers to assess how resilient a banking sector is under liquidity shocks similar to or even severer than those occurred in the sub-prime crisis. Secondly, the framework could serve as a complementary tool to the bottom-up approach for liquidity-risk stress testing. This is particularly so in view of the difficulty to incorporate contagious default risk under the bottom-up approach. By contrast, default risk of banks is indigenized in this framework and contagious default risk is thus possible through interbank and capital markets. The proposed framework can be readily applied to other banking system as the required input data are publicly available.

The reminder of the paper is organized as follows. The stress-testing framework is outlined in Sect. 2. Sections 3 and 4 discuss the data and the specifications of the stress scenarios respectively. Section 5 presents the stress-testing results for the Chinese banking sector and Sect. 6 concludes.

2 Liquidity Risk Macro Stress-Testing Framework

The stress-testing framework consists of two parts: (Aragones et al. 2001; Jackel 2002; Jarrow et al. 2003; Merton 1974; Segoviano and Padilla 2007)

1. An application of the Monte Carlo method to generate market risk shocks for different assets.
2. A system of equations which characterizes the interaction of risks and facilitates estimations of the evolution of balance sheet items, cash flows, default risk and liquidity risk of individual banks in the face of the market risk shocks.
3. Based on the simulated market-risk shocks and the system of equations, the liquidity risk indicators can be estimated for individual banks.

2.1 Monte Carlo Simulations of Market Risk Shocks

Monte Carlo is a kind of computer simulation method, which is based on "random number" is calculated. The main mathematical thinking of this way is actually very simple and intuitive. It can generally be described as follows: first, with the establishment of a probability model for solving problems related to making the necessary requirements solution value or it can be expressed as a function of the model is the mathematical expectation, then the model is a lot of random observations, and finally with the sampling random variables generated by the arithmetic mean of the solution as an approximation of the letter. The basic steps of Monte Carlo simulation are as follows:

1. According the real problem for a simple and easy to set up the probability model, so the result is exactly what we seek solutions of the probability distribution of the model or a digital features, such as the probability of a certain event, or the expected value of the model;
2. On the model established sampling random variables, the computer simulation tests, taking enough random numbers, and the incident statistics;
3. To analyze the simulation results, the solution is given by the estimate and its precision (variance) estimates;
4. If necessary, we can improve the model to improve the efficiency of estimation accuracy.

The Monte Carlo simulation method is adopted to generate market-wide stress scenarios to examine the liquidity risk of banks. The main source of the stress is from asset-market disruptions. In each stress scenario, we assume that there is a prolonged period (i.e., 1 year) of negative exogenous asset-price shocks in some major financial markets, including debt securities, equities, and structured financial assets. Each stress scenario can be treated as a prolonged period of market-wide fire sales of financial assets. The asset-price shocks are simulated from their historical price movements, when the respective asset prices had declined significantly.7 For debt securities, the shocks are imposed by simulating future paths of the risk-free interest rate, credit spreads of AAA, AA, A, BBB, and high-yield non-financial corporate bonds. Shocks for equities and structured financial assets are simulated from some selected price indices. Since the shocks are based on their historical movements, the magnitude of the shocks varies across asset classes. Banks' asset value is assumed to be MTM on a daily basis. The across-the-board declines in asset prices lead to decreases in the MTM value of banks' assets, although the exact impacts vary across banks due to different asset compositions.

2.2 Market-Risk Equations, Default-Risk Equations and Liquidity Risk Equations

In the framework, we assume that there is a prolonged period (i.e., 1 year) of negative exogenous asset price shocks in some major financial markets, which affect banks' liquidity risk through three channels: (1) increases in banks' default risk and deposit outflows; (2) reduction in banks' liquidity generation capability; and (3) increases in contingent drawdowns. Default risk of banks is endogenously determined using a Merton-type model in the framework (Blaschke et al. 2001; Briys , de Varenne, 1997).

2.2.1 Market-Risk Equations

The equations for the market risk mainly consist of the MTM equations for different asset classes, which link up the exogenous asset-price shocks with the MTM of individual banks' assets. In the system of equations, banks' assets are divided into the following types: interbank lending, loans to customers, financial investment and other assets. Financial investment, which is subject to the exogenous asset price shocks, is further broken down into debt securities, equities, structured financial assets and other financial assets. Debt securities consist of three types, sovereign, bank and corporate issuers. Debt securities issued by corporates are further broken down by credit ratings (i.e., AAA, AA, A, BBB, and speculative grades (including unrated)). There are two groups of equities: China equities and non-China equities. Except for cash and other assets, all assets are assumed to be MTM on a daily basis. The MTM methods of banks' financial investment are as follows:

The MTM value of the debt securities are essentially determined by the following formula, with different specifications on the default-adjusted interest rate at time t, R_t^k,

$$V_{t,T}^k = X_T^k \exp\left[-R_t^k(T-t)\right] \tag{1}$$

Where $V_{t,T}^k$ is the MTM value of an asset k at time t, with time to maturity (T−t). X_T^k is the face value of the asset at maturity. $R_t^k = r_t + el_t^k$, where r_t is the interbank interest rate at t; el_t^k is the expected default loss rate of asset k at t, which is equivalent to $h_t^k L^k$, where h_t^k is the default hazard rate and L^k is the loss-given-default of asset k. We assume that L^k is time-invariant. Based on (1), the percentage changes in the MTM value of asset k from time t to t + Δt can be approximated by the following equation as Δt is very small.

$$\begin{aligned} \ln\left(V_{t+\Delta t,T}^k\right) - \ln\left(V_{t,T}^k\right) &= -\Delta R_{t+\Delta t}^k (T - t - \Delta t) \\ &= -\left(\Delta r_{t+\Delta t} + \Delta el_{t+\Delta t}^k\right)(T - t - \Delta t) \end{aligned} \quad (2)$$

where $\Delta R_{\mathrm{t}+\Delta t}^k = R_{\mathrm{t}+\Delta t}^k - R_t^k$; $\Delta r_{\mathrm{t}+\Delta t} = r_{\mathrm{t}+\Delta t} - r_t$, and $\Delta \mathrm{e} l_{t+\Delta t}^k = \Delta h_{t+\Delta t}^k L^k$ with $\Delta h_{\mathrm{t}+\Delta t}^k = h_{\mathrm{t}+\Delta t}^k - h_t^k$. As we assume all assets are MTM on a daily basis, Δt is set to be 1/252. $\Delta r_{t+\Delta t}$ and $\Delta el_{t+\Delta t}^k$ in (2) are the market risk shocks which are exogenous, except for the default hazard rate of debt securities issued by banks, which is determined endogenously according to individual banks' default risk. $\mathrm{R}_\mathrm{t}^\mathrm{k}$ for different debt securities are given by the following specifications.

1. Debt securities issued by sovereigns are assumed to be default-free in the framework (i.e., $el_t^k = 0$), so that $\triangle \mathrm{r_t}$ is the only factor affecting their MTM value.
2. The expected default-loss rate of AAA, AA, A, BBB, and high-yield non-financial corporate debt securities, which are denoted by Δel_t^{AAA}, Δel_t^{AA}, Δel_t^{A}, Δel_t^{BBB} and Δel_t^{HY} respectively, are simulated from their historical daily changes in the credit spreads of the corporate bonds of the respective credit ratings.

For bank i in the banking system, the daily changes in the default hazard rate of its holdings of debt securities issued by other banks (e.g. certificates of deposits issued by other banks) are given by

$$\Delta h_t^{BD,i} = \sum_{j \neq i}^{N} w_{i,j}^{BD} \Delta h_{j,t-\Delta t} \quad (i = 1, \ldots, \mathrm{N}) \quad (3)$$

where $w_{i,j}^{BD}$ is the weight of bank i's exposure to bank j, which is assumed to be time-invariant. $w_{i,j}^{BD}$ can be proxied by the ratio of the value of debt securities issued by bank j (that bank i holds) to the value of total debt securities issued by banks (that bank i holds). $\Delta h_{j,t-\Delta t} = h_{j,t-\Delta t} - h_{j,t-2\Delta t}$, where $h_{j,t-\Delta t}$ is the default hazard rate of bank j given all information available at time t−Δt. $h_{j,t-\Delta t}$ is endogenously determined in the simulations.[1] The loss-given-default, $\mathrm{L^{BD}}$, is assumed to be 0.5 for all banks.[2]

[1]This will be discussed later in the default-risk equations.

[2]The value is close to the implied value from the historical default recovery rate of senior unsecured bank loans for the period 1989 to 2003.

For equities, structured financial assets and other financial assets, the changes in MTM value are proxied by the changes of some selected price indices. Specifically, for any asset k, the percentage change in its MTM value from t to t + Δt, $\ln\left(V^k_{t+\Delta t}\right) - \ln\left(V^k_t\right)$ is determined by:

$$\ln\left(V^k_{t+\Delta t}\right) - \ln\left(V^k_t\right) = \Delta P^k_t \quad (4)$$

Where ΔP^k_t is the change in the logarithm of the price index for asset k from t−1 to t. We denote the logarithm of price indices for Chinese equities, non-Chinese equities, structural financial assets and other financial assets by P^{EA}_t, P^{EW}_t, P^{SFA}_t and P^{OFA}_t respectively. Asset-price shocks for these four assets are imposed by simulating their future paths of ΔP^k_t.

In addition to financial investment of banks, we assume that banks' interbank lending and loans to customers are also MTM according to (2) as if they are debt securities. For interbank lending, the daily changes in the default hazard rate, $\Delta h^{BL}_{i,t}$, is endogenously determined in the same way as that for debt securities issued by banks [i.e., (3)], but replacing the weight $w^{BD}_{i,j}$, by $w^{BL}_{i,j}$, which can be proxied by the ratio of bank i's interbank lending to bank j to total interbank lending by bank i. The default hazard rate is given by

$$\Delta h^{BL}_{i,t} = \sum_{j\neq i}^{N} w^{BL}_{i,j} \Delta h_{j,t-\Delta t} \quad (5)$$

where the loss-given-default, L^{BL}, is assumed to be 0.5 for all banks.

For loans to customers, we denote the daily changes in the default hazard rate of loans to customers by Δh^{CL}_t. We assume that the asset quality of banks' loan portfolios deteriorates along with the asset market disruptions. Δh^{CL}_t is assumed to be exogenous and will be specified in the scenarios. The loss-given-default of the loans, L^{CL}, is assumed to be 0.5.

Equations (1)–(4) facilitate the calculation of the market value of total assets of individual banks on a daily basis in the stress horizon for any given set of simulated future paths of Δr_t, Δel^{AAA}_t, Δel^{AA}_t, Δel^{A}_t, Δel^{BBB}_t, Δel^{HY}_t, P^{EA}_t, P^{EW}_t, P^{SFA}_t, P^{OFA}_t[3] and Δh^{CL}_t. The impacts of the shocks on the market value of banks' assets are summarized in Table 1.

2.2.2 Default-Risk Equations

An important feature of this framework is that a bank's default risk is dependent on the market value of total assets of the bank. This is implemented using the

[3]We denote the logarithm of prices indices for China equities, non-China equities, structural financial assets and other financial assets by P^{EA}_t, P^{EW}_t, P^{SFA}_t, P^{OFA}_t.

Table 1 Impacts of shocks on market value of banks' assets

Market value of assets ↓	Shocks	Proxies
1. Cash		
2. Loans to customers ↓	PDs of customers↑	Classified loan ratio PDs
3. Interbank lending ↓	PDs of other banks↑	Endogenised banks' PDs
4. Financial assets		
(a) Debt securities issued by		
Sovereigns ↓	Interest rate r_t ↑	Shibor
Banks ↓	Interest rate r_t ↑; PDs of other banks ↑	Shibor; Indigenized banks' PDs
Corporate and others (by credit ratings) ↓	Interest rate r_t ↑; Expected default losses ↑	Shibor; Credit spreads of corporate bonds (by credit ratings)
(b) Equities		
Listed in China ↓	P_t^{EA}↓	SSECI
Listed outside China ↓	P_t^{EW}↓	MSCI world equity index
(c) Structured financial assets	P_t^{SFA}↓	ABX index
(d) Others financial assets	P_t^{EA}↓ 和P_t^{EW}↓	SSECI MSCI world equity index
5. Others		

Merton-type structural model proposed by Briys and de Varenne (1997).In essence, the model suggests that default risk of bank i at time t, which is measured by the 1-year probability of default (denoted by $PD_{i,t}$, or PD) in the framework, is determined by the bank's leverage ratio ($L_{i,t}$) and its associated volatility $\sigma_{i,t}$. $L_{i,t}$ is defined as the ratio of the total value of financial liabilities ($D_{i,t}$) to the total market value of assets ($A_{i,t}$). Therefore, $PD_{i,t}$, can be expressed by

$$PD_{i,t} = PD\left(\frac{D_{i,t}}{A_{i,t}}, \sigma_{i,t}\right) \tag{6}$$

We assume that is time-invariant (i.e.,) and the values of and change over time in the simulations. The daily percentage changes in are proportional to the corresponding changes in the MTM value of bank i's total assets that derived from the market-risk equations. Similarly, the daily percentage changes in are proportional to the corresponding changes in the bank's liabilities, which are mainly determined by the liquidity risk equations. With these two assumptions, the evolution of PDi,t in the stress horizon can be derived, given an initial value of the bank's leverage ratio Li,0 and the value of . Since the MTM value of a bank's assets tends to decrease in stress scenarios as a result of continued negative asset-price shocks, the bank's leverage ratio and thus PD tend to increase in the stress horizon.

Contagion risk is incorporated into the framework through banks' linkage with the interbank and capital markets. An increase in default risk of a bank will reduce the market value of its outstanding debt securities. Other banks which either have interbank lending to the bank or hold the debt securities issued by the bank will result in MTM losses, and thus have higher default risk. The contagion effects arising from interbank lending and those from debt securities are incorporated by

(3) and (5) respectively into the framework. The default hazard rate, hi,t, which facilitates the calculation of the MTM value of interbank lending and debt securities issued by banks, is derived from PDi,t using the following formula.

2.2.3 Liquidity Risk Equations

The liquidity-risk equations describe how the asset-price shocks affect banks' demand for liquidity. Asset-price shocks affect banks' deposit outflows indirectly via their impacts on default risk of banks. The relationship between default risk of banks and the outflow rate of retail deposits is estimated econometrically using a monthly panel dataset of 16 selected banks in China for the period January 2006–September 2008 from regulatory banking statistics obtained from the "Return of interest rate exposures (supplementary information)", which are collected by the China Monetary Authority. Based on the estimation result, the monthly retail deposit outflow rate is set to be $0.42*PD_{i,t}$. Details of the empirical estimation are in Appendix.

The daily retail deposit outflows of bank i at time t, denoted by $DO_{i,t,}$are determined by the following equation:

$$DO_{i,t} = (0.42 \times PD_{i,t-\Delta t}/21)TD_{i,t-\Delta t} \tag{7}$$

where $TD_{i,t-\Delta t}$ is total retail deposits taken by bank i at the close of business at $t-\Delta t$.

Based on the Briys and de Varenne model, the PDs of Bear Stearns before and during the debacle are derived. It is observed that if the PD is higher than 0.08, interbank deposits start to be withdrawn, and if the PD is higher than 0.69, all interbank deposits will not be renewed after maturity. The daily interbank deposit outflow rate of bank i at time t, $IOR_{i,t,}$ is defined as

$$IOR_{i,t} = \left\{ \begin{array}{ll} 0 & D_{i,t-\Delta t} \leq 0.08 \\ \dfrac{PD_{i,t-\Delta t} - 0.08}{0.69 - 0.08} \ldots\ldots\ldots\ldots & if \ldots .0.08 < PD_{i,t-\Delta t} \leq 0.69 \\ 1 & PD_{i,t-\Delta t} > 0.69 \end{array} \right\} \tag{8}$$

and the daily interbank deposit outflow of bank i at time t, $IO_{i,t}$, is determined by the following equation:

$$IO_{i,t} = Min[IOR_{i,t} \times TID_{i,t-\Delta t}, OID_{i,t-\Delta t}] \tag{9}$$

where $TID_{i,t-\Delta t}$ and $OID_{i,t-\Delta t}$ are total interbank deposits and overnight interbank deposits taken by bank i at the close of business at $t-\Delta t$.

In addition, the negative asset price-shocks increase banks' contingent liquidity risk because the likelihood of drawdowns on banks' irrevocable commitments increases in such stressful financial environments. It is assumed that a portion of individual banks' irrevocable commitments, α, is granted to SIVs which invest mainly in structured financial assets. Such SIVs are particularly vulnerable to funding risk if the asset quality of their holdings of structured financial assets deteriorates, and thus the net asset values of the SIVs decline significantly. This leads to a higher likelihood of drawdowns on credit commitments by the SIVs. In the simulations, we assume that the daily drawdowns on credit commitments from bank i at time t, DCCi,t , are determined by:

$$DCC_{i,t} = \max\left[-\Delta P_t^{SFA} UCC_{i,t-\Delta t}, 0\right] \tag{10}$$

$$UCC_{i,t} = \max\left[TCC_{i,0}\alpha - \sum_{s=1}^{t-\Delta t} DCC_{i,s}, 0\right] \tag{11}$$

Where $UCC_{i,t}$ and $TCC_{i,0}$, are the undrawn credit commitments at time *t* and the total commitments available at time 0 (i.e., at the beginning of the stress period) respectively.

With (7)–(11), daily cash outflows of individual banks can be simulated given the exogenous asset price shocks. Other cash outflows arising from banks' liabilities are assumed to follow their contractual maturities. For any business day t in the 1-year stress period, each bank is assumed to counterbalance its cash outflows by using the cash available at t. The total amount of cash available at t is defined as the sum of the remaining cash balances at the close of business day t−1; operating income (including net interest income and fee and commission income) arrived at t, interbank lending, loans to customers and financial assets matured at t. In the simulations, banks' operating incomes arrived at t are assumed to be determined by $\beta \frac{ROA_i}{252} A^{MTM}_{i,t-\Delta t}$, where $\beta < 1$ is a stress factor of banks' incomes, ROA_i is the return on assets of bank i and $A^{MTM}_{i,t-\Delta t}$ is its MTM value of total assets at time t−Δt. We assume that all banks cannot generate additional liquidity from the liability side (by taking more deposits) and they have to liquidate financial assets to offset cash outflows if there is a shortfall in cash. With this framework, each bank's net cumulative cash outflow gap, defined as the net cumulative cash inflows minus the net cumulative cash outflows, can be estimated daily in the stress horizon.

3 Data Sample and Sources

This paper will use the 2010 Annual Report published data of 16 selected banks in China to measure the impact of asset prices on bank liquidity risk. Why choose these banks? First, because of data availability, and second, because financial assets held by these banks account for the vast majority of financial assets of the banking system, Therefore, these banks are selected can reflect the entire banking system risks.

Since the framework involves estimations of daily cash flows of banks and the maturity profile presented in banks' annual report only shows the time to maturity of balance sheet items by some selected time intervals, we need to derive a daily maturity profile of balance sheet items for individual banks. In this study, for any given amount of an balance sheet item that will mature in a given time interval, the amount of the item that will mature in any given business day within the time interval is derived by dividing the total amount of the item that will mature in the time interval by the number of business days within the time interval. To facilitate the specification of stressed operating income in the stress scenarios, we calculate the return on assets (ROA) for each bank from the banks' annual reports.

To calculate the initial value of $L_{i,t}$ (i.e., $L_{i,0}$), we first obtain the daily time series of $D_{i,t}$ and $S_{i,t}$ for each bank in the 1-year period before the beginning of the stress period. $D_{i,t}$ is defined as the sum of total deposits, short-term debt and long-term debt, while $S_{i,t}$ is defined as the total market value of equity. We thus obtain a 1-year time series of $L_{i,t} = D_{i,t}/A_{i,t} = D_{i,t}/(D_{i,t} + S_{i,t})$ for each bank. The average value of the 1-year time series of $L_{i,t}$ is set to be $L_{i,0}$. Regarding σ_i, we first obtain the time series of the daily standard deviation of equity returns, $\sigma^s_{i,t}$, for each bank in the 1-year period using the exponentially weighted moving average method, with the decay factor being set as 0.94. We then calculate the corresponding annualized asset volatility by $\sqrt{250}\left(\frac{S_{i,t}}{D_{i,t}+S_{i,t}}\right)\sigma^s_{i,t}$. We set σ_i the average of the annualized asset volatility in the 1-year period. With $L_{i,0}$ and σ_i for each bank, we can calculate the initial value of $PD_{i,t}$ (i.e., $PD_{i,0}$) for each bank using the Briys and de Varenne model.

For asset price data, r_t is proxied by the 3-month Shibor. Credit spreads of AAA, AA, A, and BBB non-financial corporate debt are proxied by the corresponding credit spreads of the JPMorgan US Liquid Index, while credit spreads of high-yield corporate debt is derived by the difference between the yield to maturity of the JPMorgan Global High-yield Index and the 7-year swap rate. The SSECI and the Morgan Stanley Capital International (MSCI) World Equity Index are selected as the price indices for the Chinese $\left(P^{EA}_t\right)$ and non-Chinese $\left(P^{EW}_t\right)$ equities respectively. For simplicity, we assume that a majority of structured financial assets are related to US sub-prime mortgages. Therefore, the ABX index, which is a credit default swap index for sub-prime mortgage-backed securities, is selected as the price index for structured financial assets $\left(P^{SFA}_t\right)$. The movements of the price index for other financial assets, ΔP^{OFA}_t, are assumed to be similar to those of the equity prices. In the simulations, ΔP^{OFA}_t is calculated by the simple average of the ΔP^{EA}_t and ΔP^{EW}_t. All data are obtained from Bloomberg, except for the credit spreads of corporate debt, which are obtained from Bloomberg.

4 Specification of Stress Scenarios

The future paths of credit spreads of corporate bonds and prices of structured financial assets in the 1-year stress horizon are simulated from the historical time series of the respective variables from July 2007 to June 2008. The period covers roughly from the onset of the sub-prime crisis to the latest development. The future paths of prices of the China and non-China equities are simulated from the time series of the HSI and the MSCI World Equity Index respectively for the period mid-March 2000 to October 2002 (i.e., after the burst of the internet bubble). The simulated paths of the asset-price shocks are shown in Fig. 1.

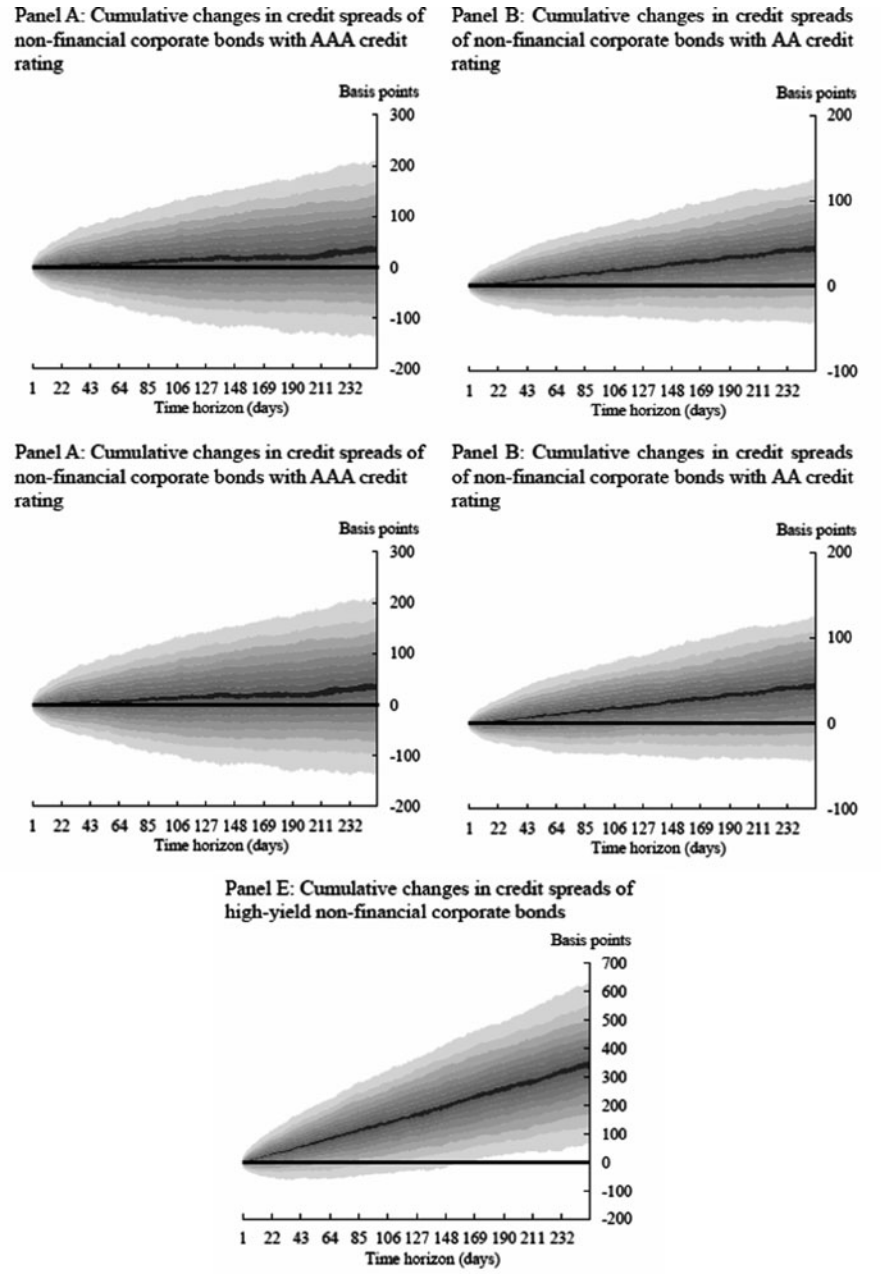

Fig. 1 Simulated paths of exogenous asset price shocks

5 Simulation Results

We assume the balance-sheet conditions of the banks at the end of December 2008 as the initial state. We then simulate daily future paths of the asset-price shocks covering the entire year 2008. The cash flows of each bank are calculated based on the simulated paths of the asset price shocks according to the system of equations in Section II. We repeat the process 1,000 times, from which the numbers of occurrences of cash shortage and default are calculated. We also calculate the expected FCST and DT conditional on occurrences of cash shortage and default respectively for each bank. The extent to which individual banks could withstand the stress scenarios is assessed by these liquidity risk indicators.

Based on the estimated probability of cash shortage and the probability of default, the stress-testing results suggest that liquidity risk of banks in China would be contained in the face of a prolonged period of asset price shocks under Scenario. Table 2 shows that five banks are estimated to have positive probabilities of cash shortage, ranging from 0.51 to 3.49%. Among the five banks, only one is estimated with positive probabilities of default due to liquidity problems in the 1-year stress horizon, with the estimated probabilities ranging from 0 to 0.85%. The estimated expected values of FCST and DT of individual banks are relatively large 239, indicating that the likelihood of sudden default of a bank in the early stage of the 1-year stress horizon would be very low.

To assess the systemic liquidity risk for the China banking system, the distribution of multiple defaults under Scenario is calculated and shown in Table 3. There is more than a 99.32% chance that no bank would default in Scenario.

Table 2 Simulation results

Bank	Probability of cash shortage (%)	Expected first cash shortage time (days)	Probability of default (%)	Expected default time
1	0.42	247	–	–
2	0.63	244	–	–
3	0.68	242	–	–
4	1.27	241	–	–
5	3.35	235	0.73	239

Table 3 Simulated distribution of the number of bank defaults

Simulated number of bank defaults	Probability (%)
=0	99.32
≤1	100
≤2	100
≤3	100
≤4	100

6 Conclusion

This paper designs a framework to integrate liquidity risk, credit risk and market risk in a macro stress testing model. In this framework, exogenous asset price shocks increase banks' liquidity risk through three channels. First, severe mark-to-market losses on the banks' assets increase banks' default risk and thus induce significant deposits outflows. Secondly, the ability to generate liquidity from asset sales continues to evaporate due to the shocks. Thirdly, banks are exposed to contingent liquidity risk, as the likelihood of drawdowns on their irrevocable commitments increases in such stressful financial environments. In the framework, the linkage between market and default risks of banks is implemented using a Merton-type model, while the linkage between default risk and deposit outflows is estimated econometrically. Contagion risk is also incorporated through banks' linkage in the interbank and capital markets. Using the Monte Carlo method, the framework quantifies liquidity risk of individual banks by estimating the expected cash-shortage time and the expected default time. Based on publicly available data as at the end of 2009, the framework is applied to a group of banks in China. The simulation results suggest that liquidity risk of the banks would be contained in the face of a prolonged period of asset price shocks. The test results show: the banking system Liquidity risk is very low, no bank is 99.32% probability of default, and the entire banking system is stable.

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Appendix

Econometric Estimation of the Relationship Between the Probability of Default and the Monthly Retail Deposit Outflow Rate

To reveal the empirical relationship between PD and the monthly retail deposit outflow rate, the following panel data regression equation is estimated:

$$\mathrm{G}_{i,t} = \partial_i + \beta_1 \ln(R_{i,t}) + \beta_2 \ln(R_{-i,t}) + \beta_3 \ln(PD_{i,t}) + \beta_4 Y_t + \varepsilon_{i,t} \tag{12}$$

Where $G_{i,t}$, is the monthly growth rate of China dollar retail deposits of bank i at time t. $R_{i,t}$ is the retail deposit rate offered by bank i at t, while $R_{-i,t}$ is that offered by other banks in the market. The estimated coefficients of $R_{i,t}$ and $R_{-i,t}$, (i.e., β_1 and $\beta_2$respectively) are expected to be positive and negative respectively. $PD_{i,t}$ is the default probability of bank i at t, which is calculated based on the Briys and de Varenne model. The empirical relationship between PD and the monthly retail deposit outflow rate is revealed by the estimated value of β_3, which is expected to be negative. Y_t is the year-on-year growth rate of GDP in China, and the estimated coefficient of Y_t is expected to be positive, as the growth rate of retail deposits should be higher under good economic conditions.

We estimate (12) using its first difference form with the generalized least squares method. β_3 is estimated to be -0.2111, which is statistically significant at the 5% level. This suggests that a bank with high default risk (i.e., $PD_{i,t}$ closer to 1) would lead to a monthly retail deposit outflow rate of about 21.44%.

The 95% confidence interval of β_3 is approximately between -0.42 and -0.01. In the stress-testing framework, instead of setting the monthly retail deposit outflow rate to be the point estimate (i.e., -0.2111), a more severe rate, which is the lower bound of the confidence interval, is assumed (i.e., monthly retail deposit outflow rate $= -0.42\ PD_{i,t}$).

Other parameters, β_1, β_2 and β_4 are estimated to be 0.4738, -0.2748, and 1.2387 respectively, with β_1 and β_2 being statistically significant at the 1% level and β_4 being statistically significant at the 10% level. Overall, the estimation result is consistent with the economic intuitions in (12).

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Comparative Study on Minimizing the Risk of Options for Hedge Ratio Model of Futures

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Abstract The option risk management model is a method to measure the finance risk and management market risk. Based on the contrast research on this option hedge ratio under the traditional minimum variance risk management model. This article has analyzed CVaR the minimum option hedging optimization model. And it explains its difference with minimum variance model. It also provides a reference for the hedgers on the option hedge's study.

Keywords Conditional risk value · Optimal hedge ratios · Option · Risk

1 Introduction

The hedge is a financial tool which people often use in the future market risk, and it can effectively dodge the spot market risk. This strategy is carried on the opposite operation through the stock cash and on-hand merchandise cash to flush the spot price the risk. That is, through the establishment of such a futures position, the futures market and spot market gains and losses mutually arrive to counterbalance, and lock in the future spot price of delivery in advance so as to achieve the preservation effect. The traditional theory of hedging mainly came from the points of views of the famous British economists, Keynes and Hicks. According to the normal backwardation theory of Keynes and Hicks, futures hedging is to build in the futures market, spot market in the opposite direction at about the same number of transactions and positions, spot market transactions in order to transfer the risk of price fluctuations. In the traditional theory of hedging, hedgers involved in futures trading are not intended to obtain high profits from futures, but futures trading in the profitable use in the spot market to compensate for possible losses. It stresses the

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four principles, namely, the opposite direction, the same type, an equal amount and the same month or nearly equal. The core of modern hedging theory is the determination of the optimal hedge ratio. There are three models of the hedge ratio calculation. They are mainly hedge risk minimization, maximize compensation to unit risk hedging and hedging utility maximization.

From the perspective of risk minimization proceeds of futures market hedging problem is to regard market and futures market trading positions as a portfolio of assets, and under the conditions of risk minimization in the portfolio incomes, determines the optimal hedge ratio.

2 Traditional Minimize Option Hedge Ratio of

Johnson, first of all, proposes the optimal commodity futures hedge ratio concept under the conditions in income variance minimized, and gives the formula for calculating the optimal hedge ratio, that is MV hedge ratio (Minimizing variance hedge ratios). That is, in detail, that R represents the value of the hedging of the final result, h(t) to hedge ratio, s_1, s_2 respectively t_1, t_2 time futures price. Short hedging value eventually change for $\triangle S - h(t)\triangle F$, bull hedging value for the final change $h(t)\triangle F - \triangle S$

There,

$$Var(R) = Var(\Delta S - h(t)\Delta F) = \sigma_s^2 + h(t)^2\sigma_f^2 - 2\rho h(t)\sigma_s\sigma_f \quad (1)$$

To $\sigma_s^2 = Var(\Delta S), \sigma_f^2 = Var(\Delta F), \rho = COV(\Delta S, \Delta F)/\sigma_s\sigma_f$

The most superior hedge ratio should cause R variance $Var(R)$ to be minimum, namely has:

$$\frac{dV}{dh(t)} = 2h(t)\sigma_f^2 - 2\rho\sigma_s\sigma_f = 0, \frac{dV^2}{dh(t)^2} = 2\sigma_f^2 > 0$$

So

$$h(t)^* = \rho\frac{\sigma_s}{\sigma_f} = \frac{COV(\Delta S, \Delta F)}{\sigma_f^2} \quad (2)$$

Formula is the hedge ratio, which is the minimum variance model. For a variance of risk minimization hedge ratio there are commonly used in several ways.

2.1 Traditional Simple Regression Models

The tradition regression model mainly (OLS) carries on to the hedge ratio's estimate through the least squares method, Witt summarized several estimate hedge ratio commonly used formula, one of them is carries on the hedge ratio on behalf of the conventional routes the estimate. Has the following regression equation:

$$\Delta \ln S_t = \alpha + \beta_1 \Delta \ln F_1 + \varepsilon_t \tag{3}$$

And, the slope coefficient β_1 estimate has given the hedge ratio value, namely

$$\beta_1 = Cov(\Delta \ln S_t, \Delta \ln F_1)/Var(\Delta F_1) = h \tag{4}$$

Where $\triangle \ln S_t$ and $\triangle \ln F_t$ as t at all times take the logarithm of the spot price and the futures price; α to intercept of the regression function; β_1 as the slope of the regression function, that is, the hedge ratio; ε_t to random errors.

2.2 *Dual Variable Vector Autoregressive Model*

Herbst, Kare, Marshali and Myers, Thompson found that the use of OLS for minimum risk hedge ratio calculation would be subject to the residual item sequence-related impacts, in order to eliminate residual item serial correlation and increase the amount of information, using the model of two variables vector Autoregressive models B-VAR (Bivariate-VAR Model) hedge ratio calculation. In the B-VAR model, the futures price and spot price relationships exist as follows:

$$\Delta \ln S_t = C_s + \sum_{i=1}^{l} \alpha_{si} \Delta \ln S_{t-i} + \sum_{i=1}^{l} \beta_{si} \ \Delta \ln F_{t-i} + \varepsilon_{st} \tag{5}$$

$$\Delta \ln F_t = C_f + \sum_{i=1}^{l} \alpha_{fi} \Delta \ln S_{t-i} + \sum_{i=1}^{l} \beta_{fi} \ \Delta \ln F_{t-i} + \varepsilon_{ft} \tag{6}$$

Where C_s, C_f to intercept, $\alpha_{si}, \alpha_{fi}, \beta_{si}, \beta_{fi}$ for the regression coefficients, $\varepsilon_{st}, \varepsilon_{ft}$ is subject to independent identically distributed random errors. In this model, we are looking for the best of the hysteresis value L, so that the residual item for elimination to $\mathrm{Var}(\varepsilon_{st}) = \sigma_{ss}$, $\mathrm{Var}(\varepsilon_{ft}) = \sigma_{ff}$, $\mathrm{Cov}(\varepsilon_{st}, \varepsilon_{ft}) = \sigma_{sf}$, you can get the hedge ratio:

$$h = \frac{Cov(\Delta \ln S_t, \Delta \ln F_t | \Delta \ln S_{t-i}, \Delta \ln F_{t-i})}{Var(\Delta \ln F_{t-1} | \Delta \ln S_{t-i}, \Delta \ln F_{t-i})} = \frac{\sigma_{sf}}{\sigma_{ff}} \tag{7}$$

The optimal hedge ratio can be given by the following regression model:

$$\Delta \ln S_t = \alpha + \beta_2 \Delta \ln F_t + \sum_{i=1}^{m} \gamma_i \Delta \ln S_{t-i} + \sum_{j=1}^{n} \theta_j \Delta \ln F_{t-j} + \varepsilon_t \tag{8}$$

$\triangle \ln F_t$ of regression coefficients β_2 is what you want to estimate the best hedge ratio.

2.3 Error Correction Hedging Model

Granger and other scholars believe that although B-VAR model solves the OLS model of residual home-related problems, yet it ignores the futures price and spot price of Cointegration between the hedge ratio. Engle and Granger proved that if two time series are coordination, then there must be an expression of error correction, if there is an error correction expressions, the two time series are coordination. Ghosh under the Granger, Engle of theory, proposed hedge ratio estimated error correction model ECM (Error Correction Model). This model, at the same time, took into account the spot prices and futures prices of non-stationary, long-term equilibrium relationship and short-term dynamic relationship.

$$\Delta \ln S_t = C_s + \lambda_s Z_{t-1} + \sum_{i=1}^{l} \alpha_{si} \Delta \ln S_{t-i} + \sum_{i=1}^{l} \beta_{si} \Delta \ln F_{t-i} + \varepsilon_{st} \tag{9}$$

$$\Delta \ln F_t = C_f + \lambda_f Z_{t-1} + \sum_{i=1}^{l} \alpha_{fi} \Delta \ln S_{t-i} + \sum_{i=1}^{l} \beta_{fi} \Delta \ln F_{t-i} + \varepsilon_{ft} \tag{10}$$

Which, Z_{t-1} for the error correction term, B-VAR model compared to, ECHM adds an error correction term, which is a stationary linear combination, in ECHM model, λ_s and λ_f at least one is not equal to zero.

$$\Delta \ln S_t = \alpha + \beta_3 \Delta \ln F_t + \sum_{i=1}^{m} \gamma_i \Delta \ln S_{t-i} + \sum_{j=1}^{n} \theta_j \Delta \ln F_{t-j} + \omega Z_{t-1} + \varepsilon_t \tag{11}$$

And, $\ln F_t$ the regression coefficient β_3 is the hedge ratio which must estimate.

2.4 General Auto-regressive Conditional Heteroscedastic Model

Lien proposed a generalized auto-regressive conditional heteroscedastic model, which not only consider a co-integration relationship between the first moment changes in futures prices and spot price, taking into consideration the second moments of changes in futures prices and spot price variance between the impact of changes in variance, and no longer limits the futures price fluctuation of conditional variances and futures price fluctuation and spot price fluctuation of covariance as a constant. In general auto-regressive conditional heteroscedastic model, the cash price and the futures price can use the following formula:

EC-GARCH hedge ratio in the regression equation can be obtained through the following,

$$\Delta \ln S_t = \alpha + \beta_4 \Delta \ln F_t + \gamma Z_{t-1} + \varepsilon_t \tag{12}$$

And, Δ lnF_t the regression coefficient β_4 is the hedge ratio which must estimate.

$$h = \frac{Cov(\Delta \ln S_t, \Delta \ln F_t | Z_{t-1})}{Var(\Delta \ln F_{t-1} | Z_{t-1})} = \frac{\sigma_{sf}}{\sigma_{ff}} \tag{13}$$

And, $Var(\varepsilon_{ft}) = \sigma_{ff}$, $Cov(\varepsilon_{st}, \varepsilon_{ft}) = \sigma_{sf}$

3 CVaR Options Optimal Hedging Ratio Model

3.1 CVaR Model Derived

Suppose hedgers consider a used set of Paul's "spot – futures" portfolio, S, F respectively for the first time t ~ t + 1 cash price and futures price variation. S_t, F_t respectively is the time spot price and the forward price, then in the t ~ t + 1 time on-hand merchandise returns ratio and the stock returns ratio respectively are $R_S =_{\triangle} S/S_t, R_f =_{\triangle} F/F_t$. Wraps the time to compare $h = C_t F_t / C_s S_t$ (Hull 1999), C_t is the stock cash number, C_s is on-hand merchandise cash number. $C_t F_t$ is the stock value quantity, $C_s S_t$ is the stock value quantity. Therefore may result in the hedge combination returns ratio is (Wu et al. 1998)

$$R_h = \frac{C_S S_t R_s - C_f F_t R_f}{C_s S_t} = R_s - hR_f \tag{14}$$

And R_h is in the t ~ t + 1 time hedge option returns ratio, R_s is in the t ~ t + 1 time option same time returns ratio, hR_h is in a t ~ t + 1 time uses in the hedge the stock returns ratio. From this may result in the hedge the option expectation returns ratio and variance formula (Wu et al. 1998; Lin 2004)

$$E(R_h) = E(R_s) - hE(R_f) \tag{15}$$

$$\sigma_h^2 = \sigma_s^2 + h^2 \sigma_f^2 - 2h\sigma_{sf} \tag{16}$$

Of the type (16) open at both ends of the square, too:

$$\sigma_h = \sqrt{\sigma_s^2 + h^2 \sigma_f^2 - 2h\sigma_{sf}} \tag{17}$$

In the above equation, $\sigma_h$is the hedge option standard deviation; σ_s is the spot option returns ratio standard deviation; σ_f is the forward option returns ratio standard deviation.

May obtain the fiduciary level according to the $CVaR$ definition $1 - \alpha$ and the loss surpasses risk value $VaR(h)$ under the condition, the option average exceeds the quota the loss is $CVaR(h)$ (Rockafellar and Uryasev 2000; Andersson et al. 2000; Harris and Shen 2006), namely

$$\begin{aligned} CVaR(h) &= -E[R_h|R_h \leq -VaR(h)] \\ &= -E\Big[R_h|\frac{R_h - E(R_h)}{\sigma_h} \leq \frac{-VaR(h) - E(R_h)}{\sigma_h}\Big] \\ &= -E\Big[\frac{R_h - E(R_h)}{\sigma_h}|\frac{R_h - E(R_h)}{\sigma_h} \leq \frac{-VaR(h) - E(R_h)}{\sigma_h}\Big]\sigma_h - E[R_h] \\ &= -E\Big[\frac{R_h - E(R_h)}{\sigma_h}|\frac{R_h - E(R_h)}{\sigma_h} \leq \Phi^{-1}(\alpha)]\sigma_h - E[R_h\Big] \\ &= -\frac{\int_{-\infty}^{\Phi^{-1}(\alpha)} x\Phi(x)dx}{\int_{-\infty}^{\Phi^{-1}(\alpha)} \Phi(x)dx}\sigma_h - E[R_h] = -\frac{\int_{-\infty}^{\Phi^{-1}(\alpha)} x\Phi(x)dx}{\alpha}\sigma_h - E[R_h] \\ &= -k_\alpha \sigma_h - E[R_h] \\ &= hE[R_f] - E[R_s] - k_\alpha\sqrt{\sigma_s^2 + h^2\sigma_f^2 - 2h\sigma_{sf}} \end{aligned} \tag{18}$$

And: In the upper row formula, $VaR(h)$ is the option risk value, is the h function. By the central limit theorem, $VaR(h)$ may express as follows simply: $VaR(h) = -\Phi^{-1}(\alpha)\sigma_h - E(R_h)$, for standardized normal distribution α quantile, and satisfies:

$$\int_{-\infty}^{\Phi^{-1}(\alpha)} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx = \alpha \tag{19}$$

To $x = (R_h - E(R_h))/\sigma_h$, The x obey standards are normal distribution. $\Phi(x)$ as the standard normal distribution, the probability density function, then $\Phi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$, Generations $k_\alpha = \frac{\int_{-\infty}^{\Phi^{-1}(\alpha)} x\Phi(x)dx}{\alpha}$, $k_\alpha = -\frac{\frac{1}{\sqrt{2\pi}} e^{-\frac{(\Phi^{-1}(\alpha))^2}{2}}}{\alpha} < 0$, When is constant, $\varphi^{-1}(\alpha)$ is constant, k_α also constant. By the above equation: $hE(R_f)$ is larger, the $CVaR(h)$ the greater. In the future spot market, the higher the price, $E(R_s)$ the greater, $CVaR(h)$ the less.

3.2 Model's Establishment

Then established based on minimizing $CVaR$ optimal portfolio hedging model is therefore

$$h_{CVaR} = \rho\frac{\sigma_s}{\sigma_f} - \frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1 - \rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}}$$

$$s.t. \min\ CVaR(h) = hE[R_f] - E[R_s] - k_\alpha\sqrt{\sigma_s^2 + h^2\sigma_f^2 - 2h\sigma_{sf}} \tag{20}$$

$$\left(\sum_{i=1}^{n} h_i < 1,\ -1 \le \rho \le 1;\ -k_\alpha > 0 \text{ and } (k_\alpha)^2\sigma_f^2 - (E(R_f))^2 > 0\right)$$

On the type (20), h derivation:

$$\frac{\partial CVaR(h)}{\partial h} = E(R_f) - k_\alpha \frac{h\sigma_f^2 - \sigma_{sf}}{\sqrt{\sigma_s^2 + h^2\sigma_f^2 - 2h\sigma_{sf}}} \overset{To}{=} 0 \tag{21}$$

In this (to 21)

$$h^2 - 2\frac{\sigma_{sf}}{\sigma_f^2}h + \frac{\sigma_s^2(E(R_f))^2 - (k_\alpha)^2\sigma_{sf}^2}{\sigma_f^2[(E(R_f))^2 - (k_\alpha)^2\sigma_f^2]} = 0 \tag{22}$$

Solve the equations as h (22),

$$h_1 = \frac{E(R_f)^2\sigma_{sf} - k_\alpha^2\sigma_f^2\sigma_{sf} - \sqrt{-E(R_f)^4\sigma_f^2\sigma_s^2 + E(R_f)^2k_\alpha^2\sigma_f^4\sigma_s^2 + E(R_f)^4\sigma_{sf}^2 - E(R_f)^2k_\alpha^2\sigma_f^2\sigma_{sf}^2}}{E(R_f)^2\sigma_f^2 - k_\alpha^2\sigma_f^4} = \frac{\sigma_{sf}}{\sigma_f^2} - \frac{E(R_f)}{\sigma_f^2}\sqrt{\frac{\sigma_{sf}^2 - \sigma_f^2\sigma_s^2}{(E(R_f))^2 - (k_\alpha)^2\sigma_f^2}} \tag{23}$$

$$h_2 = \frac{E(R_f)^2\sigma_{sf} - k_\alpha^2\sigma_f^2\sigma_{sf} + \sqrt{-E(R_f)^4\sigma_f^2\sigma_s^2 + E(R_f)^2k_\alpha^2\sigma_f^4\sigma_s^2 + E(R_f)^4\sigma_{sf}^2 - E(R_f)^2k_\alpha^2\sigma_f^2\sigma_{sf}^2}}{E(R_f)^2\sigma_f^2 - k_\alpha^2\sigma_f^4} = \frac{\sigma_{sf}}{\sigma_f^2} + \frac{E(R_f)}{\sigma_f^2}\sqrt{\frac{\sigma_{sf}^2 - \sigma_f^2\sigma_s^2}{(E(R_f))^2 - (k_\alpha)^2\sigma_f^2}} \tag{24}$$

Continues to carry on to type (20) about the h two partial derivatives, has

$$\frac{\partial^2 CVaR(h)}{(\partial h)^2} = -k_\alpha \frac{\sigma_s^2\sigma_f^2(1-\rho^2)}{(\sigma_s^2 + h^2\sigma_f^2 - 2h\sigma_{sf})^{3/2}} \ge 0 \tag{25}$$

The great value of the second condition available $CVaR(h)$ there is a minimum value. So when $h = \min(h_1, h_2)$, the $CVaR(h)$ there is an optimal solution. By differential method you can find:

$$CVaR(h_2) - CVaR(h_1) = \frac{2(E(R_f))^2}{\sigma_f^2}\sqrt{\frac{\sigma_{sf}^2 - \sigma_f^2\sigma_s^2}{(E(R_f))^2 - (k_\alpha)^2\sigma_f^2}} \geq 0 \tag{26}$$

So, have the $CVaR(h_2) \geq CVaR(h_1)$. Therefore, the minimum of $CVaR(h)$ the corresponding root for h_1. And by the definition of the covariance matrix $\sigma_{sf} = \rho\sigma_s\sigma_f$ generation-(23), simplification and consolidation, get the confidence level in the $1-\alpha$ under option $CVaR$ optimal hedging ratio model

$$h_{CVaR} = \rho\frac{\sigma_s}{\sigma_f} - \frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1-\rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}} \tag{27}$$

Formula, ρ to R_s, and the correlation coefficient between R_f. $-1 \leq \rho \leq 1$; $-k_\alpha > 0$ and $(k_\alpha)^2\sigma_f^2 - (E(R_f))^2 > 0$.

3.3 Model Comparison Vertical Analysis

When the consideration risk characteristic and takes refuge from danger the function, generally supposes the parameter is known and decides, achieves the balanced condition and under the equilibrium state nature by this inspection endogenous variable, this kind of analysis is called the static analysis. When the partial parameters change, we usually start to change the parameters again after a static analysis, and then change before and after the two sets of parameters values of endogenous variables under comparison, this analysis method is called the comparison vertical analysis. Here, we used the comparison static economy analysis to conduct the research to the option risk management optimal solution.

Equation (27) may result in by the type

$$h_{CVaR} = \rho\frac{\sigma_s}{\sigma_f} - \frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1-\rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}}$$

1. works as forward option expectation returns ratio $E(R_f) = 0$, namely, when the influence forward price change's factor achieves is balanced, type (27) becomes

$$h'_{CVaR} = \rho\frac{\sigma_s}{\sigma_f} - \frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1-\rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}} = \frac{\sigma_{sf}}{\sigma_f^2} = \rho\frac{\sigma_s}{\sigma_f} \tag{28}$$

   At this point the $CVaR$ hedge ratio optimal model tends to be the smallest hedge ratio combinations model (Chen et al. 2003) $\rho\sigma_s/\sigma_f$.

2. when between R_s and R_f correlation coefficient $\rho = \pm 1 (-1 \leq \rho \leq 1)$, The futures and stock rate of return totally relevant, By substituting the $\rho = \pm 1$ (27) the result was the type (28).

When $1 - \alpha \to 100\%, -k_\alpha \to +\infty, \frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1-\rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}} \to 0$, then (27) the results still tend to type (28). Type (27) can be regarded as pure hedging and speculative demand of two parts. Part of pure minimal set of security than the combined model variance hedging, that is $\rho\sigma_s/\sigma_f$. This is because the minimum variance hedge ratio on the basis of the variance measure of risk-hedging is the same person. Part is the type of speculative demand (27) the second part of, is

$$\frac{E(R_f)\sigma_s}{\sigma_f}\sqrt{\frac{1-\rho^2}{(k_\alpha)^2\sigma_f^2 - (E(R_f))^2}}$$

The congenial demand part the shift in attitude changes along with wrap guaranteeing to the risk, mainly through reflected in here to the fiduciary level $1 - \alpha$ selections. States knowing by front, because is smaller than the standardized normal distribution "α the quantile" that spot combination returns ratio conditional mean $k_\alpha < 0$. Wrap guaranteeing will more loathe the risk, the fiduciary level $1 - \alpha$ will be higher. $-k_\alpha$ this positive number to be bigger, (27) will obtain h_{CVaR} by the type to be bigger.

The above studies several kind of situations, in fact are this article *CVaR* most superior hedge ratio several kind of peculiar circumstances.

4 Summary

In this paper, risk minimization hedging the minimum variance comparison of several traditional models introduced in order to build options *CVaR* as the objective function optimal hedge ratio model, the optimal hedge ratio derived *CVaR* optimal hedge ratio, *CVaR* by Analysis of the optimal hedge ratio derived minimum variance (MV) (MV) is one of several special cases that illustrate hedge both with pure hedging and speculation, reflects hedging's ability to take risks, and risk capacity below the *CVaR* supervision than minimum variance control below the risk of ability, further illustrates this model of rationality and control risk on the advantages and flexibility, to provide a certain degree of economic investors.

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The Application of Option Pricing Theory in Participating Life Insurance Pricing Based On Vasicek Model

Danwei Qiu, Yue Hu, and Lifang Wang

Abstract In this paper, we combined with the option pricing theory of financial mathematics on the basis of actuarial theory to research the fair premium of endowment life insurance dividends. Taking advantage of the application of the Ito's Formula of option pricing theory, construct a risk neutral investment portfolio with the Vasicek single factor term structure of interest rate model. And then making use of the Δ-hedging ideas to get the stochastic differential equations of the fair premium of the insurance contract.

Keywords Endowment life insurance dividends · Fair premium · Δ-hedging · Ito's Formula · Risk · Vasicek model

1 Introduction

Life insurance dividends is one of the products of life insurance, it refers to that the insurance company will assign the insurance of such dividend distributable surplus of the last fiscal year in the form of cash dividends or value-added dividends in proportion to a life insurance policy holders. The surplus is generated by the profits of life insurance company with running the participating insurance insurance. The surplus of participating insurance changes with the change of company earnings as dividends insurance status and market conditions. The surplus generated by the profits of life insurance company with running the participating insurance insurance is a non-deterministic. Therefore, dividend distribution of life insurance companies is with uncertainty. But the life insurance companies are generally provided to the participating policyholders guaranteed minimum income. As the level of

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participating insurance dividends closely linked to the investment returns of life insurance companies, so we need to analyze the portfolio of life insurance companies. The investment portfolio of China Life Insurance Company consists of bank deposits, long-term debt and equity securities on a three-part. On this basis, we analyze the motion equation of the portfolio of life insurance companies. Participating insurance as a new insurance products, not only has the same insurance protection function as with traditional insurance, but also has the ability to resist inflation, it can meet the residents to protect, investment, value added, and many other needs, but also can reduce the insurance company's investment risk and interest rate risk.

As for the participating insurance with annual payment of the minimum guaranteed interest rate, the interests of policy holders can be divided into three parts. The first part is to protect the interests, that is the interests of the beneficiaries of insurance policies obtained due to the death of the insured; The second part is under the survival of the insured, the insured person should be got a minimum guaranteed annual interest; The third part is that the insured person should be obtained bonus every year which with the changes in operating performance with the life insurance company. The scheduled to mortality, interest rates and reservation booking fees of participating insurance which are higher than the actual surplus will be returned to the insured in the form of dividends. In general, the participating insurance's dividends are from: (1) When the actual mortality rate falls below a predetermined mortality, there are differences in death; (2) When the investment rate of return greater than the intended yield, there is spreads benefits; (3) when additional premium over the actual operating costs, there is cost difference benefits. Excessive experience has shown that, while the participating policy dividends are from "three difference". But in fact, differences in death and cost difference benefits accounts for a very small proportion. Because in an operating well insurance company who has a long history, there is little possible that it will have greater errors in both underwriting and costs with its higher actuarial level. Therefore, in this paper, analyzing fair premium in the analysis of pricing life insurance dividends, only assume that dividend uncertainty is uncertain return on investment by insurance funds that caused by the spreads benefits.

Term structure of interest rates is a curve in time is composed of different interest rate period of a point. It can also be expressed as a point in time in different period zero-coupon bond yield to maturity consisting of a curve. It is the asset pricing and financial risk management an important benchmark. Vasicek single-factor model is the interest rate term structure model. Short-term interest rates $r(t)$ at time Δt the instantaneous changes are in two parts, part of it is the short-term interest rates relative to the mean instantaneous expected return, that is drift part. The other part of it reflects the unexpected changes in interest rates, that is fluctuations part.

Definition 1 (brown movement). *If the random process $B = \{B_t, t \geq 0\}$ meet the following three conditions: (1) Process is with independent increments; (2) Incremental is subjected to normal distribution; (3) for each ω, $B_t(\omega)$ is a continuous function of time t, then we can call $B = \{B_t, t \geq 0\}$ is a brown movement,*

$dS(t) = \mu dt + \sigma dB(t)$ is a generalized brown movement, where μ is instantaneous expected drift rate, and σ is instantaneous standard deviation.

Definition 2 (Ito process). *If the process $\{S(t), 0 \leq t \leq T\}$ can be expressed by $dS(t) = \mu(t, S(t))Sdt + \sigma(t, S(t))SdB(t)$, where $\mu(t,s), \sigma(t,s)$ are continuous function of binary, $\{B(t), t \geq 0\}$ is brown movement, then we can claim that $\{S(t), 0 \leq t \leq T\}$ is Ito stochastic process, it is referred to as Ito process.*

Theorem 1 (Ito Theorem). *Assumption $\{S(t), 0 \leq t \leq T\}$ is given by the Ito process $dS(t) = \mu(t, S(t))Sdt + \sigma(t, S(t))SdB(t), g = g(s,t)$ is twice differentiable continuous function and have second-order continuous partial derivatives, then we can see that $g(S(t), t)$ satisfy the following Ito differential equation:*

$$dg = \left(\frac{\partial g}{\partial S}\mu S + \frac{\partial g}{\partial t} + \frac{1}{2}\frac{\partial^2 g}{\partial S^2}S^2\sigma^2\right)dt + \frac{\partial g}{\partial S}\sigma S dB$$

In this article, we mainly consider endowment life insurance dividends: the initial of insure (t = 0), if the insurant would survive after T years healthily, then he will get insurance premium benefit from insurance company, including insurance capital, guaranteed minimum interest and bonus. If the insurant would be died in T years, then he can get the death benefit under the contract. The insurance policy in force from the second year and share operating profit with insurance companies, the amount of dividends will be operating by the condition of the company, but the guaranteed minimum income.

Fischer· Black and Myron· Scholes think that there is a natural link between options and insurance. Options and insurance policy are avoided or transfer of financial instruments, each of which is a certificate or has interests. So factors with options for insurance, you can use the option pricing method to achieve the actuarial equivalent of the fair premium model.

This will be participating policyholder as to purchase a life insurance death benefit, pro rata share of investment income as well as to guarantee a minimum rate of return of the exercise price of a combination of European put option.

In order to more accurately reflect the fair premium dividend policy, this article uses the strategy of participating insurance given by Nielsen and others to describe dividends in the time t of payment $P(t)$. Considering life insurance company risk-neutral portfolio, we will make use of Δ-hedging to get the differential equations of fair participating insurance premium.

2 Fair Premium Pricing

Here given some definitions: T means the validity of the insurance contract and γ_κ means the guaranteed minimum interest. The way of insurance companies paid dividends is accumulate dividend payment each year, and then one-time payment due to all the insurance $P(T)$. When in the time t, the insured risky asset price is A_t. And the payment of insurance company is $P(t)$, including guarantee insurance capital and accumulated interest or probable dividends.

Dividend is a key factor in the fair to determine the dividend premium life insurance contract. Life in the contract of dividends is decided by dividend changes in the market of the investment. It mainly contains the following factors: the contract to take effect, the value of existing investments, before an investment value and the value of the previous payment period. When it is time t, the expression for the payment $P(t)$ is:

$$P(t) = \begin{cases} P(k-1) & \text{t} \in [\text{k}-1, k) \\ B_k(A(k), A(k-1), P(k-1)) & \text{t = k} \end{cases} \tag{1}$$

Including dividend payment function B_k can vary each year. Each B_k depends only on the present value of investment $A(k)$. The investment value of a year ago is $A(k-1)$ and the payment value of a year ago is $P(k-1)$.

If the current investment market response is good, it will give a higher interest rate R. In 1995, Nielsen and others gave the formula $B_k(A(k), A(k-1), P(k-1))$ for dividend policy:

$$\begin{aligned} B_k(A(k), A(k-1), P(k-1)) = \\ (1 + \max\{r_\kappa, R(A(k), A(k-1), P(k-1))\})P(k-1) \end{aligned} \tag{2}$$

Where

$$\begin{aligned} &R(A(k), A(k-1), P(k-1)) = \alpha\left(\frac{A(k-1)}{P(k-1)} - 1 - \gamma\right) \\ &0 \le \alpha \le 1, \quad \gamma > 0 \end{aligned} \tag{3}$$

The following to discuss was dividend endowment life insurance on the fair premium $V(t)$, $V(t)$ stands on the contract on behalf of future cash flows arising from the present value at time t, which is the present value of future cash flow estimates. Not consider the impact of mortality here, but only consider the pure financial model. The equity premium can be regard as no-arbitrage price of the contract. In 1973, Black and Scholes think the no-arbitrage price of life insurance as a risk-neutral probability measures to comply with the expected price calculation.

Assume that the markets are arbitrage-free, balanced, comprehensive and effective market, formed by the three kinds of assets, one is the insurance contract above, one is the stock S, and the other one is a kind of bond Z, bond prices decided by the interest rate r, while r is changed. The stochastic model of interest rates is used by Vasicek Term Structure Models, using Vasicek interest rate model and stock returns model and the model based on the bond to discuss the differential equations of portfolio income. In which the price of stocks and bonds differential models are:

$$dS = \mu S dt + \sigma_1 S dB_1, \quad dZ(t) = Z(t)r(t)dt$$

$$\begin{cases} dr(t) = a(\bar{r} - r(t))dt + \sigma_2 dB_2 \\ r(0) = r_0 \end{cases}$$

Where r is a instantaneous interest rate.

$$r(t) = r(s)e^{-k(t-s)} + \bar{r}(1 - e^{-k(t-s)}) + \sigma_1 \int_s^t e^{-k(t-\tau)} dB(\tau), 0 \le s \le t$$

$\bar{r}$ on behalf of long-term average of short-term interest rates; a representative of the mean speed of recovery, that is, the speed of interest rates back to $\bar{r}$; σ_2 is the volatility of interest rate changes; a, $\bar{r}$, σ_2 are the model parameters to be estimated. B_1, B_2 are subject to the standard one-dimensional geometric Brownian motion. When $r(t) > \bar{r}$, Vasicek model has a negative drift term, from an average sense, then the short-term interest rates $r(t)$ will drop, when $r(t) < \bar{r}$, Vasicek model has a positive drift term, interest rates $r(t)$ will rise. To changes in interest rates tends to reveal a trend in the average level of $\bar{r}$, from this point, Vasicek model has a strong economic basis: when interest rates higher, the borrower will reduce the demand for capital, which will lead to lower interest rates; when interest rates low, borrowers have a higher demand for capital, which will lead to higher interest rates.

To the participating insurance contract as a whole European Option, that is contract only to the end of the contract expiration date, and one-time payment of all payments to policyholders. The insured can not end the contract during the contract effective (Lead to termination of the contract without regard to the death). Equity premium must follow the contract fair premium is equal to the value of the contract payment due date. It means insurance companies paid to policyholders are equal to the insured investment income. The condition of the final value for equity premium equation is: $V(T) = P(T)$. At other times the fair premium of contracts decided by the no-arbitrage market and risk-neutral probability measure.

In the risk-neutral world, on the complete financial market, in the market there exists a unique equivalent martingale measure Q, the contingent claim for any given time t has its income p, the fair premium of European option have the price $V(t) = E^Q(e^{-r(T-t)}P(T)|F_t)$ at any time t. Where $\{F_t, t \ge 0\}$ is under the complete probability space F the non-reducing flow of sub-algebra σ. Where E^Q indicates the expectation under the equivalent martingale measure. We can know from (1) that $P(t)$ can be decided by $(A(t), A(t-1), P(t-1))$, and $A(t)$ can be decided by $(S(t), r(t))$, so $P(t)$ can also be decided by $(S(t), r(t))$, then we can get that when $0 \le t \le T$, two-element model of the fair price is: $V(t) = V(t, S(t), r(t), S(t-1), r(t-1), P(t-1))$. Command that $k \in \{1, 2, ..., T\}$. For any k, we can define the function F_k for all $S, r, P > 0$, it satisfied the relation:

$$F_k(S(k), r(k), P(k)) = V(k, S(k), r(k), S(k-1), r(k-1), P(k-1)).$$

When $k-1 \le t < k$, by the principle of no arbitrage, k must be left continuous, that means when $t \to k^-$, $V(t) \to V(k)$. Otherwise, there will be arbitrage opportunity, it means there exists a $\varepsilon > 0$ and time series $t_n < k$, when $t_n \to k$, there will be a relation $V(k) \ge V(t_n) + \varepsilon$ or $V(t_n) \ge V(k) + \varepsilon$ for any n. In the first case, we can buy contracts when t_n close enough to k, and sell contracts at time k to achieve arbitrage. In the second case, we can sell contracts at time t_n, and buy contracts at time k to achieve arbitrage. And because S, r are continuous on the time t, so we can get the conclusion.

$$\begin{aligned}
&\lim_{t \to k^-} V(t, S(t), r(t), S(k-1), r(k-1), P(k-1)) \\
&\quad = V(k, S(k), r(k), S(k-1), r(k-1), P(k-1)) \\
&\quad = F_k(S(k), r(k), B_k(A(k), A(k-1), P(k-1)))
\end{aligned}$$

When $k-1 \le t < k$, we define the function:

$$f(k, S, r) = V(t, S(t), r(t), S(k-1), r(k-1), P(k-1))$$

Then

$$\begin{aligned}
f(k, S, r) &= \lim_{t \to k^-} f(t, S, r) \\
&= \lim_{t \to k^-} V(t, S(t), r(t), S(k-1), r(k-1), P(k-1)) \\
&= \mathrm{F}_k(S(k), r(k), B_k(A(k), A(k-1), P(k-1)))
\end{aligned}$$

The derivation above gives a fair price of contract, the general pricing model:

1. When $k-1 \le t < k$, fair price can be expressed as a function with $f(t, S, r)$.
2. When $t = k$, according to the principle of no arbitrage, fair price is: $f(k, S, r) = F_k(S(k), r(k), B_k(A(k), A(k-1), P(k-1)))$
   Then we can get the expression of stochastic differential equations of $f(t, S, r)$ under the condition of $k-1 \le t < k$, and finally we can obtain the fair premium of any time in the case of knowing function $f(k, S, r)$.

3. When $k-1 \le t < k$, by the Ito formula, derivation of the function $f(t, S, r)$, we can get:

$$\begin{aligned}
df &= \frac{\partial f}{\partial t} dt + \frac{\partial f}{\partial S} dS + \frac{\partial f}{\partial r} dr + \frac{1}{2}\left(\frac{\partial^2 f}{\partial S^2} dS^2 + 2\frac{\partial^2 f}{\partial S \partial r} dS dr + \frac{\partial^2 f}{\partial r^2} dr^2\right) \\
&= \frac{\partial f}{\partial t} dt + \frac{\partial f}{\partial S}(\mu S dt + \sigma_1 dB_1) + \frac{\partial f}{\partial r}(a(\bar{r} - r(t))dt + \sigma_2 dB_2) \\
&\quad + \frac{1}{2}\left[\frac{\partial^2 f}{\partial S^2}(\mu^2 S^2 dt^2 + \sigma_1^2 S^2 dB_1^2 + 2\mu S^2 \sigma_1 dt dB_1)\right. \\
&\quad + 2\frac{\partial^2 f}{\partial S \partial r}(\mu S a(\bar{r} - r(t))dt^2 + \mu S \sigma_2 dt dB_2
\end{aligned}$$

$$
\begin{aligned}
&+\sigma_1 Sa(\bar{r}-r(t))dtdB_1+\sigma_1\sigma_2 SdB_1dB_2)\\
&+\frac{\partial^2 f}{\partial r^2}(a^2(\bar{r}-r(t))^2dt^2+\sigma_2^2dB_2^2+2a(\bar{r}-r(t))\sigma_2 dtdB_2)\Bigg]\\
=&\frac{\partial f}{\partial t}dt+\frac{\partial f}{\partial S}(\mu Sdt+\sigma_1 dB_1)+\frac{\partial f}{\partial r}(a(\bar{r}-r(t))dt+\sigma_2 dB_2)\\
&+\frac{1}{2}\left[\frac{\partial^2 f}{\partial S^2}\sigma_1^2 S^2 dB_1^2+2\frac{\partial^2 f}{\partial S\partial r}\sigma_1\sigma_2 SZ_1Z_2dt+\frac{\partial^2 f}{\partial r^2}\sigma_2^2 dt\right]
\end{aligned}
$$

Owing to $dB_1 \approx Z_1\sqrt{dt}$, $dB_2 \approx Z_2\sqrt{dt}$ and $dB_1dt \approx Z_1(dt)^{3/2}$, $dB_2dt \approx Z_2(dt)^{3/2}$

where Z_1, Z_2 are subject to the standard normal distribution. Which means $Z_1 \sim N(0,1), Z_2 \sim N(0,1)$. Their probability density function is $f(x)=\frac{1}{\sqrt{2\pi}}e^{-x^2/2}$, so ${Z_1}^2=1$, ${Z_2}^2=1$. Remove the higher order terms dt, we can get the relation:

$$
df = \beta dt + \gamma dB_1 + \eta dB_2
$$

Where:

$$
\beta=\frac{\partial f}{\partial t}+\frac{\partial f}{\partial S}\mu S+\frac{\partial f}{\partial r}a(\bar{r}-r(t))+\frac{1}{2}\frac{\partial^2 f}{\partial S^2}{\sigma_1}^2S^2+\frac{\partial^2 f}{\partial S\partial r}\sigma_1\sigma_2 SZ_1Z_2+\frac{\partial^2 f}{\partial r^2}\sigma_2^2
$$

$$
\gamma=\frac{\partial f}{\partial S}\sigma_1 S; \quad \eta=\frac{\partial f}{\partial r}\sigma_2
$$

Making use of hedging idea to risk neutral investment portfolio on f, Z, S, the number of assets which were invested are n_1, n_2, n_3, the magnitude of value for the investment was

$$
\Pi = n_1 S - n_2 f + n_3 Z
$$

Then we can have:

$$
\begin{aligned}
d\Pi &= n_1 dS - n_2 df + n_3 dZ\\
&= (n_1\mu S - n_2\beta + n_3 Zr)dt + (n_1\sigma_1 S - n_2\gamma)dB_1 - n_2\eta dB_2
\end{aligned}
$$

Besides, $d\Pi = r(n_1S - n_2f + n_3Z)dt = r\Pi dt$. Finally without considering the premise of mortality rate, using the option pricing theory, obtained the stochastic differential equations of fair premium on the participating life insurance policy under the conditions of European Options:

$$
\frac{\partial f}{\partial t}+\frac{\partial f}{\partial S}\mu S+\frac{\partial f}{\partial r}a(\bar{r}-r(t))+\frac{1}{2}\frac{\partial^2 f}{\partial S^2}{\sigma_1}^2S^2+\frac{\partial^2 f}{\partial S\partial r}\sigma_1\sigma_2 SZ_1Z_2+\frac{\partial^2 f}{\partial r^2}\sigma_2^2-rf=0
$$

The above equitation obtained the stochastic differential equation which is satisfied by fair premium in the risk-neutral conditions when $k-1 \leq t < k$. Obviously, fair premium Vhas the relationship with stock volatility σ_1, stock drift rate μ, interest rate volatility σ_2, and a, $\bar{r}$ in the Vasicek model.

Derived by the above, in the single-factor model, increased the interest rate model, endowment life insurance dividends obtained a fair premium of a two-factor pricing model, this provides us a more accurate reference method in the fair premium pricing.

3 Conclusion

In this article, we mainly studies fair premium pricing of endowment life insurance dividends. Using option pricing theory and actuarial principles, combined with Vesicek term structure of interest rate models. We can obtain a participating insurance fair premium differential equations, it provides a more accurate reference for the dividend pricing of insurance products. This article finally obtains the participating life insurance model, it is an improvement of the existing participating life insurance actuarial models, and this model is more realistic. However, this article is also deficient, although life insurance company portfolio asset class division, but generally speaking this division is still relatively crude. Moreover, Vesicek interest rate term structure model is the simplest model, and the more widely used model, but it has its own drawbacks. So I hope to learn in the future to have further study in order to overcome these deficiencies.

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The Study of Applying Black-Scholes Option Pricing Model to the Term Life Insurance

Lifang Wang, Yue Hu, and Danwei Qiu

Abstract With the rapid development of insurance markets, the setting of premium became an important issue. Financial option is an important tool in the financial markets, and the B-S Option Pricing Model, which is risk-neutral pricing model, is based on strict assumptions to calculate the price of the call option. Utilizing the connection between European call option and European put option of risk-free assets, we observe that European put option formula can be obtained by the value of European call option with the same validity and contract price. Insurance and financial options have many similarities, which is actually a kind of put options. Give some assumptions, the B-S Option Pricing Model is applied to term life insurance, and we can summarize the problems that the B-S Option Pricing Model is not suitable to set premium through comparison with insurance actuarial method.

Keywords B-S option pricing model · Premium · Risk-neutral · Term life insurance

1 Introduction

After nearly 30 years of development, China's insurance industry, successfully setting up an innovative way based on domestic and facing the world, has achieved lots of great achievements attracting world-wide attention. After China's WTO entry, its insurance industry has being forced to accelerate the opening-up to foreign firms, and a large amount of strong competitors has been pouring into our country' insurance market. At present, the number of foreign industry companies in China has reached more than 100. With a history of more than 100 years and an abundance

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of business experience, foreign insurance companies has solid capital strength, advanced management technology and flexible marketing approaches, all of which makes the development of China's insurance industry an ordeal in the competition of seizing the world's largest insurance market.

One of the key problems in insurance theory is to determine the insurance premium. When determining the premium, the insurer adopts proper premium computational models. If the premium is on the high side, which makes the insurer gain more profits, the relatively higher premium is of no advantage to attract more customers. Conversely, if the premium id on the low side, the insurer's investment income cannot balance the payment for the insurant, which leads to business loss and is harmful to insurer's operating stability. Therefore, the study of premium computational models is of great theoretical and practical significance.

The study of option pricing dates from the first article on option pricing by Louis Bachelier, the French financial expert in 1990. However, the first complete option pricing model was proposed by Black and Scholes in the 1970s. That is the Black-Scholes Option Pricing Model. According to this model, only the present value of the share price relates to the future prediction, which has nothing to do with the variable's past history and evolving forms. It indicates that the determination of the option price is very complex, which can be influenced by contract term, current share price, interest rate level of risk-free asset and delivery price. Xiangyou Wu studied the application of B-S Option Pricing Model to the pricing of valued insurance, and constructs a premium computational formula based on the B-S Option Pricing Model. Based on the inspiration of our predecessors, this article will study the application of the Black-Scholes Option Pricing Model to term insurance.

2 B-S Option Pricing Model

Financial option refers to the purchaser's behavior to buy or sell contracts that contains the rights of a certain number of financial assets (i.e. Underlying Financial Assets such as stocks, foreign currency, short-term and long-term bond financing and foreign currency futures contract, stock index futures contract and so on) according to Exercise Price or Striking Price within the prescribed period.

2.1 The Derivation of Black-Scholes Option Pricing Model

Option pricing model is based on the hedge portfolio. Investors can build portfolio of options and its stocks to ensure to determine the reward. From the derivation of Black-Scholes Option Pricing Model, it is easy to see that the option pricing is essential no-arbitrage pricing. Black-Scholes option pricing equation is that the value of the financial product today, should be equal to the future income of discount

$$c = e^{-r(T-t)} E[\max(S_T - X, 0)] \tag{1}$$

where E is the expected value based on the assumption of risk-neutral. All the rates are risk-free interest rate, including discount rate of the expected value and the required rate of return (μ) of logarithmic normal distribution. The evaluation of (1) is a process of integral. Notice the model of stock price:

$$S_T = S_0 e^{\sigma B_T + (r-\sigma^2/2)(T-t)}$$

in which $B_T, T = 1, 2, \cdots$, are normal random variables with mean 0 and variance T. Give $B_T = \sqrt{T-t}Z$, where Z ~ N(0,1), and we can obtain

$$\begin{aligned} c &= e^{-r(T-t)} E[\max(S_0 e^{\sigma\sqrt{T-t}Z + (r-\sigma^2/2)(T-t)} - X, 0)] \\ &= \frac{e^{-r(T-t)}}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \max(S_0 e^{\sigma\sqrt{T-t}Z + (r-\sigma^2/2)(T-t)} - X, 0) e^{-x^2/2} dx \end{aligned}$$

if $S_0 e^{\sigma\sqrt{T-t}Z + (r-\sigma^2/2)(T-t)} - X > 0$, the integrand is nonzero, then we can solve the equation of

$$S_0 e^{\sigma\sqrt{T-t} - tZ + (r-\sigma^2/2)(T-t)} - X = 0$$

Easily we get the solution $a = \frac{\ln(\frac{X}{S_0}) - (r - \frac{\sigma^2}{2})(T-t)}{\sigma\sqrt{T-t}}$.

So we can get the options pricing formula:

$$\begin{aligned} c &= \frac{e^{-r(T-t)}}{\sqrt{2\pi}} \int_a^{\infty} (S_0 e^{\sigma\sqrt{T-t}Z + (r-\sigma^2/2)(T-t)} - X) e^{-x^2/2} dx \\ &= \frac{e^{-r(T-t)}}{\sqrt{2\pi}} \int_a^{\infty} -X e^{-x^2/2} dx + \frac{e^{-r(T-t)}}{\sqrt{2\pi}} \int_a^{\infty} S_0 e^{\sigma\sqrt{T-t}x + (r-\sigma^2/2)(T-t)} e^{-x^2/2} dx \\ &= -e^{-r(T-t)} X(1 - N(a)) + \frac{e^{-r(T-t)}}{\sqrt{2\pi}} \int_a^{\infty} S_0 e^{\sigma\sqrt{T-t}x + (r-\sigma^2/2)(T-t)} e^{-x^2/2} dx \\ &= -e^{-r(T-t)} XN(-a) + \frac{e^{-r(T-t)}}{\sqrt{2\pi}} S_0 e^{(r-\sigma^2/2)(T-t)} \int_a^{\infty} e^{\sigma\sqrt{T-t}x} e^{-x^2/2} dx \\ &= -e^{-r(T-t)} XN(-a) + \frac{S_0 e^{-\sigma^2/2\cdot(T-t)}}{\sqrt{2\pi}} \int_a^{\infty} \exp(-\frac{(x - \sigma\sqrt{T-t})^2}{2} + \frac{\sigma^2(T-t)}{2} dx \\ &= -e^{-r(T-t)} XN(-a) + S_0 e^{-\sigma^2/2\cdot(T-t)} e^{\sigma^2/2\cdot(T-t)} N(-(a - \sigma\sqrt{T-t})) \\ &= -e^{-r(T-t)} XN(-a) + S_0 N(-(a - \sigma\sqrt{T-t})) \end{aligned}$$

That is

$$c = SN(d_1) - Xe^{-r(T-t)}N(d_2) \tag{2}$$

where $d_1 = \dfrac{\ln(\frac{S}{X}) + (r + \frac{\sigma^2}{2})(T - t)}{\sigma\sqrt{T - t}}$,

$$d_2 = \frac{\ln(\frac{S}{X}) + (r - \frac{\sigma^2}{2})(T - t)}{\sigma\sqrt{T - t}} = d_1 - \sigma\sqrt{T - t}$$

In (2), S means the original price of underlying assets. X means the Strike price of an option represented in a contract. σ means the price volatility of underlying assets, which is a constant. μ means the price drift rate of underlying asset underlying assets, which is a constant. γ means the risk-free interest rate, which is a constant. T-t means the maturity date of the option. $N(x)$ means the cumulative distribution function of standard normal distribution variables. Equation (2) is European call option pricing formula of risk-free assets.

There are some strong assumptions on the (2):

- The price of underlying assets submitting to logarithm normal distribution;
- Within the option period, risk-free rate and the price volatility of underlying assets are constant;
- The market is frictionless, which means there is no transaction cost or revenue. All the assets can be infinitely, fractionized, and can be carried on the oversell operation;
- Within the option period, the underlying assets fail to pay bonus or other incomes;
- Financial markets have no risk-free arbitrage opportunities;
- Transactions in financial assets can be continuous, and the price of underlying assets also changes continuously;
- These are European call options, which can not be carried out until the maturity (Wu 2003; Zhang et al. 2008).

2.2 European Put Option Formula

Consider two portfolios: portfolio A and portfolio B

Portfolio A: an European call option and a zero coupon bond which has face value the same as the strike price of option by X (present value is $Xe^{-r(T-t)}$).

Portfolio B: an European put option has the same validity and contract price as the European call option of Portfolio A and one unit underlying asset.

When the option is at maturity, the rate of return of portfolio A is $X + \max(S_T - X, 0) = \max(S_T, X)$; the rate of return of portfolio B is $\max(X - S_T, 0) + S_T = \max(X, S_T)$

The value of two portfolios is $\max(X, S_T)$. Because European option can not be carried out ahead of maturity, the two portfolios have the equal value according to no arbitrage principle. There is an equation given by

$$c + Xe^{-r(T-t)} = P + S \tag{3}$$

where c, P and S are the prices of European call option, European put option and underlying assets.

Equation (3) means the connection between European call option and European put option of risk-free assets. It means that European put option formula can be obtained by the value of European call option with the same validity and contract price.

As a consequence,

$$\begin{aligned} P &= c + Xe^{-r(T-t)} - S \\ &= SN(d_1) - Xe^{-r(T-t)}N(d_2) + Xe^{-r(T-t)} - S \\ &= Xe^{-r(T-t)}N(-d_2) - SN(-d_1) \end{aligned}$$

That is

$$P = Xe^{-r(T-t)}N(-d_2) - SN(-d_1) \tag{4}$$

Equation (4) is the European put option formula.

3 Option Features of Insurance

The option features of insurance refers to the property that the buyer and seller of an option contract have unequal rights and obligations, that is, the long side has the right to decide to either implement or waive the right according to the market changes, while the short side only has the obligation but no right. In other words, the seller has to honor the agreement as the buyer requires provided that the buyer enforces the right. Conversely, if the buyer thinks that the enforcement of the right is unfavorable to him, the seller has no right to ask the buyer to perform the contract. Therefore, the buyer needs to pay a certain price, i.e. the option price (Stampfli and Goodman 2001; Wang 2004).

Just like option, insurance is a financial instrument used to avoid or transfer the risks, and a contingent interest voucher whose holder has the right to decide to either implement or waive the right before the policy matures. However, the seller of the contract only has the passive obligation of keeping the appointment and has no right to ask the buyer to honor the agreement. The policy-holder's purchase of insurance in full is equivalent to the purchase of a put option with the subject matter as its underlying assets. The exercise price is the insured amount. If insurance accident happens and causes total loss of the subject matter during the insured period, the insured can execute the put option by selling the damaged subject matter to the seller of the insurance policy (i.e. the insurer) at exercise price, thus making the value of the possessed subject matter restore to the state before the damage occurs.

Therefore, an insurance contract is actually a put option, in which insurance premium is paid to buy a put option with insurance as its contract period and the agreed compensation (i.e. the insured amount) as its exercise price. Insurance premium is the option price.

4 The Application of B-S Option Pricing Model

Here, we exam a man aged (x) who has bought a n-year term insurance for insurance premium of X and rate of r. The fundamental assumptions are as follows:

1. Assume the insurant pays a one-time payment of the insured amount to the insurance company;
2. The insurant's death probability function is continuous;

Assuming the insurant's current price is S_0, the older the insurant is, the easily will the insurant die, thus making the premium higher. ${}_np_x$ means that the man aged (x) remains alive in the future n years. ${}_nq_x$ means that the man can live no more than n years in the future.

Then we can determine the insurant's possible yield rate on the due date is $u_i(i = 0, 1)$, $u_i = S_i/S_0$, $Eu_i = {}_np_x$ is the expectation of u_i. S_1 stands for the insurant's value upon his death within the insurance period, i.e. the attainable compensation X. In this way, $S_1 = 0$. S_0 means that the insurance company don't need to pay the compensatory sum if the insurant is alive during the insurance period.

$$\sigma = \sqrt{E(u_i - Eu_i)^2} = \sqrt{2 \cdot {}_np_x \cdot (1 - {}_np_x)}$$

refers to the fluctuation ratio of the insurant's value.

We assign certain values to the variables in the premium valuation formula to analyze how to use this formula to calculate the insurance premium. Assumptions are as follows:

The insurant is a male aged 55, i.e. $x = 55$;

Insurance period lasts for 5 years, i.e. $t = n = 5$;

Assuming the premium is 200,000 yuan, the current value of the insurant is $S_0 = 200,000$ yuan, i.e. $X = 200,000$, $S_0 = 200,000$;

The risk-free rate of interest in the market is 3%, i.e. $r = 3\%$;

According to experience life table of China's life insurance industry (1990–1993) (male),

$${}_5p_{55} = \frac{l_{60}}{l_{55}} = \frac{853,391}{898,738} = 0.94954$$

From the assumed condition,

$$d_1 = 0.56, \quad d_2 = -0.13, \quad \sigma = 0.3096,\ N(-d_1) = 0.2877, \quad N(-d_2) = 0.5478$$

Through the European put option pricing formula,

$$P = Xe^{-rt}N(-d_2) - S_0N(-d_1)$$

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}, \quad d_2 = d_1 - \sigma\sqrt{t} = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r - \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

From this, we can know that a 55-year-old insurant who buys a 5-year term insurance needs to pay a one-time payment of 36,759.1659 yuan to the insurance company. That is the lowest premium required by the insurance company which accepts this kind of insurance. However, extra charges, including other factors like commission, administrative cost and so on, have to be taken into consideration in practice.

According to Law of Large Numbers, the net premium amount collected by the insurer should consist with the gross expenditure of insured amount. Actuarial present value takes people's death and survival probability into consideration. The expected present value or the actuarial present value of the insured amount is the net single premium of the insurance policy. Therefore, actuarial present value of this policy can be obtained according to actuarial theory, i.e.

$$200,000 \cdot A^1_{55.\overline{5}|} = 200,000 \sum_{k=0}^{4} v^{k+1} \cdot {}_{k|}q_{55} = 9,196.7316$$

The result obtained by this method is that a 55-year-old insurant who buys a 5-year term insurance needs to pay net single premium of 9,196.7316 yuan regardless of other expenses.

When comparing these two methods, we can obviously find the difference between these desired values because we have assumed that $S_0 = X$. Here, whatever value of $S_0 = X$ is, there always exists

$$P_1 = Xe^{-rt}N(-d_2) - S_0N(-d_1) > P_2 \cdot A^1_{55:\overline{5}|}.$$

Therefore, it is inappropriate to apply the B-S option pricing model to term life insurance.

5 The Conclusion

This article studies the application of the Black-Scholes Option Pricing Model to term insurance. We find its result is different from with the traditional insurance actuary pricing. This article adopts the same data, but here appears two different results. And the results will change a lot when the value of S_0 is different. Why? One reason is that China now has no risk-free rate, and we only estimate it in statistical method. Another reason is that we can't measure the value of insurant, so it has some limitation when it was used. We know that we can make use of the B-S Option Pricing Model to get the pricing of valued insurance, but it is not a good method to apply the B-S option pricing model to term life insurance.

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Evolutionary Variation of Service Trade Barriers in Banking: A Case of ASEAN+3

Xiaobing Feng

Abstract Although there are extensive research on ASEAN+3 discovering the synchronization of economic patterns including exchange rate management policies in the region, the research on the pattern of trade policies in banking sector is still limited. In this paper, we evaluate the trade barriers in banking and its evolution over time using three sequential survey data from World Bank as well as other international organizations. It was found that there exists salient dispersions in trade restriction policies and the dispersion remains over time. There is no trend toward more liberalization in the sector either.

Keywords Factor analysis · Service trade in banking · Trade restrictiveness index

1 Introduction

Trade barriers in banking services are general term that describes any government policy or regulation that restricts factor movements in international banking service trade. The main challenge in the research has been to transform essentially regulatory measures into quantitative data, which would allow comparison across time and countries. The earliest simple frequency measure has been developed by (Hoekman 1995). A more elaborate set of frequency measures which are termed trade restrictive index (TRI), has been constructed by a research team from Australia Productivity Commission, University of Adelaide and National University of Australia for six industries including banking in Australia (McGuire 1998; McGuire and Schuele 2001; Dee 2005). Researchers from OECD (Dinh and Dee 2010; Dihel and Shepherd 2007; Nordås and Kox 2009) challenge the methodology of TRI evaluation using subjective allocation of weights to the various regulation

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components. They instead use the approach of statistic factor analysis to identify the weight through the variation of data.

There however exist two problems in the current approaches: Firstly, low cross-country variation in restrictions may have little or no relationship with the relative economic importance of particular restriction categories. The more important restrictions, if they were applied widely and consistently across countries, could also have low cross-country variation and thus low factor analysis weights (Doove et al. 2001). To compromise the problem, in this paper, a survey is conducted by interviewing CEOs in twenty multinational banks in China to evaluate the weights subjectively, meanwhile, a factor analysis is applied. A weighted average of weights from two sources is hence derived.

Secondly, economy wide econometric studies are subject to the Lucas Critique (Lucas 1976).The estimates of flow on economic variables are appropriate only if the economy stays with the same structure, however it could be highly misleading when confronting the structural change. The ideal way to address this issue is to evaluate the TRI at an annual base. However, countries do not usually change trade policies so frequently. In this study TRIs are therefore updated on intervals of 2 or 3 years, which is also constrained by the availability of the survey data.

The main sources of the regulatory components of TRI are the GATS schedules (for WTO members). The information in GATS schedules is ,however ,limited by the positive listing approach. Consequently they do not include all barriers which are in place. This research will instead adopt mainly information from three sequential surveys by World Bank (Barth et al. 2006). The world bank survey not only contains information on Entry Barriers and National Treatment, but also operational and prudential regulations. Furthermore it takes place at three different time periods 1998–2001, 2003, 2007–2008 which allows us to examine the evalutionary of the TRI across the countries over time by formulating a panel dataset.

Finally, while most of the study take a global view, the research on the regional scale is limited. This paper takes a regional perspective to estimate the TRI and economic impacts in ASEAN+3. To the best of our knowledge, two study focus on the regional trade restriction in banking. Claessens (Claessens and Glaessner 1998; Rajan and Sen 2002) conducted the TRI research covering this area but with mainly descriptive method.

This study intends to answer the following important questions: how the country in ASEAN+3 adjust the trade barriers in banking from time to time? Is there a consistent pattern in the TRI like other important economic policies such as exchange rate arrangement policy discovered in the region (Feng and Wang 2010; Feng et al. 2010a, b)?

The remaining of the paper is arranged as follows: Sect. 2 constructs and measures the trade restriction index; Sect. 3 describes the data and their sources; Section concludes the paper and indicates the future research.

2 Measurements of Trade Barriers in Banking

There are three steps in measuring the trade barriers in banking: identification of components, allocation of scores and estimation of weights.

2.1 Identification of Non-prudential and Prudential Components and Scores

The non-prudential components are identified by the following two steps: first, taking WTO GATS schedule as standard to convert World Bank Survey Data (WBS) to WTO GATS framework; second, combining data from World Bank Survey, APEC Individual Action Plan and Local Legislation as additional information.

In order to trace the evolution of banking barriers in ASEAN+3, information on the variation of the regulations is needed. WTO commitment schedule provides a benchmark to evaluate the TRI and it is static. A growing body of research has used the World Bank's survey data in banking regulations and practices based on the information provided by financial supervisory authorities all around the world (Barth et al. 2009). The three sequential surveys conducted at periods of 1998–2000, 2002–2003, 2006–2007 allow one to examine the changes of the regulations in the region of ASEAN+3. The data of 2009 is derived from APEC individual action plan (APEC IAP) and central banks of the respective countries.

We convert the WBS into the framework of WTO GATS along the four modes of the trade. The majority of the information from WBS belongs to the third mode, the commercial presence. We rely on the coding system of the two database for matching and comparison. There exists very close match between the two data basis. The information for the rest of the three modes whenever available is provided by APEC IAP which has been conducted at an annual basis starting from year 2000.

In addition to the rich time line of the database, WB survey data also provides information on prudential restrictions on foreign banking service such as capital adequacy ratio. It is recognized that such banking service barriers as capital reversal, are intended to reduce the unexpected shocks from entry of foreign banking. In this paper two most common prudential measures: capital adequacy and liquidity ratio are taken into consideration for TRI construction.

The score of each component is assigned a 1 if any type of restriction appears and 0 if no restriction appears. When the survey result is a continuous number rather than a discrete number such as "yes" or "no", a ratio between 0 and 1 is calculated.

2.2 Estimation of Weights

Weights are developed to measure the relative importance in the composite TRI. For example, prohibitions on local currency operation is more restrictive than restriction of the skill and expertise of management personnel in banking. Two approaches are used in estimating the weights: a subjective assessment method and a statistical factor analysis method.

A small scale survey is run within twenty CEOs of domestic and foreign banks in Shanghai and a questionnaire regarding the importance of all the restrictive components is distributed. A statistics way of estimating weights is factor analysis. Following Feng et al. 2010a, b, the detailed weights estimation by factor analysis is presented in Appendix Tables 1 and 2.

Before the factor analysis, various umber of variables and different orders are experimented, the rest of combination of variables have not passed the Kaiser-Meyer-Olkin measure(KMO) or the Bartlett's test of Sphericity. Table 1 in appendix posits the results of KMO and Bartlett Tests which are suitable for factor analysis

The second and fifth columns in Table 2 in the appendix list the eigenvalues before and after the rotation, which are greater than one. F1 to F4 are the four factors that have been extracted. Columns three and six represent the percentage of variances that have been explained by the underlying factors before and after the rotation. The Rotation has the effect of optimizing the factor structure and the relative importance of the factors are equalized.

The actual weights are simple weighted average of the subjective weights and statistic estimated weights.

2.3 Evaluation Results of TRI in ASEAN+3

TRI is computed using the assigned scores and weights with identified components, which is represented in (1).

$$TRI_{jt} = \sum_{j=1}^{J} \sum_{i=1}^{I} Score_{it} * Weight_{it} \tag{1}$$

Where i = 1,2. . .. I, are components , j = 1,2. . . J are countries, t = t_1, t_2.,t_3. . .T

Figure 1 summarizes the steps showing how the index is constructed; Fig. 2 presents the results of the calculated TRI.

Figure 2 shows the wide dispersion of the trade restriction index in these countries, in particular, the dispersion remains over the sample periods. There is no sign of convergence in the restriction policy among these nations in the banking service sector. In the same vein, no uniform trend toward more liberalization can be

Table 1 Summary of data sources

Data source	Purpose	Data source	Purpose
World bank database	Components scores	Country legislation: central bank and banking law of each country	Components scores
WTO	Components scores	Self run-survey	Weights
APEC	Components scores		

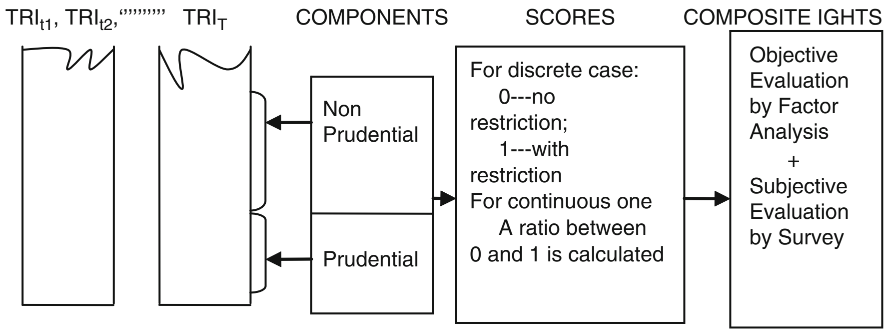

Fig. 1 An Illustration of Construction of trade restrictiveness index (TRI)

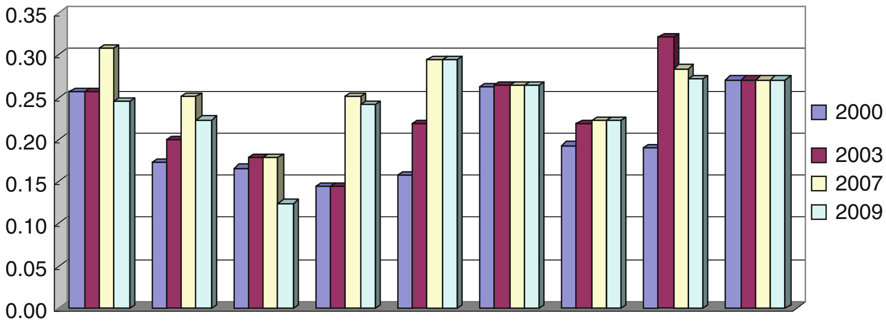

Fig. 2 TRI of ASEAN+3, from 2000 to 2009. From left to right, the countries are China (2000, 2003, 2007, 2009), Indonesia (2000, 2003, 2007, 2009), Japan (2000, 2003, 2007, 2009), Korea (2000, 2003, 2007, 2009), Malaysia (2000, 2003, 2007, 2009), Philippine (2000, 2003, 2007, 2009), Singapore (2000, 2003, 2007, 2009), Thailand (2000, 2003, 2007, 2009) and Vietnam (2000, 2003, 2007, 2009)

identified. Countries tend to be more cautious and reserved due to, most likely, the intense risk management aspects of the regulations required by BIS.

The TRI in the graph further indicates that Japan is the most liberal nation in the banking service trade within the sample periods, South Korea, Indonesia and the regional financial center Singapore may also be regarded as relatively liberal following Japan. China and Vietnam are among the most restrictive nations in the region even though there is tendency to become more liberal as time evolves.

3 Data Description

The data sources are summarized in Table 1. Because the data of Cambodia, Myanmar and Republic of Laos is not available, these countries are not researched in this study.

4 Conclusions and Future Research

The banking sector is one of the most important service sectors for economies in ASEAN+3, in particular, the developing economies. It is one of the largest contributors to gross domestic product, production and employment. In order to further develop and reform the banking sector, it is indispensible for countries to identify the impediments or restrictions in the trade.

Unlike a few other economic macro-variables such as exchange rate which shows the sign of convergence in the behavior pattern in the region, the dispersion of trade policies in banking sector is salient. Furthermore, the dispersion pattern remains over the sample period. The country differences in the development stages, in capital markets, trade policy evolution and economic development stages can be the reasons for the observed dispersion.

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Appendix

Table 1 The results of KMO and bartlett tests

KMO measure		*0.622 > 0.5*
Bartlett's test of Sphericity	χ Square	174.521
	Significance	0.000 (significant)

Table 2 Variance explained-weights identified

Component	*Extraction sums of squared loadings*			*Rotation SS loadings*		
	Eigenvalue	% of variance	Cumulative %	Eigenvalue	% of variance	Cumulative %
F1	3.350	30.457	30.457	2.573	23.388	23.388
F2	2.737	24.883	55.341	2.299	20.901	44.289
F3	1.300	11.815	67.156	2.069	18.811	63.100
F4	1.006	9.141	76.297	1.452	13.197	76.297

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Corporate Board Governance and Risk Taking

Shenglan Chen

Abstract This paper investigates the relationship between corporate board governance and risk taking in China's capital markets. Using a sample of Chinese listed firms from the period 2000 to 2005, the results suggest that board size and the ownership of board have negative effect on corporate risk taking. The results also suggest that the effect of the ownership of board on risk taking is stronger for non state-controlled listed firms than state-controlled listed firms.

Keywords Board · Corporate governance · Risk taking

1 Introduction

Corporate risk taking is an important research topic. John et al. (2008) argue that better investor protection could lead corporations to undertake riskier but value-enhancing investments. The effects of large shareholder diversification and ownership structure on corporate risk taking have been examined (Faccio et al. 2010; Paligorova 2010).

Boards of directors can play a significant role in controlling agency problems, particularly in monitoring executive management (Fama and Jensen 1983). However, few research focus on the relationship between the corporate board and risk taking.

Using a sample of Chinese listed firms from the period 2000 to 2005, I investigate the relationship between corporate board and risk taking. The results suggest that board size and the ownership of board have negative effect on corporate risk taking. The results also suggest that the effect of the ownership of board on risk taking is stronger for non state-controlled listed firms than state-controlled listed firms.

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The remainder of this study proceeds as follows. Section 2 reviews the literature. I review the research design in Sect. 3. Section 4 provides the main results, and the final section provides concluding comments.

2 Literature Review

2.1 Corporate Risk Taking

According to agency theory, managers avoid taking risks, including those that enhance firm value, due to career concerns (Amihud and Lev 1981). According to this view, managers may even spend corporate resources to diversify their companies' operational risks to protect their career. Large shareholders have powerful incentives to collect information and monitor managers in order to maximize their profits. As the ownership stake increases, ceteris paribus, shareholders have greater incentives to raise a firm's profit by taking risky projects.

Paligorova (2010) suggests many large companies have the same largest shareholders. These companies are viewed as groups. Groups can be connected also through informal ties such as social ties. Group organizational structure allows large shareholders to act from a more diversified position and thus take more risky projects. The type of the shareholders plays a role in risk taking. Family controlled companies may avoid risk taking due to their goal of transferring the firm to the next generation. Using a large cross-country sample, Paligorova (2010) find a positive relationship between corporate risk taking and equity ownership of the largest shareholder. This result is entirely driven by investors holding the largest equity stakes in more than one company. Family shareholders avoid corporate risk taking as their ownership increases.

Faccio et al. (2010) focus on the impact of large shareholder diversification on corporate risk taking. They exploit the data available in Amadeus to reconstruct the stock portfolios of a large panel of shareholders who hold equity stakes in privately-held and publicly-traded European firms. They find strong statistical evidence that firms controlled by non-diversified large shareholders invest more conservatively than firms controlled by well diversified large shareholders. Further, and more importantly, the economic impact of large shareholder diversification on risk taking is non-negligible.

John et al. (2008) examine the relationship between investor protection and the risk choices in corporate investment. Previous research shows, in poor investor protection countries, corporations may have dominant insiders with nontrivial cash flow rights and large private benefits in the firms that they control (Morck et al. 2005; Stulz 2005). Their high exposure may lead them to be conservative in directing corporate investment. Better investor protection could lead corporations to undertake riskier but value-enhancing investments. For example, better investor protection mitigates the taking of private benefits leading to excess risk-avoidance.

Using a cross-country panel and a U.S.-only sample, they find that corporate risk-taking and firm growth rates are positively related to the quality of investor protection.

2.2 Board Governance

The board of directors plays an important role in corporate governance, such as hiring, firing, and assessment of management, or assessment and project selection (Adams et al. 2010).

Hermalin and Weisbach's (1988) model shows how the board updates its beliefs about the manager's ability based on the performance. In light of these updated beliefs, the board may choose to dismiss the manager. Coles et al. (2008) argue that boards have different sizes because firms face different problems. They find that firm performance is increasing in board size for certain types of firms, namely those that are highly diversified or that are high-debt firms.

Boone et al. (2007) find evidence consistent with the idea that successful CEOs are able to bargain for less independent boards. This result indicates that once CEOs become more powerful, the governance role of board will be weakened.

Raheja (2005) argues that the optimal board structure is determined by the trade-off between maximizing the incentive for insiders to reveal their private information, minimizing coordination costs among outsiders and maximizing the ability of outsiders to reject inferior projects. More recently, Bermig and Frick (2010) analyze the effects of supervisory board size and composition on the valuation and performance of all German listed firms. They find a significantly positive influence of board size on Tobin's Q.

The research of China's capital markets mainly focus on bank risk taking (e.g., Kong and Dong 2008). Few empirical studies examine the impact of board governance on corporate risk taking. This paper investigates the relationship between board governance on corporate risk taking in China's capital markets.

3 Research Design

3.1 Sample Selection and Data Source

The initial sample consists of non-financial firms of China's capital markets from 2002 to 2008. To be included in the sample, firms must also have data available on the annual database. For each firm with available earnings and total assets for at least 4 years over the 2000–2008 period, I compute the proxy for corporate risk taking. The final sample contains 5,691 firm-year observations. The financial information of firms is obtained from CSMAR-A database, which collects financial and market information of all firms listed in Shanghai and Shenzhen stock exchanges.

3.2 Research Variables

Risk taking variable. The measure of corporate risk-taking behavior is the industry-adjusted volatility of firm profitability (John et al. 2008), *Risk*. Profitability is measured by the firm's ratio of earnings before interests and taxes (EBIT) to total assets (Assets). For each firm with available earnings and total assets for at least 4 years over the 2000–2008 period, I compute the deviation of the firm's EBIT/Assets from the industry average for the corresponding year. I then calculate the standard deviation of this measure for each firm.

Board governance variable. There are 4 board governance variable as follows: *CEOD*, a dummy variable equal to one if the chairman of the board and the CEO are the same person and zero otherwise; *BSize*, the logarithm of number of corporate board; *IndepR*, number of independent board divided by number of corporate board; *DSh*, the percentage of ownership of the board shareholders.

Control variables. Other control variables are as follows: *Size*, the logarithm of total assets; *ROA*, net income divided by total assets; *Lev*, total liabilities divided by total assets; *Growth*, change rate in sales.

3.3 Research Models

Since the sample is pooled across company-year observations, the annual observations of a given company might not be drawn independently and, to correct this statistical problem, I adjust the coefficients' standard errors by "two-way clustering" on each company and each year (Gow et al. 2010). The model used is as follows:

$$\begin{aligned} Risk = {} & \beta_0 + \beta_1 CEOD + \beta_2 BSize + \beta_3 IndepR + \beta_4 DSh \\ & + \beta_5 Size + \beta_6 ROA + \beta_7 Lev + \beta_8 Growth \\ & + Year\ fixed\ effect + Industry\ fixed\ effect + \varepsilon \end{aligned} \tag{1}$$

Where

Risk = the time series standard deviation of corporate profitability; *CEOD* = a dummy variable equal to one if the chairman of the board and the CEO are the same person and zero otherwise; *BSize* = the logarithm of number of corporate board; *IndepR* = number of independent board divided by number of corporate board; *DSh* = the percentage of ownership of the board shareholders; *Size* = the logarithm of total assets; *ROA* = net income divided by total assets; *Lev* = total liabilities divided by total assets; *Growth* = change rate in sales.

4 Empirical Results

4.1 Descriptive Statistics

Table 1 reports descriptive statistics for the variables. I winsorize all the continuous independent variables at the top 1% and bottom 99% percentiles in order to avoid outlier problems. The mean and median of *Risk* are 0.043 and 0.024, respectively. The mean of *CEOD* is 0.111, indicating that the chairman of the board and the CEO are the same person in 11.1% of the sample. The mean and median of *BSize* are 2.239 and 2.197, respectively. The mean and median of *IndepR* are 0.271 and 0.333, respectively. The mean and median of *DSh* are 0.002 and 0.000, respectively.

Table 2 reports a Pearson correlation matrix for the risk taking variable and board governance variables. The correlation coefficient between *Risk* and *BSize* is −0.064, which is significantly negative. The correlation coefficient between *Risk* and *IndepR* is 0.255, which is significantly positive.

4.2 Regression Results

Table 3 reports the regression results. In model 1, the coefficient of *CEOD* is 0.002, which is not significant (t-statistics = 0.82). This result shows that *CEOD* does not have significant effect on corporate risk taking behaviour. The coefficient of *BSize* is −0.014, which is marginal significantly negative (t-statistics = −1.68). This result

Table 1 Descriptive statistics

	N	Mean	SD	1%	Median	99%
Risk	5,691	0.043	0.059	0.000	0.024	0.285
CEOD	5,691	0.111	0.314	0.000	0.000	1.000
BSize	5,691	2.239	0.229	1.609	2.197	2.773
IndepR	5,691	0.271	0.125	0.000	0.333	0.455
DSh	5,691	0.002	0.015	0.000	0.000	0.133
Size	5,691	21.144	0.917	18.972	21.074	23.750
ROA	5,691	0.013	0.084	−0.468	0.026	0.147
Lev	5,691	0.501	0.234	0.081	0.490	1.733
Growth	5,691	0.228	0.550	−0.747	0.149	3.601

Table 2 Pearson correlation matrix

	Risk	*CEOD*	*BSize*	*IndepR*	*DSh*
Risk	1.000				
CEOD	0.015	1.000			
BSize	−0.064*	−0.043*	1.000		
IndepR	0.255*	0.006	−0.029*	1.000	
DSh	−0.014	0.044*	0.006	0.078*	1.000

*Statistically significant at the 5% level (two-tailed)

Table 3 Regression results

	Dependent variable: *Risk*				
	Model 1	Model 2	Model 3	Model 4	Model 5
CEOD	0.002	0.000	0.000	−0.001	0.003
	(0.82)	(0.11)	(0.26)	(−0.35)	(0.84)
BSize	−0.014*	0.004	−0.007**	−0.004	−0.009
	(−1.68)	(1.43)	(−2.02)	(−1.23)	(−1.44)
IndepR	0.120***	0.116***	−0.013	−0.016	−0.027
	(3.15)	(3.93)	(−1.19)	(−0.98)	(−1.56)
Dsh	−0.135***	−0.026	−0.066*	−0.000	−0.113**
	(−5.96)	(−1.03)	(−1.84)	(−0.00)	(−2.03)
Size		−0.007***	−0.007***	−0.005***	−0.009***
		(−5.04)	(−5.64)	(−4.70)	(−3.44)
ROA		−0.293***	−0.273***	−0.240***	−0.314***
		(−5.58)	(−5.34)	(−4.65)	(−5.28)
Lev		0.035***	0.039***	0.031***	0.044***
		(4.24)	(4.57)	(3.14)	(6.30)
Growth		−0.000	−0.001	−0.001	−0.000
		(−0.24)	(−0.30)	(−0.99)	(−0.10)
Constant	0.042	0.133***	0.144***	0.106***	0.196***
	(1.38)	(3.68)	(5.51)	(4.68)	(3.49)
Year			Yes	Yes	Yes
Industry			Yes	Yes	Yes
N	5,691	5,691	5,691	4,272	1,419
adj. R-sq	0.069	0.352	0.411	0.383	0.442
F	167.856	231.243	147.441	101.047	59.627

*, **, and *** denote significance levels of 10%, 5%, 1%, respectively. The coefficients' standard errors are adjusted for the effects of non-independence by clustering on each company and each year. Adjusted t-statistics are reported in parenthesis

shows that *BSize* has some negative effect on corporate risk taking behaviour. The coefficient of *IndepR* is 0.120, which is significantly positive (t-statistics = 3.15). This result shows that *IndepR* has significant effect on corporate risk taking behaviour. At last, the coefficient of *DSh* is −0.135, which is significantly negative (t-statistics = −5.96). This result shows that *DSh* has significant negative on corporate risk taking behaviour.

Some firm characteristic variable are controlled in model 2. The coefficient of *CEOD* is 0.000, which is not significant (t-statistics = 0.11). The coefficient of *BSize* is 0.004, which is not significant (t-statistics = 1.43). The coefficient of *IndepR* is 0.116, which is significantly positive (t-statistics = 3.93). The coefficient of *DSh* is −0.026, which is not significant (t-statistics = −1.03).

Year fixed effect and industry fixed effect are controlled in model 3. The coefficient of *CEOD* is 0.000, which is not significant (t-statistics = 0.26). The coefficient of *BSize* is −0.007, which is significantly negative (t-statistics = −2.02). The coefficient of *IndepR* is −0.013, which is not significant (t-statistics = −1.19). The coefficient of *DSh* is −0.066, which is marginal significantly negative (t-statistics = −1.84).

To summarize, the results indicate that *CEOD* does not have significant effect on corporate risk taking behaviour; *BSize* has negative effect on corporate risk taking behaviour; *IndepR* does not have significant effect on corporate risk taking behaviour; *DSh* has significant negative on corporate risk taking behaviour. In Model 4, using a sub-sample of state controlled firms, all the board governance variables are not significant. However, the coefficient of *DSh* in Model 5 is changed to -0.113, which is significantly negative (t-statistics $= -2.03$). The results suggest the effect of *DSh* on is stronger for non state-controlled listed firms.

5 Conclusion

This paper investigates the relationship between corporate board governance and risk taking behaviour in China's capital markets.

Using a sample of Chinese listed firms from the period 2000 to 2005, I find evidence that whether the CEO also serves as chairman and the independence of board doesn't affect corporate risk taking. However, board size and the ownership of board have negative effect on corporate risk taking.

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The Risk Factors Analysis of the Term Structure of Interest Rate in the Interbank Bond Market

Yujun Yang, Hui Huang, and Jing Pang

Abstract This article uses the Svensson model to develop the term structure of interest rate in China's interbank bond market, and then analyzes the variation of the term structure of interest rate through principal components analysis and sensitivity analysis. The results show the term structure can be explained by the four principal components rather than three principal components compared with foreign developer market. The first principal component seems different than the parallel shift factor of the yield curve usually found in foreign studies and the fourth factor has a significant impact on the term structure especially the spot rate within 1 or 2 years. The difference of the risk factors exhibits a distinctive feature of China's interbank bond market.

Keywords Risk factors · Sensitive analysis · The interbank bond market

1 Introduction

Term structure of interest rates, which reflects the changes in market expectations of future interest rates, is the pricing benchmark of various financial derivatives, as well as the foundation for financial product development, hedging, risk management,

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arbitrage, investment and other financial activities. Since interest rate liberalization in China is not entirely accomplished, many complex factors such as government policies and interventions have significant impacts on the interest rate in the bond market, which means that the term structure of interest rate changes in China may have its own unique features that are different from the foreign market. By deriving the term structure from the real inter-bank bond market transaction data, this article investigates characteristics of spot interest rate ranging from 1 to 20 years implied by bond price. In addition, using principal component analysis, this research extracts the key risk factors to explore the risk features of the inter-bank bond market in China.

2 Literature Review

The variation of term structure of interest rates over time is the main source of bond market's volatilities. By extracting the risk factors through principal component analysis, a main stream of foreign studies demonstrated that the major of the variance of the interest rate is contributed by two or three factors, which means that two to three major risk factors are enough to make a satisfactory explanation of the whole dynamic changes of the spot interest rate curve. Litterman and Scheinkman (1991) (Buhler and Zimmermann 1996) pioneered the research of using principal component analysis to extract the factors, their study showed that the three factors called as level, slope and curvature can explain the major variation of the interest rates. Many researchers followed started amount of empirical studies on bond markets in different countries. Buhler and Zimmermann (1996) (Johnson 2005) worked on the bond markets in Germany and Switzerland, Martellini and Peiaulet (2000) (Knez et al. 1991) analyzed the term structure of interest rates in France, Johnson (2005) (Martellini and Priaulet 2000) explored the variation of the term structure of interest rate about Canadian public debts. Domestic researchers started the study on term structure by principal component analysis in recent years. Shiwu Zhu and Jianheng Chen (2003) (Yeh and Lin 2002) developed the term structure of interest rate for 1–30 years on basis of the bond price data on SSE from April 19, 2002 to April 5, 2003, the results of principal component analysis showed that three factors may explain 94% of the overall variance of changes in interest rates. Compared with the over 5-year times series data in foreign studies, the domestic studies covered a much shorter series of data about 1 or 2 year, which reduced the reliability of their empirical evidence. In addition, our bond transactions are mainly realized in the inter-bank market, the term structure has not yet involved in the existing literature.

3 Methodology

The term structure of interest rate normally can be derived by two methods. One is the dynamic estimation method, and the other is the static estimation. Dynamic estimation method models the stochastic behavior of interest rates; it requires a relatively well-developed bond market with abundant derivatives which can produce instantaneous arbitrage-free opportunity. Once the market does not match with these premises, such model may not be applicable. Our domestic bond market is still in its early stage without various products and derivatives. Such model is not suitable for the construction of term structure in our market. Static estimation method employs curve fitting techniques to estimate the term structure of interest rates which includes sub-fitting and full-fitting. In order to ensure the accuracy of fitting, sub-fitting usually sets up multiple nodes, which also increases the number of model parameters needed to be estimated. The full-fitting uses the parametric ratios to fit. Since the curve estimated by SV model(NSS mode) is differential everywhere and the coefficients give strong economic implications which are more in line with the expectation theory, the model is adopted by many central banks of different countries. The model was proposed by the Svensson in 1994 based on the Nelson-Siegel model, it derives the instantaneous spot interest rate through the establishment of long-term instantaneous interest rate function. One of the biggest advantages of this model lies in the less number of coefficients needed to be estimated. Therefore, it is most appropriate for estimation of the term structure with a small number of bonds. In addition, the model coefficients can give significant economic implications. This article deploys the Svensson model which has been widely accepted to estimate the spot rate curve.

4 Empirical Analysis

4.1 Principal Component Analysis

Based on the data from January 1, 2003 to November 31, 2009, this article uses the parameters of the SV model (the data are from Reset database) on every weekend in this period to build 366 spot rate curves by MATLAB coding. After deleting the outliers, we finally obtain 356 spot rate curves of the inter-bank bond market. Based on the time series of 1–20 year spot interest rates calculated by the term structure, we analyze the correlation matrix by principal component analysis and extract the risk factors to investigate the risk characteristics of our inter-bank bond market.

The KMO and Bartlett tests on the first order difference of the 20 spot rates are 0.929 and 0.000 respectively, which demonstrates that the sample is qualified for. The results from the principal component analysis are illustrated in Table 1 and the factor loading matrix is showed in Table 2. We can get the following conclusions:

1. There are four eigenvalues that are larger than 1, the four principal components account for 99.627% of variance changes. However, the first principal component only contributed 59.511% to the variance variation, and the difference of its factor loadings is significantly large, for example, the factor loading of 12-year is eight times more than that of 3-year. Therefore, the first factor cannot be qualified as the level factor. This result is similar to empirical results obtained by

Table 1 Results of principal component analysis

Component	Eigenvalue	Variance contribution (%)	Accumulated variance contribution (%)
1	11.902	59.511	59.511
2	4.468	22.338	81.849
3	1.937	9.683	91.532
4	1.619	8.095	99.627

Table 2 Factor loading matrix

Variable	Principal component			
	1	2	3	4
1 year	0.219	0.206	0.310	0.895
2 year	0.188	0.570	0.245	0.760
3 year	0.111	0.789	0.571	0.175
4 year	0.163	0.857	0.463	−0.152
5 year	0.332	0.879	0.207	−0.268
7 year	0.717	0.605	−0.288	−0.181
8 year	0.824	0.411	−0.375	−0.100
10 year	0.935	0.110	−0.334	−0.004
12 year	0.978	−0.089	−0.176	0.030
15 year	0.957	−0.267	0.105	0.028
19 year	0.838	−0.361	0.402	−0.007
20 year	0.804	−0.368	0.455	-0.015

Buhler and Zimmermann (1996) (Johnson 2005) in Swiss, as well as in line with the conclusions by Shiguo Ye (Zhu and Chen 2003) in Taiwan. Based on their interpretation, this phenomenon may be due to monetary uncertainty in the sample period.

2. The variation of the second factor loading is in line with other studies. The short-term and long-term interest rates vary in opposite directions to the second factor, with contribution comes to 22.338%. The second factor played a more important role in domestic market than in foreign market.[1]
3. In line with other studies, the short-term and long-term factor loadings of the third main component are positive, while the mid-term is negative (6–13 years), which represents the phenomenon that the short-and long-term interest rates changes in the opposite direction with mid-term, so it can be considered a curvature factors.
4. The variance contribution of the fourth principal component accomplished about 8.095% with high volatility of factor loadings, which is different from the foreign studies. We believe it can be explained as the policy factors. In the process of the interest rate liberalization in China, interest rates change in its own way, which makes government policies play a more significant role.
5. The contributions of the last three factors are greater than those in other studies, which exhibits the uniqueness of the inter-bank bond market in China.

[1]See Martellini (2000) (Knez et al. 1991) and Grahame (2005) (Martellini and Priaulet 2000).

Table 3 Relative importance of each factor

Maturity	Factor1 (%)	Factor2 (%)	Factor3 (%)	Factor4 (%)	Other factors (%)
1year	4.78	4.23	9.59	80.05	1.33
2 year	3.52	32.44	5.98	57.77	0.24
3 year	1.23	62.29	32.56	3.05	0.83
4 year	2.67	73.50	21.42	2.31	0.05
5 year	11.01	77.26	4.27	7.21	0.21
7 year	51.41	36.63	8.30	3.26	0.37
10 year	87.45	1.22	11.18	0.00	0.14
15 year	91.57	7.13	1.09	0.08	0.12
20 year	64.62	13.58	20.71	0.02	1.05

4.2 Relative Importance of the Factors

Based on the principal component analysis, we then explore the relative importance of risk factors in interest rate with different maturities using sensitivity analysis. The factor loading of the principal component estimation:

$$S_{jk} = \sqrt{\lambda_j}\mu_{jk} = \Delta X_j / \Delta F_k \tag{1}$$

Where λ_j is the eigenvalue; μ_{jk} is the k-th factor value of the j-th eigenvector, which means the sensitivity of the j-th spot rate changed to the k-th factor.

The relative importance of each factor is illustrated in Table 3. According to Table 3, we got the following conclusions: the first factor plays a significant role in the spot rate with maturity over 8 years, while hardly affects the one less than 5 years; the impact of the second factor is significant on the spot rate with maturity from 2 to 7 years, which almost does not work on the one from 10 to 16 years; the third factor greatly affects the spot rate of 3–4 years; the fourth factor's influence on the spot rate within 1–2 years is relatively large; the impacts of other factors are minor.

In summary, what affects the spot rates less than 7 years are complex, the first factor produces a small impact; the spot rates over 8 years are significantly influenced by the first factor; the slope factor contributes a lot to the spot rate from 3 to 6 years; among the many factors affect the spot rate within 1–2 years, the fourth factor accounted for 50%, which demonstrates the uniqueness of its change.

5 Conclusion

Using the Svensson model, we developed term structure of interest rates implied by the bond price. We then extracted key risk factors by principal component analysis and analyzed the risk features of China's bond market. The relative importance of the factors is then discussed in detail, from which we come to the following conclusions: the variation of the term structure of interest rate may be contributed by the following four risk factors: the first factor is not qualified as the level factor, which has a significant effect, more than 60%, on the spot rate with maturity over 8 years; the second and the third factors are defined as slope and curvature respectively, the slope factor plays an important role on the spot rate with maturity from 3 to 6 years. What is different from the foreign studies is that the variance contribution of the fourth factor achieved 8.095%, which accounted for over 50% of the spot rate with maturity from 1 to 2 years. The above evidence demonstrates the uniqueness of the term structure in China's inter-bank bond market.

The above analysis shows that the term structure on China's inter-bank bond market is different from others in many ways which include the number of risk factors, the sensitivity of different spot rate on the various risk resources and more puzzled information implied by the term structure. This phenomenon may be caused by complex reasons such as the coexistence of two interest rate systems, the missing benchmark in China's bond market, the segmented market and etc. The difference in risk factors also illustrates the uniqueness of China's interbank bond market.

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Pricing of Convertible Bond Based on GARCH Model

Mengxian Wang and Yuan Li

Abstract Negative returns affect much more greatly on volatility than positive volatility because of existence of market panic, and stock volatility decreases because of terms of redemption and protection. We propose GARCH models with thresholds to describe volatility and establish the pricing formula of convertible bonds. In the study of convertible bonds, the issuing date of convertible bonds is an important variable. Because structural changes will happen to the return on assets before and after the converting. We find a method to identify structural change-point by applying CUSUM algorithm. In the study of redemption policy, the average stock price meeting the redemption conditions is calculated and is taken as the redemption condition.

Keywords Convertible bonds · Pricing · Risk · Sensitive analysis · Stochastic volatility · Structural changes · Uncertainty

1 Introduction

Ingersoll, Brennan and Schwartz applied option pricing method to the convertible bond pricing for the first time. Brennan and Schwartz (1980) proposed Two-factor model on the basis of a single factor model. Ho and Pfeffer (1996) proposed a two-factor model. Davis and Lischka (1999) proposed a three-factor model for pricing convertible bonds. In China, less study is devoted to it because convertible bonds

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are still at a primary stage of development (Fan-Xin and Fang-Zhao 2001; Guo-Duo and Cheng-Hai 2001; Mei-Zheng and Ci-Hua 2008).

In this paper, convertible bond option pricing formula is established on the basis of stochastic volatility. GARCH models are adopted for the modelling of the volatility. Due to the market panic, negative returns have greater impact on volatility. After the issuance of convertible bonds, underlying stocks' price volatility would decline due to the existence of the terms of redemption and protection. In this regard, volatility is modelled by adopting the GARCH model with threshold structure. Taking into account the convertible bond issues' impact on the volatility of the delay, we can use CUSUM algorithm (Chang-wen et al. 2003) to identify the structural change point. We get a new pricing model for convertible bonds on this basis.

2 Hypothesis

The underlying stock of Convertible bonds can be free to buy or sell. No transaction costs and taxes. Corporate convertible bond issues' objectives is to maximize the wealth of shareholders. Investor decision-making objective is to maximize the value of convertible bonds. Controlling shareholders' objectives is to maximize the net assets per share. Publishers only finance through convertible bonds.

We price convertible bonds from the most important volatility factors, namely interest rates, stock prices and credit risk which have impact on the pricing of convertible bonds. The credit grade of convertible bonds in our country is at high level and is guaranteed by the third party such as a bank. The spread of bond credit risk can be considered as a constant. Brennan and Schwartz (1980) obtained the result that the domestic interest rate fluctuations have little effect on the value of convertible bonds.

Convertible bonds usually adjust conversion price at the time of the dividend, allotment of shares, and issuing stock. Most convertible bonds circulating in the market have the Ex adjustment terms. Therefore, the pricing model for convertible bonds in China can be regarded as non-dividend stock. American call option with no bonus shares is equivalent to European call option. Thus it is possible to use Monte Carlo calculations for the model.

3 Convertible Bond Pricing Model

The description of the applicable pricing models of convertible bonds in China is as follows.

First of all, the value of the convertible bond is divided into two parts. One part is the cash of convertible bond, which is the value when convertible bonds are not converted. It should be discounted with the discounted value of corporate bonds, because paying back this part of value is linked to business operations risk. It's formulated as follows:

$$Bond_i = \sum_{t=i}^{t=T} I_t/\left(1 + r_f + r_c\right)^t + F/\left(1 + r_f + r_c\right)^T \quad (1)$$

F is par value of convertible bonds. r_f is risk-free interest rate. r_c is credit risk premium of corporate bonds. I_t is cash flows at the time t.

The second is the value of equity. It is independent of the company's operational risk. Therefore, this part should be discounted with risk-free rate. We use Monte Carlo method to calculate the value of the interest in this part. In the risk-neutral world, there are the following three end situations of the path of convertible bonds.

The first is that the path of stock price movement does not trigger redemption or sale condition provision. The value of convertible bonds on the due date is referred to as the greater of conversion value and straight bonds value. Equity's discounted value is shown below:

$$V_T = \max(S_t \times k, Bond_T) \quad (2)$$

$$D_i = (V_T - Bond_T) \times e^{-R_f(T,t_0)\times(T-t_0)} \quad (3)$$

T is convertible bond's due date. V is value of convertible bonds. D_i is discounted value of convertible bonds' equity in the i-th simulation. $R_f(t_1, t_2)$ is risk-free discount rate for discount from Point t_1 to Point t_2. k is conversion ratio. $Bond_T$ is Convertible bonds' Straight bonds value at T.

The second situation is the redemption of convertible bonds. The redemption trigger of convertible bonds is that stock price runs in the redemption price line for a certain length of time. The price will exceed the transfer price at this time. Holders of convertible bonds shared transfers. At this point the value of convertible bonds is the conversion value with the formula expressed as follows:

$$V_T = S_t \times k \quad (4)$$

$$D_i = (V_T - Bond_T) \times e^{-R_f(T,t_0)\times(T-t_0)} \quad (5)$$

The third kind of situation is that the stock price maintains under the price line for a certain period of time required. It will trigger the sale provision. Convertible bond holders now have the right to sell back. They can choose to sell the option back, share transfer, or continue to hold. Conversion value is less than sale value, because the proportion of sale is less than one. Thus investors will not choose conversion. They have to choose to hold it continuously or sale, which depends on which value is relatively greater. According to the findings of Zhen-Long Zheng and Hai Lin (2004) (Chang-wen et al. 2003), the following formula:

$$(S_t \times F_v/P) \times N(d_1) - Bond_T e^{-r(T-t)} N(d_2) + Bond_t \quad (6)$$

can be used to represent the approximate value of convertible bonds. F_V is the value of bond's face. If the value of convertible bonds is greater than that of sale, investors continue to hold convertible bonds and the path would not end. We continue to simulate and examine several situations above. Otherwise, the path comes to the end, and the value of convertible bonds is equal to the value of sale. It can be expressed by the following formula (Hong 2007):

If $P_P > (S_t \times F_V/P) \times N(d_1) - Bond_T e^{-\gamma(T-t)} N(d_2) + Bond_t$

$$D_i = (P_P - Bond_t) \times e^{-R_f(T,t_0)\times(T-t_0)} \tag{7}$$

P_P is sale price. P_T is conversion Price. By simulating stock price many times, we obtain the value D_i of the equity component of convertible bonds by each simulated stock price path. D_i's mean is the discounted value of expected returns of the equity component of convertible bonds in the risk-neutral world. This discounted value is added to the discounted value of bonds equals to the value of convertible bonds which is expressed as follows:

$$\sum_{t=i}^{n} D_i/n + Bond_0$$

3.1 Volatility Model

Convertible bond price is sensitive to volatility of stock prices. Thus this paper adopts GARCH model to estimate volatility.

$$\begin{cases} \varepsilon_t = z_t \sigma_t \\ \sigma_t^2 = \text{var}(\varepsilon_t | F_{t-1}) = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \\ \sigma_t^2 = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right) \end{cases} \tag{8}$$

To ensure that conditional variance is non-negative, α and β must be non-negative. Sequence is wide and smooth only if $\alpha + \beta < 1$.

Most investors can be appropriately impacted in the bear market. Therefore, due to market panic, negative returns have greater impact on the underlying stock than positive returns. So we obtain the following volatility model:

$$\sigma_t^2 = \text{var}(\varepsilon_t | F_{t-1}) = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + (\beta_1 + \beta_2 I(\varepsilon_{t-1} \le 0))\varepsilon_{t-1}^2 \tag{9}$$

When stock price reaches the pre-set redemption price, company has the right to redeem convertible bonds with redemption price set. The greatest profit of convertible bond investors is the conversion value or redemption price. When the underlying stock price continues to decline and remains lower than the conversion price substantially or even falls to the back to sale price range of convertible bonds, listed companies will sell convertible bonds back or adjust the price. Therefore, stock volatility decreases because of terms of redemption and protection. We use GARCH (1,1) form with the threshold structure to model the lagged values of the conditional variance and the disturbance. We estimate parameters through the history return and design the non-symmetrical GJR-GARCH model as follows:

$$\begin{cases} \log(S_t/S_{t-1}) = \mu + \varepsilon_t \\ \varepsilon_t = z_t \sigma_t \\ \sigma_t^2 = \alpha_0 + (\alpha_1 - \alpha_2 I(t \geq t_0))\alpha_{t-1}^2 + (\beta_1 + \beta_2 I(\varepsilon_{t-1} \leq 0))\varepsilon_{t-1}^2 \end{cases} \tag{10}$$

If we consider the delay of market reaction after the issuance of convertible bonds, we can use CUSUM Algorithm to detect change point. Rewriting the above equation by additive noise, we get:

$$\varepsilon_t^2 = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right) z_t^2 = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)\left(z_t^2 - 1\right) + f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)$$

Let $V_t = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)\left(z_t^2 - 1\right)$, we get $\varepsilon_t^2 = V_t + f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)$.

V_t is martingale difference series, $E[V_t] = E[V_t|F_{t-1}] = 0$, and $\text{cov}[V_s, V_t] = \text{cov}[\text{V}_\text{s}, \text{V}_\text{t}|\text{F}_{\text{t}-1}] = 0$

when $s < t$. So that we have $E\left[\varepsilon_t^2|F_{t-1}\right] = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)$ and $\text{var}\left[\varepsilon_t^2|F_{t-1}\right] = f\left(\varepsilon_{t-1}, \sigma_{t-1}^2\right)\left(E\left[z_t^4 - 1\right]\right)$.

3.2 Parameter Estimation

Consider the maximum likelihood estimation of parameter of GARCH regression model.

$$\begin{cases} r_t = \log(S_t/S_{t-1}) \\ r_t = \mu + \varepsilon_t \\ \varepsilon_t = z_t \sigma_t \\ \sigma_t^2 = \alpha_0 + (\alpha_1 - \alpha_2 I(t \geq t_0))\sigma_{t-1}^2 + (\beta_1 + \beta_2 I(\varepsilon_{t-1} \leq 0))\varepsilon_{t-1}^2 \end{cases}$$

Let $\zeta(\mu) = \left[1, \sigma_{t-1}^2, -\sigma_{t-1}^2 I(t \geq t_0), \varepsilon_{t-1}^2, \varepsilon_{t-1}^2 I(\varepsilon_{t-1} \leq 0)\right]$, $\delta = \left[\alpha_0, \alpha_1, \alpha_2, \beta_1, \beta_2\right]$. z_t and F_{t-1} are independent of each other. $Y_t \sim N(0,1)$. The log-likelihood function of GARCH model can be expressed as

$$L(\delta) = \sum_{t=1}^{T} \ln(r_t|F_{t-1}, \delta) = \sum_{t=1}^{T} l_t(\delta) = -T\ln(2\pi)/2 - \sum_{t=1}^{T} \ln\left(\sigma_t^2\right)/2 - \sum_{t=1}^{T} \varepsilon_t^2/2\sigma_t^2$$

Demand $L(\delta)$ of the first and second order differential about δ, we get

$$\frac{\partial L(\delta)}{\partial \delta} = \frac{1}{2}\sum_{t=1}^{T} \sigma_t^{-2} \frac{\partial\left(\sigma_t^2\right)}{\partial \delta}\left(\frac{\varepsilon_t^2}{\sigma_t^2} - 1\right)$$

$$\frac{\partial^2 L(\delta)}{\partial\delta\partial\delta^\tau} = \sum_{t=1}^{T}\left(\frac{\varepsilon_t^2}{\sigma_t^2}-1\right)\frac{\partial}{\partial\delta^\tau}\left[\frac{1}{2}\sigma_t^{-2}\frac{\partial\left(\sigma_t^2\right)}{\partial\delta}\right] - \frac{1}{2}\sum_{t=1}^{T}\sigma_t^{-4}\frac{\partial\left(\sigma_t^2\right)}{\partial\delta}\frac{\partial\left(\sigma_t^2\right)}{\partial\delta^\tau}\frac{\varepsilon_t^2}{\sigma_t^2}$$

Where $\dfrac{\partial\left(\sigma_t^2\right)}{\partial\delta} = \zeta_t(\mu) + (\alpha_1 - I^*(t \geq t_0)\alpha_2)\dfrac{\partial\left(\sigma_{t-1}^2\right)}{\partial\delta}$

Meanwhile $E\left[\sum_{t=1}^{T}\left(\frac{\varepsilon_t^2}{\sigma_t^2}-1\right)\frac{\partial}{\partial\delta^\tau}\left[\frac{1}{2}\sigma_t^{-2}\frac{\partial\left(\sigma_t^2\right)}{\partial\delta}\right]\middle|F_{t-1};\delta\right] = 0$

Therefore, the information matrix corresponds to the parameter δ of GARCH Regression Model.

$$I_\delta = \frac{1}{T}\left[\frac{\partial\sigma_t^2}{\partial\delta}\frac{\partial\sigma_t^2}{\partial\delta^\tau}\right]$$

Consistent estimates can be obtained from $\partial\sigma_t^2/\partial\delta$.

$\hat{\delta}_{i+1}$ is the $i+1$ step iteration estimation of parameter. We get $\hat{\delta}_{i+1}$ by $\hat{\delta}_{i+1} = \hat{\delta}_i + \lambda\left(\sum_{t=1}^{T}(\partial\ln^\tau(f_t)/\partial\delta)(\partial\ln(f_t)/\partial\delta)\right)^{-1}\sum_{t=1}^{T}\partial\ln^\tau(f_t)/\partial\delta$, where $\partial\ln^\tau(f_t)\ /\partial\delta$ is the value of the first-order differential at $\hat{\delta}$, λ is a step variable. Under the given direction of vector, it makes the likelihood function $L(\delta)$ achieve maximum. We can calculate a volatility $\hat{\sigma}_{t,0}$, $1<t<n$. We note $m=1$. Given M, we use ε_{t-1}, $2\leq t\leq n$ and $\hat{\sigma}_{t-1,m-1}$, $2\leq t\leq n$. Regressing ε_t^2, $2\leq t\leq n$, we get the estimate value $\hat{f}$ of f and calculate $\hat{\sigma}_{t,m}^2 = \hat{f}_m\left(\varepsilon_{t-1}, \hat{\sigma}_{t-1,m-1}^2\right)$, $2\leq t\leq n$, by $\hat{f}$,

if $m<M$, we add 1 to m and turn to step 1.

In order to enhance the stability of the algorithm, the estimated volatility will be averaged. Then compute the last non-parametric regression. The non-parametric regression of ε_t^2 about ε_{t-1} and $\hat{\sigma}_{t-1}^2$ is the final estimate value $\hat{f}$ of f. Then we use the final estimate form of function to obtain the final estimate $\hat{\sigma}_t^2 = \hat{f}\left(\varepsilon_{t-1}, \hat{\sigma}_{t-1}^2\right)$ of volatility. Peter Buhlmann and Alexander J. McNeil (2002) gave a proof to the issue whether the algorithm can approach the true value. They also pointed out that estimated effect would be significantly increased after a few cycles.

4 Empirical Studies

Namsan convertible bonds, Hengyuan convertible bonds, Chengxing convertible bonds and wheel CB are selected as experimental samples. Theoretical value of convertible bonds is calculated under different volatility, and then compared with true price. We select treasury bonds with the same general structure and the same period as the risk-free interest rate, because they are of particularly low default risk. Account type in 2008 bonds with the coupon rate of 3.56% will be selected.

4.1 Historical Volatility Model

Annual volatility is obtained by getting the weighted average of the stock closing prices 90–180 days before the issuance of convertible bonds with a basis of 242 market days a year.

$$\hat{\sigma} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(r_i - \bar{r})^2} \times \sqrt{241}$$

4.2 GARCH Volatility Model

We use the following forms of GARCH (1,1) model to calculate stock price volatility.

$$\begin{cases} \sigma_t^2 = \mathrm{var}(\varepsilon_t | F_{t-1}) = \gamma V_L + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \\ \varepsilon_t = z_t\sigma_t \end{cases}$$

$\gamma + \alpha + \beta = 1$. V_L is long-term volatility of model. F_{t-1} is the information set of time. We can see that volatility predicted by the model depends not only on the value of a forecast and the latest market volatility, but also on the volatility of long-term average. Let $\gamma V_L = \omega$, we can get equation $\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2$.

Using the maximum likelihood method to estimate the type, we get three parameters of model. Model parameters can be used to calculate the long-term average rate of volatility.

$$V_L = \omega/(1 - \alpha - \beta)$$

4.3 Threshold Structure GARCH Model

$$\begin{cases} \varepsilon_t = z_t\sigma_t \\ \sigma_t^2 = \mathrm{var}(\varepsilon_t | F_t) = \alpha_0 + (\alpha_1 - \alpha_2 I(t \geq t_0))\sigma_{t-1}^2 + (\beta_1 + \beta_2 I(\varepsilon_{t-1} \leq 0))\varepsilon_{t-1}^2 \end{cases}$$

After calculation, transition point is near issue date. t_0 is taken as the issuing date of convertible bonds.

Table 1 MSE

	Historical model	Historical model	Historical model
Namsan convertible bonds	13.8421	7.0441	2.7397
Hengyuan convertible bonds	36.9950	35.6360	34.2984
Chengxing convertible bonds	43.3312	30.1643	27.5007
Wheel convertible bonds	155.6698	96.2923	75.6752

4.4 Empirical Results

Volatility will be calculated in the model to simulate the path of the underlying stock. There are one million simulation times with step length of 0.02 years (Table 1, Figs. 1–4).

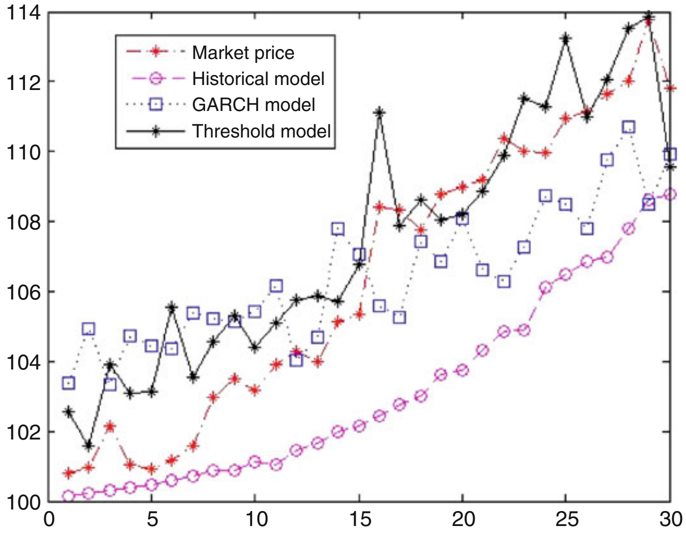

Fig. 1 Nanshan CB

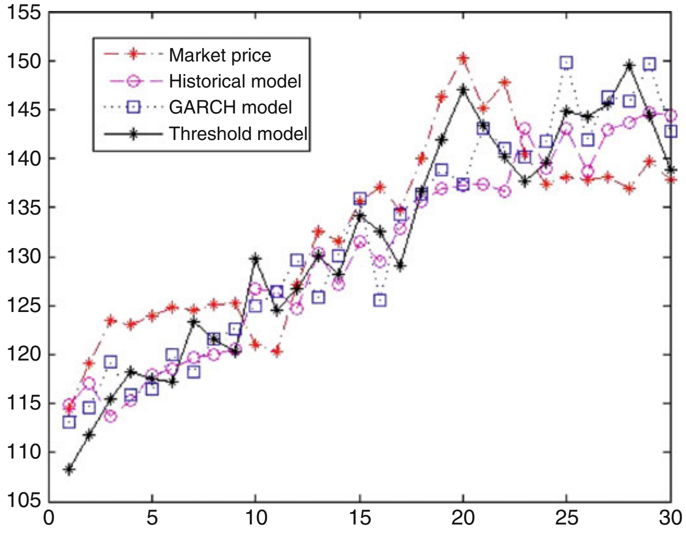

Fig. 2 Chengxing CB

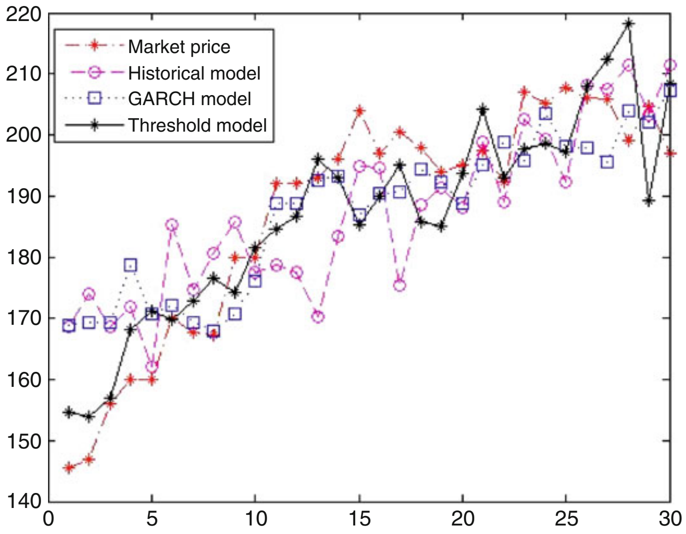

Fig. 3 Hengyuan CB

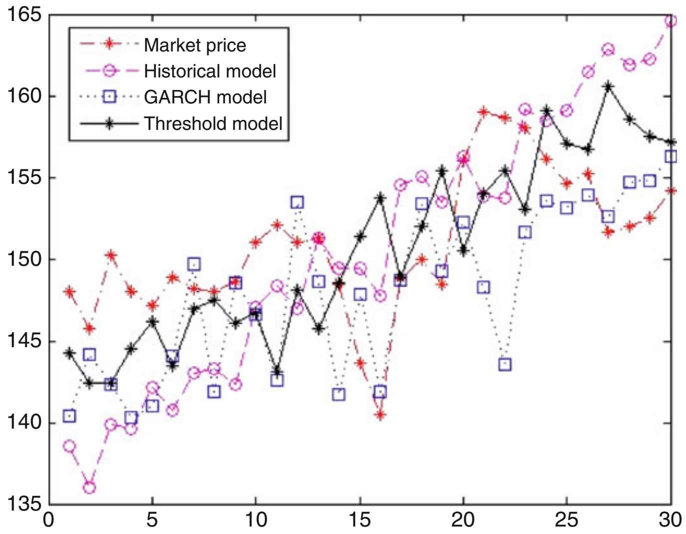

Fig. 4 Wheel CB

5 Conclusion

Through the empirical analysis we find that GARCH (1,1) model can fit well the real value of convertible bond time series. With the expansion of market size and market system, variability of market risk and earnings are constantly changing, so we need to adjust the model to adapt to new circumstances. There is “leverage effect” on volatility of China’s stock market’s returns, which means that bad news has greater impacts on volatility than good news. After its issuance, as the convertible bonds can move forward and attack, and defend when retreat, it makes the volatility of convertible bonds down. With threshold structure of GARCH volatility model, we better fit time series of convertible bonds’ actual value. The estimated volatility of Threshold structure of GARCH (1,1) approximates the real value more closely than the standard GARCH (1,1) model. Convertible bond research helps us build a good portfolio for avoiding market risks.

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Sentiment Capital Asset Cognitive Price and Empirical Evidence from China's Stock Market

Wei Yan, Chunpeng Yang, and Jun Xie

Abstract This paper presents the concept of 'Sentiment Capital Asset Cognitive Price'. Based on the results of previous researches and BSV model's research method, this paper establishes a type of sentiment capital asset cognitive price model, and obtains the analytic expression of the sentiment capital asset cognitive price. An empirical test for this model is given ultimately. The evidence from China's stock market proves the significant effect of sentiment on the market.

Keywords Behavioral finance · Investor sentiment · Sentiment capital asset cognitive price model

1 Introduction

Fama (1965) presented the concept of *Efficient Market*, and proposed the *Efficient Market Hypothesis* by deepening the concept (Fama 1970). However, since the end of 1970s, many phenomena of abnormal investor behavior and financial anomalies, which didn't satisfy the standard financial theory, emerged in the security market. On this basis, an analysis framework of behavioral finance was constructed since 1980s. During these more than ten years from its appearance to prosperity, many scholars proposed some capital asset pricing models from the angle of investor's cognitive bias, such as BSV model (Barberis et al. 1998), DHS model

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(Daniel et al. 1998), HS model (Hong and Stein 1999) and BHS model (Barberis et al. 2001). However, these investor bias cognitive models lacked generality because they aimed to explain a special type of anomaly. Therefore, it needs to modify the separate research method, and analyze the problem of asset pricing comprehensively.

Investor sentiment as a significant branch of the behavior finance started to be investigated since 1990s. Taking the investor sentiment to be a method of solving behavioral capital asset pricing problem may provide a new research way. The purpose of this paper is to investigate the affect of investor sentiment on capital asset pricing problem. It proposes the concept of *Sentiment Capital Asset Cognitive Price*, and establishes this model subsequently. BSV model has an important position among the asset pricing models based on investor cognitive bias. Hence, adopting BSV model's advantages, and evading its shortcomings, this paper ameliorates it and proposes an investor sentiment asset cognitive pricing model finally. Compared with BSV model, this paper makes better improvement as follows: (1) BSV model's research threshold and theoretical support is investor conservatism and representativeness heuristic. Therefore, this paper investigates cognitive price of a capital asset which affected by investor sentiment; (2) To satisfy the hypothesis in their paper, BSV model's every parameter is initialized by investor. But the sentiment cognitive price model's every parameter comes from the performance of practical market data. The other parts of this paper will describe, assume, construct and solve the model, and present an empirical evidence of test for China's stock market.

2 Description, Assumption, Construction and Solution of Model

2.1 Model Description and Assumption

Most of the hypotheses are as the same as BSV model, such as the earnings in period t is $Y_t = Y_{t-1} + y_t$, where y_t is the shock to earnings in period t and can be either positive or negative, that is $y_t = \pm y$. An investor thinks that the shock of earnings is always a certain probability from one of the two states: M_H, M_L, where the probability from M_H is p_t and the probability from M_L is $1 - p_t$. Now, we let the investor sentiment in t is S_t, and if $\Delta S_t = S_t - S_{t-1} > 0$ then means that the investor sentiment in t is greater than the value in $t - 1$, otherwise means that the investor sentiment decreases. When the investor sentiment is at the increasing state or decreasing state, the cognitive probability matrixes of the shocks from two states M_H and M_L, are shown in Table 1.

where $p_H^1 + p_H^2 + p_H^3 + p_H^4 = 1$, $p_L^1 + p_L^2 + p_L^3 + p_L^4 = 1$.

The transition probability matrix of the two states is showed in Table 2.

Table 1 The cognitive probability matrixes when sentiment increases and decreases

M_H	$y_{t+1} = +y$	$y_{t+1} = -y$	M_L	$y_{t+1} = +y$	$y_{t+1} = -y$
$y_t = +y$	p_H^1	p_H^2	$y_t = +y$	p_L^1	p_L^2
$y_t = -y$	p_H^3	p_H^4	$y_t = -y$	p_L^3	p_L^4

Table 2 The transition probability of the two states

	$M_{t+1} = M_H$	$M_{t+1} = M_L$
$M_t = M_H$	r_1	r_2
$M_t = M_L$	r_3	r_4

where $r_1 + r_2 + r_3 + r_4 = 1$.

The investor obeys the Bayes Rule when he renews the information, so p_{t+1} can be calculated as:

$$p_{t+1}=\frac{[r_1p_t+r_3(1-p_t)]\Pr(y_{t+1}|M_{t+1}=M_H,y_t)}{[r_1p_t+r_3(1-p_t)]\Pr(y_{t+1}|M_{t+1}=M_H,y_t)+[r_2p_t+r_4(1-p_t)]\Pr(y_{t+1}|M_{t+1}=M_L,y_t)}$$

In addition, a lot of researches showed that investor sentiment affect the asset return or discount rate. So, different with BSV model, this paper assume that a cognitive discount rate by the investor affect his asset cognitive price indirectly. Let the cognitive discount rate $\mu_t^s = \beta \cdot \mu_t$, where μ_t is the real discount rate in period t, β is the sentiment coefficient of discount rate in period$t$, $\beta > 0$ and fluctuates around 1. Influenced by investor sentiment, β abide by the following rules:

(1) when sentiment increases $\beta < 1$, let $\beta = \sqrt{1 - (p_H^j)^2}$;

(2) when sentiment decreases $\beta > 1$, let $\beta = \sqrt{1 + (p_L^j)^2}$.

where $j = 1, 2, 3, 4$. The value of j will be determined by the positive or negative shock in period $t - 1$ and period t. So, the investor determines the asset cognitive price based on the above rules.

2.2 Model Construction and Solution

Because the equilibrium price of the asset equals to the net present value of the future earnings which the investor anticipate, so:

$$P_t = \mathrm{E}\left[\frac{Y_{t+1}}{1 + \mu_t^s} + \frac{Y_{t+2}}{(1 + \mu_t^s)^2} + \cdots\right]. \quad (1)$$

where E is the subjective expected function in which the investor is not conscious that the real process is a random walk. Similar with BSV model, we can get the cognitive price which affected by the investor sentiment:

$$P_t = \frac{Y_t}{\mu_t^s} + \frac{y_t}{\mu_t^s}(p_1 + p_2 q_t)\,. \tag{2}$$

where $p_1 = \gamma_0{}'(1 + \mu_t^s)[(1 + \mu_t^s)I - Q]^{-1} Q\gamma_1$,

$$p_2 = \gamma_0{}'(1 + \mu_t^s)[(1 + \mu_t^s)I - Q]^{-1} Q\gamma_2$$

where $\gamma_0{}' = (1, -1, 1, -1)$, $\gamma_1{}' = (0, 0, 1, 0)$,

$\gamma_2{}' = (1, 0, -1, 0)$, I is the fourth-order unit matrix.

$$Q = \begin{pmatrix} r_1(p_H^1 + p_H^4) & r_1(p_H^2 + p_H^3) & r_3(p_H^1 + p_H^4) & r_3(p_H^2 + p_H^3) \\ r_1(p_H^2 + p_H^3) & r_1(p_H^1 + p_H^4) & r_3(p_H^2 + p_H^3) & r_3(p_H^1 + p_H^4) \\ r_2(p_L^1 + p_L^4) & r_2(p_L^2 + p_L^3) & r_4(p_L^1 + p_L^4) & r_4(p_L^2 + p_L^3) \\ r_2(p_L^2 + p_L^3) & r_2(p_L^1 + p_L^4) & r_4(p_L^2 + p_L^3) & r_4(p_L^1 + p_L^4) \end{pmatrix}$$

3 Empirical Evidence

Based on investor decision-making process and the expression of asset cognitive price, it can be seen that: the asset cognitive price is unique when all the parameters are confirmed. However, the parameters rely on the numerical of investor sentiment. We must firstly calculate the value of investor sentiment. This paper quotes the Shanghai composite index as an asset. Hence, we firstly construct the market sentiment index.

Baker and Wurgler (2006, 2007) constructed the indirect market sentiment index, and some economists defined it as BW sentiment index. They selected six variables. Yu and Yuan (2005), Kurov (2010) used the proxies and method of Baker and Wurgler (2006) to calculate the market sentiment index. Liao et al. (2011) also chose ten variables as the proxies for market sentiment index. Proxies selecting is miscellaneous and subjective, besides, there is no reasonably verifiable introduction and no rejection about unreasonable proxies, so there is no scientific procedure and basis for the constructing of market sentiment index. To solve this problem, it's necessary to choose the right proxies with some standard procedure and appraisable criterion. According to the rule and procedure proposed by our early research result, we will construct a market sentiment index.

3.1 Construction of Investor Sentiment

By using our rules to select proxies and employing the method of principal component analysis, we take the first principal component as sentiment index *Sent*. Therefore, the relation between sentiment index and every final proxy is:

$$Sent = 0.5051 \cdot TV_t + 0.4825 \cdot PS_{t-1} + 0.5015 \cdot NS_{t-1} + 0.5105 \cdot TV_{t-1}. \tag{3}$$

where the proxies are current trading volume of Shanghai composite index, Shanghai composite index lagged one period, new-open stock account of Shanghai market lagged one period and trading volume lagged one period, respectively.

3.2 Calculation of Cognitive and Transition Probability Matrixes

According to the relation of sentiment value and Shanghai composite index, the cognitive probability matrixes when the sentiment increases or decreases can be obtained by statistics. The results are shown in Table 3.

Based on the time series value of sentiment which we calculate above, we show the transition probability matrix of the two states in Table 4.

3.3 Calculation of the Cognitive Price of the Asset

Let the cognitive function of the investor sentiment and the proxies from May 9, 2008 to May 7, 2010 is the same as before. Based on the formula of the cognitive price which we derived above, let the initial value of p_t is 0.5, we get the cognitive price of every week which showed in Fig. 1.

The solid line in Fig. 1 is the cognitive price, and the dotted line is the actual closing price of the Shanghai composite index every week. The statistics show that the positive max ratio of difference about the cognitive price and the actual price is 16.77%, mean ratio of the difference is 8.87%, and the negative max ration of difference is −8.87%, mean ration of the difference is −4.66%. A little values of the cognitive price are higher than the actual price in the unilateral downward market. And a few values of the cognitive price are lower than the actual price in the unilateral upward market. That is, the cognitive price have a stimulating effect on the actual price, in other words, the investor sentiment and cognitive price have great effect on the actual price of the asset.

Table 3 The cognitive probability matrixes when sentiment increases and decreases

M_H	$y_{t+1} = +y$	$y_{t+1} = -y$	M_L	$y_{t+1} = +y$	$y_{t+1} = -y$
$y_t = +y$	0.5182	0.2727	$y_t = +y$	0.1122	0.1633
$y_t = -y$	0.1364	0.0727	$y_t = -y$	0.3163	0.4082

Table 4 The transition probability of the two states

	$M_{t+1} = M_H$	$M_{t+1} = M_L$
$M_t = M_H$	0.3478	0.1787
$M_t = M_L$	0.1787	0.2947

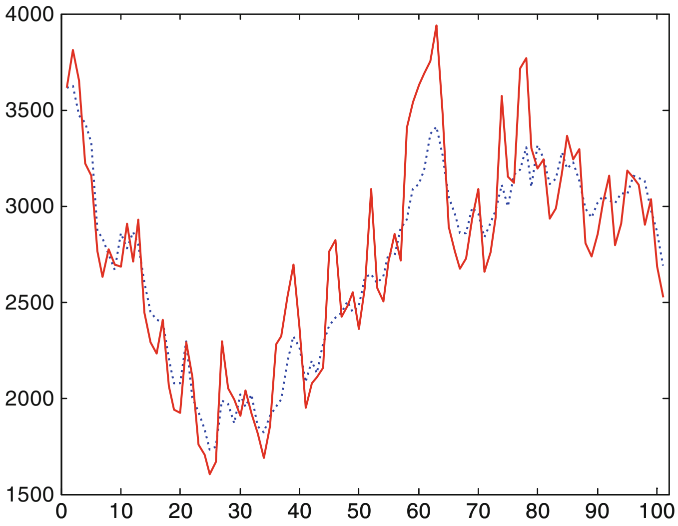

Fig. 1 The actual closing price of Shanghai composite index and the sentiment cognitive price

4 Conclusions

Although the research on investor sentiment has been nearly 20 years, it still focuses on the empirical study and few of theoretical models are presented. That is, the basic framework of finance theory in this field is still imperfect. In this paper, we established a cognitive price model for an asset based on investor sentiment, by improving the cognitive bias model of BSV. A sentiment coefficient of the discount rate was designed and the expression of the asset's sentiment cognitive price was obtained ultimately. At last, the empirical evidence from China's stock market proves the significant effect of sentiment on the market.

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Carbon Emission Markets

Walid Mnif and Matt Davison

Abstract New regulatory frameworks designed to comply with the Kyoto protocol have been developed with the aim of decreasing global greenhouse gas emissions over both short and long time periods. Incentives must be established to encourage the transition to a clean energy economy. Emissions taxes represent a "price" incentive for this transition, but economists agree this approach is suboptimal. Instead, the "quantity" instrument provided by cap-and-trade markets are superior from an economic point of view. This chapter summarizes the current state of world cap-and-trade schemes as well as recent literature devoted to quantitative pricing and hedging tools for these markets.

Keywords Carbon · Emission · Markets

1 Introduction

In 1997, an international agreement known as the Kyoto Protocol was adopted by over 184 states with the aim of reducing global greenhouse gas emissions. Greenhouse gases (GHGs), as defined by the World Bank, are the gases released by human activity that are responsible for climate change and global warming. The six gases listed in the Kyoto Protocol are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). For each gas a Global Warning Potential (GWP) indicator is defined to measure the impact of a particular GHG on the additional heat/energy retained in the earth's ecosystem through an addition of an unit of the gas given to the atmosphere. The unit of measure is ton of CO_2 equivalent (tCO_2e). Table 1 summarizes the (GWP) for each GHG.

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Table 1 GWP for GHG
Source: World Bank, Sustainable Development Department

GHG	tCO_2e
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
Perflurocarbons	6,500
Hydroflurocarbons	11,700
Sulfur Fluoride	23,900

The Kyoto Protocol defines emission caps for industrialized and transition countries with the goal of decreasing GHG emissions by 5.2% relative to 1990 levels during the commitment period 2008–2012. The tools it provides for meeting this goal are the Clean Development Mechanism (CDM), Joint Implementation (JI) and International Emissions Trading (IET). The latter allows for Emission Allowances Trading (EAT) between governments. The CDM is a mechanism designed to assist developing countries in achieving sustainable development by permitting industrialized countries to finance projects for reducing greenhouse gas emission in developing countries and to receive credit for doing so. The JI is a mechanism whereby an industrialized nation as specified by Kyoto's Annex I[1] may acquire Emission Reduction Units (ERU) when it helps to finance projects that reduce net emissions in another industrialized country (including countries with economies in transition). For emission reductions resulting from JI projects, countries are granted Certified Emission Reductions (CERs). Both CER and JI projects have a number of conditions attached to them. Each project, together with the protocol used for measuring its emission reductions, must be approved by the executive board. Countries may use EATs, ERUs and CERs to comply with their emission caps.

The Kyoto commitment was introduced for the period 2008–2012. The role of the post 2012 portion is to stabilize atmospheric concentrations by 40–45% by 2050, compared to 1990 levels. As it takes time to achieve the target of the new regulations and to put incentives in place, companies must be confident that the system will endure in order to make decisions that require a long time line. To create this confidence, the World Bank is already buying credit for the post Kyoto commitment, while European policy makers are confident that 2012 will be followed by another compliance period.

We focus on allowances markets rather than project-based transactions and secondary Kyoto, which suffer from inefficiency and instable complex regulation. The effect of this inefficiency can be seen for the project-based transactions where the traded volume plummeted from 636 $MtCO_2e$ in 2007 to 283 $MtCO_2e$ in 2009. Little academic literature is available on this topic.

[1]Industrialized countries: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America.

The chapter is organized as follows. Section 2 summarizes the current state of world cap-and-trade schemes. The recent literature devoted to financial quantitative modeling for these markets is presented in Sect. 3. In a short final section, conclusions and future work are presented.

2 Carbon Markets

The new regulatory framework forces countries to transition into a clean energy economy. A policy instrument that could be used is a carbon emissions tax. Such a tax imposes a price that an emitter has to pay per unit of GHG emission. Companies will have to choose between paying the emission tax or reducing their pollution, encouraging emissions reductions if the marginal costs of abatement is less than the imposed tax. As consequence the optimal tax for each company must be equal to the marginal cost of abating. This marginal abatement cost varies across emitters and information about it is often unavailable to the regulator. As a result, the tax instrument is suboptimal. Furthermore it will be difficult to comply with the reduction commitment as the regulator does not directly control the emitted amount. Goers et al. (2010) provide more details about the inefficiency of emission taxes.

Inspired by the U.S. Acid Rain Program (1990) that was designed to control sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from fossil fuel-burning power plants, some regulators decided to implement cap-and-trade mechanism as most cost-efficient instrument to comply with emission reduction target.

A cap-and-trade system is a market-based mechanism that uses market principles to achieve emissions reduction. The government running the cap-and-trade program sets an absolute limit, or cap, on the amount of GHG, and issues a limited number of tradable allowances which sum to the cap and represent the right to emit a specific amount. The market is aimed to provide price signals describing the true cost of the emission of a tonne of carbon. This is a crucial input for planning the transition to a clean energy economy, while protecting sensitive sectors from undue disruption and keeping local industry internationally competitive.

Higher emissions prices would induce companies with lower abatement costs to profit from the price difference by abating more CO_2 than they would need to comply with regulations, and then to sell the spare certificates for the higher certificate price. Each company faces a basic choice between buying or selling allowances, and reducing emissions through use of alternative technologies. Three general classes of techniques for the physical reduction of emissions are available. Firstly, emissions can be reduced by lowering the output scale. Secondly, the production process or the inputs used may be modified, for example fuels can be switched (Gas/Coal). Finally, tail end cleaning equipment can be installed to remove pollutants from effluent streams before they are released into the environment.

2.1 European Union Emissions Trading Scheme

The European Union Emissions Trading Scheme (EU ETS) market is a cap-and-trade system limited to European industrial installations. It is the largest carbon emission market in the world with 6.3 billion tCO_2e trading volume and US$118.5 billion exchanged value in 2009. It was established in 2005,[2] 3 years before the beginning of the first Kyoto commitment phase. It comprises combustion installations exceeding 20 MW, refineries and coke ovens as well as the metal, pulp and paper, glass, and ceramic industries. In total more than 12,000 installations among 30 countries (27 European Union States plus Iceland, Liechtenstein and Norway). Companies covered by the ETS subject receive at the end of every February a certain number of EU allowances (EUAs). The initial allocation assigned to each company depends on the National Allocation Plan.[3] Each allowance gives the right to emit one tCO_2 in the current calendar year. On April 30th of the following year, companies must submit EUAs to the national surveillance authorities. If companies do not provide EUAs that cover their total emission, they must pay a penalty[4] and deliver the missing EUAs in the following year. EUAs are initially allocated to the market participants for free with limited information during the first trading period.[5] Some companies have as consequence made gains described as windfall profits.

In addition to using carbon trading, only CDM were considered within the phase I (2005–2007). The JI was added during phase II (2008–2012). The contribution of CDM and JI are limited in order to ensure local emission reduction targets.

As the EU ETS market started in 2005, there are differences between the first trading period (2005–2007) and the first Kyoto commitment period (2008–2012). In fact, in most European countries, the EUAs issued in the first trading period were only valid during this trading period (although France and Poland allowed limited banking between 2007 and 2008). In France and Poland, companies could bank at most the difference between the initially allocated allowances and their accumulated emissions. Furthermore, companies can bank CERs from the first period, but we highlight the fact that the use of CERs is limited.

The EU ETS allows borrowing from a future year within the same trading period. As the compliance date is at the end of April, the company can use the received EUAs at the end of February to comply with the preceding year. The recent global economic crisis decreased the demand side of the market in 2009,

[2] The first trading started in 2004 in anticipation of the formal initiation of the scheme in January 2005. The traded volume was about 8.5 $MtCO_2$.

[3] An important component of each plan is a quantity set aside for new installations and new companies, known as the New Entrants' Reserve.

[4] Penalty is set at € 40 per metric ton of carbon equivalent above the cap in 2005–2007 period and € 100 for the phase 2008–2012.

[5] A very limited number of EUAs were auctioned during the first phase. Referring to Article 10 of the European Directives, auctioning will increase to 10% of total emissions in phase II (2008–2012).

with emissions falling by 11.2%. As a result some companies, such as steel and cement, raised cash by taking advantage of the overlap between the issuance of the 2009 allowances and the 2008 deadline for compliance. In fact they sold their 2008 EUAs and borrowed the 2009 allocations to comply with their 2008 emissions. The EUA prices dropped sharply from the € 31 reached in July 2008 to € 8 in February 2009. This is a strong illustration of the importance of banking and borrowing rules in driving spot prices and their volatilities.

Carbon futures markets seem to be more liquid than the corresponding spot markets. In fact, an EUA spot transaction is considered as a good so it is subjected to Value-Added Tax (VAT) while a futures and options contracts are VAT exempt because they are treated as financial transactions within the European Union. The largest and most liquid spot market for EUAs is the NYSE Euronext while the key futures market is the European Climate Exchange (ECX). Not only are companies regulated, but private or institutional investors are allowed to buy or sell allowances. The EU ETS allows non-emitting firms or individual investors to trade to increase liquidity and for speculation and diversification purposes. They need only establish an account in the emission registry of an European member state. U.S. funds are responsible for 10–15% of traded volume on ECX during the phase II.

Despite of the competition from NYSE Euronext, ECX does not have a spot market. They use the EUA Futures as underlying asset to write an option. For only the first period, futures with monthly expiries were traded in ECX. In 2008, quarterly futures contracts were introduced. These contracts are listed on an expiry cycle of: March, June, September and December contract months and they are listed up to June 2013. December annual contracts are also traded from December 2013 to December 2020. In October 2006, European style put and call options on EUA Futures started to be traded on ECX. In March 2009, ECX introduce EUA Daily Futures contracts which are exchange-traded cash contracts. Daily Futures Contracts will be physically delivered by the transfer of EUAs from the seller to the buyer.

Several empirical studies were done to understand the market behavior during the phase I. They show that the EU ETS is characterized by a very high historical volatility. Referring to Daskalakis et al. (2009), EUA spot prices in Powernext Carbon[6] and Nord Pool[7] moved closely with the average mean absolute difference being around 7 cents (fixed transaction costs are on the order of 3 cents per EUA). Moreover, the correlation coefficient of weekly spot returns between the Powernext and Nord Pool EUA markets is very strong, reaching almost 90%.

Daskalakis et al. (2009) found that there is no correlation between price returns for CO_2 and power. This result conforms to Sevendsen and Vesterdal (2003) who come to the conclusion that the largest CO_2 emitters do not have enough market share and thus all market participants are assumed to be pure price takers. At conventional significance levels, they also show that logarithmic spot process are non stationary. Since EUAs are considered to be commodities for consumption, this

[6]NYSE Euronext acquired Powernext Carbon in December 2007.

[7]Nord Pool was sold entirely to NASDAQ OMX to create the NASDAQ OMX Commodities.

result contradicts the common findings of mean reverting behavior observed in commodities and energy markets.

Daskalakis and Markellos (2008) examined the efficiency of EU ETS, concentrating on the weak-form of market efficiency according to which all the information contained in historical prices should be reflected in today's price. They conclude that the historical prices cannot be used to form superior forecasts or to accomplish trading profits above the level justified by the risk assumed.

Paolella and Taschini (2008) undertook an econometric analysis of emission allowance spot market returns and found that the unconditional tails can be well represented by a Pareto distribution while the conditional dynamics can be approximated by GARCH-type innovation structure.

Franke (2005) shows that if companies tacitly collude to manipulate the market, then CO_2 returns should have positive autocorrelations. A brief analysis of these autocorrelations in Seifert et al. (2008) reveals no strong empirical evidence in favor of this conjecture.

Ben and Trück (2009) analyze the behavior of CO_2 spot prices' log-returns over the period starting from January 3, 2005 until December 29, 2006. They compared results from a simple normal distribution, AR(1),[8] GARCH(1,1), and a Markov switching between two regimes (base regime and spike regime). They concluded that the GARCH(1,1) and Markov switching models outperform both the normal and AR(1) models, and are quite similar.

The European regulator set up the third compliance phase during 2013–2020. The emission target is to reach, in 2020, a level of 21% less than 2005. The detailed regulatory framework remains uncertain, but two major baselines consider carbon leakage and auctioning policy. "Carbon leakage" describes the transfer of a company to another country or state with less stringent constraints on carbon emissions in order to survive international competition. An auctioning policy will spur the carbon leakage as it will likely increase the production cost.[9] Economists agreed that auctioning will offset the downside effect of grandfathering and allow a more significant carbon price signal. Starting from 2013, the European regulator was engaged to set auctioning as an alternative for allowance allocation. To fight carbon leakage, company in a given sector need pay for only a fraction of their allowances with companies in sector deemed exceptionally (leaky) receiving allowances free. The assistance will decrease annually such that in 2027 full auctioning will be applied in all sectors.

Analysts believe that the EU ETS options market is mature enough to be comparable to other many options markets. Furthermore they expect the market to be short post 2012 which explains the active trading of the December 2013 EUA contracts.

[8]They studied the models AR(p), $p \geq 1$, and they found only AR(1) is significant.

[9]European policy makers are studying the possibility of imposing carbon taxes on goods imported from foreign countries which do not penalize emissions. Companies not exposed to foreign competition (e.g. in the electricity sector) will presumably pass the additional marginal cost to the final consumer.

2.2 Other Emissions Trading Markets

In 2009, New Zealand (NZ) opted for a carbon trading scheme to comply with its Kyoto protocol commitment. The scheme started in July 2010. It regulates stationary energy, industrial process and liquid fossil fuels for transport. It will progressively include some other sectors (i.e. synthetic gas and waste on January 2013) until fully implemented by 2015. 2010–2012 is the transition period in which one NZ allowance is used to surrender two tCO_2e. Within this period, the market is a combination between a cap-and-trade and a tax system, known as hybrid market. In fact initially the allowances are distributed for free with a possibility to purchase more from the regulator at a predefined price of NZ$25. In case of non-compliance, the company will have to cancel the allowances they failed to deliver with a penalty of NZ$30 per unit. Borrowing from post 2012 is prohibited while unlimited banking is permitted.

In the U.S., the American Clean Energy and Security Act of 2009, known as the Waxman-Markey Bill, was passed by the House of Representatives in June 2009. It consists of a cap-and-trade scheme to reduce emissions by 17% from 2005 levels by 2020. The Bill still need to be considered by the Senate, probably during the next legislative term. Despite the federal carbon regulation, the Regional Greenhouse Gas Initiative (RGGI) was set up in 2008 among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. It is a mandatory cap-and-trade market covering only the power sector. It aims to reduce 10% of its emission by 2018. In 2009, 805 $MtCO_2$ was traded for an equivalent value of US$ 2.2 billion.

Four western Canadian provinces (British Columbia, Manitoba, Ontario, Quebec) have developed the Western Climate Initiative (WCI) program together with seven U.S. states (Arizona, California, Montana, New Mexico, Oregon, Utah, Washington) to jointly implement a cap-and-trade scheme starting in January 2012. The initiative targets 15% emissions reduction below 2005 levels by 2020.

Some voluntary markets are implemented as domestic initiative to spur transition into clean energy (i.e. China, Japan). Brazil intends to establish a voluntary market-based instrument to reduce emissions up to 38.9% by 2020.

Several questions may arise: Is it possible to set up an international linkage between different emissions trading schemes? If yes, is it the most cost-effective method for abatement?

3 Modeling and Pricing in Emission Markets

Cap-and-trade is a policy instrument to combat the climate change impact. This mechanism allows to avoid climate risk at corporate level even though it adds some other operational risks (see Labatt and White 2007). As consequence companies need a financial modeling framework to price emission allowances and their derivatives for risk management purpose.

Several approaches to this problem were developed during the past decade. Existing work can (for the most part) be divided into those involving equilibrium models and those using quantitative finance style stochastic modeling. We review now this literature. We notice that some of the models that deal with allowances pricing under one compliance period are not flexible enough to take into consideration the impact of banking and borrowing possibilities under a multi-period trading scheme on allowance price dynamics. However they allow for good understanding of the market mechanism.

3.1 Equilibrium Models

Dales (1969) was the first economist to introduce market idea for trading the right to pollute. Three years later, Montgomery (1972) provided a theoretical foundation of a market in licenses and developed a decentralized system based for achieving environmental goals at a number of different locations. These two seminal papers are the origins of the development of the recent contributions.

Carmona et al. (2009) explore the relation between the price evolution of emission allowances and the way in which a multi-agent electricity producer decides when to switch from a hard coal power plant to a cleaner Combined Cycle Gas Turbine (CCGT). A one period discrete time mathematical model is developed to determine the optimal switching policy that minimizes the overall cost under zero net supply conditions. The resulting equilibrium carbon price is equal to the marginal price of an extra allowance to lower the expected penalty payment amount.

Seifert et al. (2008) assume that emission rate dynamics are given by a stochastic process, where the uncertainty is driven by a standard Brownian process. The existence of this term in the model is explained by a potential emission variation due to some external randomness (e.g. weather changes and economic growth). Under the assumption of risk-neutral market participants, the central planner choose an optimal abatement policy as function of time and total expected accumulated emissions over the entire compliance period. The latter variable is a controlled stochastic process with dynamics derived from the emission rate's stochastic differential equation with a drift controlled by the abatement policy undertaken. The marginal abatement costs is assumed to be linearly increasing with respect to the emissions abatement strategy. It is also defined as the spot price, and has a martingale property under the objective probability measure. Its motion is not correlated to the specification of the emission process rate. A logarithmic utility function was introduced to study the impact of risk aversion on allowances price.

Chesney and Taschini (2008) deal with pricing spot allowances price for one period market scheme and assume that the emitter release GHG exogenously and continuously under a geometric Brownian motion. A company may trade only at an initial time in order to minimize final costs comprising the sum of the initial trading cost[10] and the expected penalty payment applying to any future allowance shortages. The spot price obtained is equal to the discounted[11] penalty price times the probability weight of non-compliance scenarios. Chesney and Taschini (2008) extend the basic model to the case of an economy where two companies can trade at multiple discrete times. They suppose that the allowance price is equal to the penalty level at the compliance date when at least one company faces an allowance shortage. Also companies trade using only information about their own pollution and the accumulated emissions volume of their counterparty at the previous trading possibility. The equilibrium price process for each trading time is defined as function of the traded quantity. The latter is obtained by solving a system of two equations, incorporating the market clearing condition. Using the method of moments to approximate the sum of more than one geometric Brownian motion by another geometric Brownian motion, an extension of the model to a multi company framework is possible.

Carmona et al. (2010) propose a competitive equilibrium model under one compliance period. The output goods are assumed to be exogenous and inelastic. A producer in the economy has the choice between several technologies for each good characterized by different marginal cost production, emission factor and production capacity. The stochastic properties of the demand and costs are known for all firms from the beginning. The overall demand is considered to be satisfied and less than the total production capacity. To avoid paying penalties, the planner switches its production to a cleaner available technologies or has recourse to the ETS to buy allowances. The authors show the existence of market equilibrium such that the zero net supply condition is fulfilled, the demand is covered, and the strategies maximize the expected terminal wealth. To avoid issues with discounting, Carmona et al. (2010) work with forward prices applying at the compliance time T. The forward allowances prices in time T currency is a bounded martingale under the objective probability measure with value less than the penalty level. Also time T spot goods prices and optimal production strategy are merit-type equilibrium with defined adjusted costs. These properties are necessary conditions to the existence of the equilibrium. It is shown that the market equilibrium is equivalent to a representative agent problem where the emission is reduced at a cost-effective way. A generalized cap-and-trade scheme is introduced by including taxes and subsidies in the original formulated problem. Furthermore it allows the regulator to distribute allowances dynamically and linearly in the production quantity. By assigning adequate values to these variables, a comparative analysis is made between the standard cap-and-trade market (a), cap-and-trade market with auctioning of allowances (b), tax scheme (c), and a cap-and-trade scheme with relative allowance allocation (d) vis-à-vis emissions reduction, incentives to invest in a

[10]It can take positive values and be considered a gain when the company decides to sell allowances at the initial time, or negative and seen as a cost if allowances are purchased.

[11]The discount rate is the weighted average cost of capital.

Table 2 Comparison of schemes from Carmona et al. (2010)

	Reduction target	Incentives	Windfall	Social cost	Consumer cost
a	+	+	−	+	−
b	+	−	−	+	−
c	−	−	+	−	−
d	+	+	+	+	+

cleaner energy, windfall profits, social cost, and end-consumer cost. Table 2 reports the results.

Hinz and Novikov (2010) solve the central planner problem treated in Seifert et al. (2008), Carmona et al. (2009), and Carmona et al. (2010) by including additional assumptions in the equilibrium mathematical model. Under no-arbitrage condition, they assume the existence of an equivalent risk neutral probability Q such that the equilibrium price is a Q-martingale. Also the agent opts immediately to abate when allowance prices exceed its abatement cost. At the compliance date, the spot price is zero if the market is long and equals the penalty level otherwise. As consequence the spot price under Q will depends only on the cumulative abatement volume and the overall allowance shortage. The model is developed under a discrete time framework. As an illustrative example, they focus on the martingale case with independent increments for the cumulative emissions and deterministic abatement functions combined with the least-square Monte-Carlo method of Longstaff and Schwartz (2001). An algorithm is formulated to price allowances and European call written on the spot allowances price.

Borovkov et al. (2010) study the continuous time version of the solution obtained by Hinz and Novikov (2010). They show the existence of the allowance price when the conditional expectation of the total cumulative emissions is a Q-martingale diffusion process with a deterministic volatility. The allowance price is derived by solving a nonlinear partial differential equation (PDE), while a European call option is priced by solving a linear PDE. An extension to a jump diffusion setting is developed and the spot price is obtained by solving a partial integro-differential equation. Borovkov et al. (2010) prove uniqueness of the allowance price and use a numerical finite difference scheme to compute it.

Kijima et al. (2010) extend the work of Maeda (2004). They suppose the existence of a competitive market within a single-period economy, where the regulated emitters must comply with emission reduction target set up by the regulatory authority at the future time T. Two markets are available: the spot market, and the derivatives market written on the T allowances price and assumed to be complete. Financial traders are considered in the model and trade only in contingent claims market to hedge the risk in their exogenous income. The authors assume that each economic agent has a negative exponential utility with an appropriate risk-aversion coefficient. The key assumptions for their model to obtain closed-formulas are the following: they suppose the cost abatement function to be continuously differentiable, increasing and strictly convex with a derivative that starts at zero when there is no abatement, and goes to infinity asymptotically.

Infinite penalties are imposed, so that the emitter must abate emission or buy allowances at time T to comply with the regulatory emission target. The state price density is provided for each of the cases in which banking and borrowing are allowed or not, giving a pricing solution for any contingent claim. Moreover, the market clearing condition when banking and borrowing are forbidden must be satisfied, otherwise being replaced by the equality between the aggregate abatement target and the whole emission reduction over all the compliance period. Under a piecewise linear quadratic abatement cost function, price spikes may occur, more frequently in the forward than in the spot price (in contrast to intuition deriving from the usual Samuelson effect for commodities). The relationship between the spot and forward prices are analyzed. They show that when there are many financial traders the forward price is smaller than expected future spot price, known as normal backwardation.

3.2 Stochastic Modeling

We introduce the papers that use applied probability techniques in order to provide a pricing and hedging solution to the market participants. These approaches offer general flexible tools for pricing complex contingent claims.

Çetin and Verschuere (2009) present a probabilistic pricing and hedging framework. They assume that the market contains only two forward contracts P_t and S_t with subsequent maturities T_1 and T_2, $T_1 < T_2$, respectively. S_t dynamics are modeled by a Markov process with a drift expressed as an affine function of a càdlàg Markov chain taking values depending on the market position. Under the assumption of no banking, P_t is zero if the market is long; otherwise taking the value of the penalty level plus S_{T1}. If the market is short the investor must pay the penalty and deliver at later time T_2 the missing allowances. The model framework is incomplete because there are two sources of uncertainty in the stochastic differential equation for S_t, and one of them is not tradable. As a result, contingent claims have, in addition to the hedgeable risk, a relative intrinsic risk (Föllmer and Sondermann 1986) which cannot be covered. Çetin and Verschuere (2009) uses the Föllmer-Schweizer decomposition to price P_t as an expectation under an equivalent probability measure called the minimal martingale measure. The associated hedging strategy is a locally-risk minimizing strategy as defined by Föllmer and Schweizer (1991). A filtration projection technique is used to price the allowance and a digital option, which pays an unit amount of money if the market is short at time T_1, under incomplete information. The effect of intermediate announcements is also studied.

Carmona and Hinz (2009) assume the existence of an equivalent martingale measure Q such that the price process of a future contract A_t is a martingale. Within a single T compliance period model, A_T is equal to the penalty level π when the emitted quantity is greater than the number of allowances. Carmona and Hinz (2009) define N as a set of allowance shortage events. N is described as the set where some positive-valued random variable Γ is located above the boundary 1. The total normalized emission can be seen as a special choice. Carmona and Hinz (2009) identify a class of parameterized positive Q-martingales with values less than the penalty level. These Q-martingales satisfy the following condition: under the objective probability measure, the probability of the events such that the limit of A_t equals to π is the same as one minus the probability of the events such that the limit of A_t equals to 0. For ease of calibration to historical data, they provide a formulation of the likelihood density under the assumption that the market price of risk is constant over time. The model is extended to a two-period market model without borrowing, with unlimited banking and withdrawal. The prices of European call options written on futures contracts and maturing before the first compliance date are derived for both models.

Grüll and Kiesel (2009) assume that the emission rate follows a geometric Brownian motion, similar to the assumption of Chesney and Taschini (2008). They use the result of Carmona et al. (2010) and assume that the price of the futures contract maturing at the compliance date T may be computed from the penalty price times the probability of the set of events where the total cumulative emissions at time T exceeds the cap predetermined by the regulator. The spot price is approximated using three different approaches which depend on the approximation method used to compute the total cumulative emissions at time T. In the first, linear approach cumulative time T emissions are estimated using T times the emissions rate at time T. The second and third approaches are a bit more sophisticated, relying on moment matching techniques for the cumulative emissions estimate. They differ only because the second approach uses a log-normal distribution in the matching while the third uses a reciprocal gamma distribution.

Under a risk-neutral assumption, Huang (2010) models emission rate dynamics as a stochastic process. Instead of a geometric Brownian motion dynamics as in Chesney and Taschini (2008) and Grüll and Kiesel (2009), he assumes that the process can follow either an arithmetic Brownian motion or a mean reversion process. At the compliance date, the spot price is zero if the aggregate emissions exceed the allocated emissions limit and equals the penalty level otherwise. Formulas are provided for spot prices, European options prices (call and put) as well as their Greeks. Futures prices can be derived from the spot price when the convenience yield is neglected.

4 Conclusion

The regulatory framework related to carbon emissions market has not yet been solidified. For both political and economic reasons, a state of flux continues to exist in carbon market rules. As an example of rule changes rooted in economic theory, economists have recently reconsidered the conclusion that cap-and-trade markets are more efficient than carbon taxes. As an improvement over both tax and cap-and-trade regimes, economists have proposed a hybrid market which combines aspects of carbon taxes with features of cap-and-trade schemes. Much current research (Grüll and Taschini 2011; Mnif and Davison 2010) is concerned with presenting pricing and hedging frameworks for this new market design.

It is important that this uncertainty in market rules be resolved, since the result of this ambiguity is that companies do not yet have clear information signals for making clean energy investment decisions. Should they make these investments now, or wait for new regulations to be introduced? Quantitative finance techniques are ill suited to address such questions of regulatory risk.

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Part II
Credit Risk Management

Dynamic Asset Allocation with Credit Risk

Bian Shibo and Zhang Xiaoyang

Abstract In this paper, we investigate how investors who face both equity risk and credit risk would optimally allocate her wealth among the following securities: a defaultable bond, a stock and a bank account. We model the defaultable bond price through a reduced-form approach and solve the dynamics of its price. Using stochastic control methods, we obtain a closed-form solution to this optimal problem. From the solution it is clear that the optimal strategy of the defaultable bond is not a continuous function because of jump risk. The post-default optimal strategy for defaultable bond is zero, and the pre-default optimal strategy for defaultable bond depends on the credit spreads, the default intensity and the investment horizon.

Keywords Credit risk · Dynamic asset allocation · HJB equation · Reduced-form approach

1 Introduction

Credit risk is no stranger to investors these days. U.S.A bursts subprime lending crisis in 2008. Dubai bursts credit crisis in 2009. Europe bursts sovereign debt crisis in 2010. The investors suffered huge losses in these crisises. So, credit risk has become another kind of risk investors have to face on top of market risk. As a result, dynamic asset allocation problems with credit risk have become an important area of research.

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In the "classical" dynamic asset allocation literature, only market risk or cognitive risk associated with market risk (in the incomplete information case) is considered. In spite of several major contributions to the theory of optimal asset selection only a handful of papers consider the case where one or more of the securities in the portfolio are subject to credit risk.

Korn and Kraft (2003), Kraft and Steffensen (2005) firstly studied optimal portfolio with credit risk. They utilized the structural approach (Merton 1974) to price credit risk. Elasticity and duration are used as control variables in their optimization problem. The optimal amounts invested in each security are expressed as functions of either the elasticity or duration variables. The structural approach has a drawback: the investor must know the corporate value, which is not actual. Thus, parameters of the model are difficult to obtain.

To overcome the drawback of structural approach, scholars research this problem in framework of reduced-form model (Jarrow and Turnbull 1995). Walder (2002) considers the optimal portfolio problem by assuming that the investor can invest in a treasury bond and a portfolio of defaultable zero-coupon bonds. Hou and Jin (2002) and Hou (2003) address the optimal portfolio problem of the investor by giving the investor the ability to allocate her wealth among a stock, a default-free bank account, and a credit-risky financial instrument.

A key weakness of the approach by both Walder (2002), Hou and Jin (2002) and Hou (2003) is that they assumed that the investor invests a defaultable bond portfolio, which satisfies the conditional diversification assumption of Jarrow et al. (2005) (hereafter JLY). JLY demonstrate that if the market for defaultable bonds consists of infinitely many bonds in which defaults are conditionally independent, the market does not value the jump risk. JLY refer to the asymptotic disappearance of the jump-risk premium as "conditional diversification" Consequently, the solution of these simplified portfolio problem can be found analogously to a problem with stochastic interest rates but without credit risk.

However, if the market for defaultable bonds is thin, then the concept of conditional diversification does not hold. In this case there would be a significant compensation for jump risk. The validity of conditional diversification is an empirical issue. To date, researches by Elton et al. (2001) and Driessen (2005), have shown that jump risk is significantly priced in the defaultable security market.

To make the problem more realistic, this paper investigates how investors who face both equity risk and credit risk would optimally allocate her wealth among the following securities: a defaultable bond, a stock and a bank account. Because we assume the investor only invest in a defaultable bond, the conditional diversification assumption is not hold. Then, the portfolio risk is from the defaultable bond's jump risk and the stock's volatility risk. Bring jump risk into the investment portfolio is the key innovation of our paper. From the research result it is clear that because of jump risk the optimal strategy of the defaultable bond is not a continuous function, but a piecewise function according to whether the dedaultable bond default in time t. The optimal strategy for defaultable bond also depends on the credit spreads, the default intensity and the investment horizon.

2 Financial Market Model

Simply put, credit risk can be identified with default risk, the possibility that counterparty in a financial contract fails to fulfill a contractual commitment. Many financial instruments are credit-risk sensitive: defaultable bonds, vulnerable claims, credit derivatives, and so on. We only consider defaultable bonds in this asset allocation setup. Defaultable bonds by definition bear credit risk (and possibly other risks such as liquidity risk), since the obligors (bond issuers) may fail to repay coupons and/or principals of the debt. In modeling credit risk, we adopt the so-called reduced-form approach advocated by Jarrow and Turnbull (1995), Madan and Unal (1998) and Duffie and Singleton (1999), among others.

2.1 Information Structure

To begin with, we assume financial assets are traded continuously in a frictionless and no-arbitrage market. Investors in this economy are price takers, so that their individual decisions would not affect price formation in a direct or obvious way. Assume that there is a complete probability space (Ω, G, Q), endowed with a reference filtration $F = (\mathrm{F}_t)_{t\geq 0}$ which satisfies the usual conditions. The probability measure Q is a martingale probability measure, which is assumed to be equivalent to the statistical measure P. Let τ be a non-negative random variable on this space. It represents default time of the defaultable bond considered in this paper. For the sake of convenience, assume $Q(\tau = 0) = 0$ and $Q(\tau > 0) > 0$ for any $t \in T$. Define a right-continuous process H with $H(t) = 1_{\{\tau < t\}}$ where $1_{\{\tau < t\}}$ is the indicator function. Denote by H the associated filtration on the same probability space, with $H = (\mathrm{H}_t)_{t\geq 0}$ for all $t \in T$. Now, let G be another filtration (satisfying the usual conditions as well) on the probability space such that. $\mathrm{G}_t = \mathrm{F}_t \vee \mathrm{H}_t$. Such information structure is standard in the reduced-form approach.

2.2 Dynamics of Financial Assets Prices under Q

The maturity date of the defaultable zero-coupon bond is T_1. Other contractual features of this bond include: the promised principal, 1; default time τ. If $\tau \in (0, T_1)$, the value of the defaultable bond after default is assumed to be zero, but the investor can recover a fraction $z(\tau)$; if $\tau \in (T_1, \infty)$, there is no default during the life time of the bond, the investor can receive one. So the cumulated cash-flow process D of a defaultable zero-coupon bond is

$$D(t) = 1_{\{\tau > T_1\}} + \int_0^t z(u)dH(u)$$

It is apparent that the second term in above accounts for the recovery upon default, since $\int_0^t z(u)dH(u) = z(\tau)\times 1_{\{t\geq\tau\}}$.

There exists a money market account in this economy starting with 1, represented by process $B(t)$, given by

$$B(t) = \exp\left(\int_0^t rdu\right)$$

where the short-term interest rate process r is assumed to be a constant process.

It is well-known in finance theory [(Duffie 1996), for example] that the absence of arbitrage opportunities holds when there exists a martingale measure Q equivalent to P under which the discounted (using money market account) gains processes for all assets are martingales. One easily gets the following pricing formula for defaultable zero-coupon bond whose price is denoted by $p(t,T_1)$

$$\begin{aligned} p(t,T_1) &= B(t)E^Q\left(\int_t^{T_1} B(u)^{-1}dD(u)|\mathrm{G}_t\right) \\ &= B(t)E^Q\left(\int_t^{T_1} \begin{matrix} B(u)^{-1}z(u)dH(u) \\ +B(T_1)^{-1}(1-H(T_1) \end{matrix} |\mathrm{G}_t\right) \end{aligned} \tag{1}$$

where E^Q is the expectation operator under the probability measure Q.

Definition 1. $Q(\tau{>}t|F) = e^{-h^Q}$*, where the risk neutral intensity* h^Q *is assumed to be constant.*

Using Definition 1 and Corollary 2.6 in Jeanblanc and Rutkowski (2000), we can derive that

$$\begin{aligned} p(t,T_1) = 1_{\{\tau>t\}}E^Q&\left(\int_t^{T_1} \exp\left(-\int_t^u (r+h^Q)ds\right)z(u)h^Q du|\mathrm{F}_t\right) \\ &+ 1_{\{\tau>t\}}E^Q\left(\exp\left(-\int_t^{T_1}(r+h^Q)ds\right)|\mathrm{F}_t\right) \end{aligned} \tag{2}$$

It should be noted that, (2) eliminates the jump terms associated with process H and that the conditioning filtration is F instead of G. To put the above results into perspective, we adopt the recovery of market value (RMV hereafter) assumption according to Duffie and Singleton (1999), that is,

$$z(t) = (1-\imath)p(t-,T_1) \tag{3}$$

where $0 < \imath < 1$ is the write-down proportion (or loss rate) of the debt and assume it is constant. Under this convention, a neat result due to Duffie and Singleton (1999) is as follows:

$$p(t,T_1) = 1_{\{\tau>t\}} \times E^Q\left(\exp\int_t^{T_1}\left(-\int_t^u (r+\delta)ds\right)|\mathrm{F}_t\right) \quad (4)$$

where, $\delta = h^Q \imath$ is credit spread.

Definition 2. *The F–hazard rate (or intensity) process h^Q is an F–progressively measurable, non-negative stochastic process such that $M^Q(t) = H(t) - \int_0^t (1-H(u-))h^Q du$ is a G-martingale under Q, where $H(u-) := \lim_{s\uparrow u}, H(u) = 1_{\{\tau<u\}}$.*

Using Itô's lemma and Definition 2 on (4), we can derive the dynamics for the price process of the defaultable zero-coupon bond

$$dp(t,T_1) = p(t,T_1)\big((r+\delta-h^Q)dt - dM^Q(t)\big) \quad (5)$$

Assume that the stock price and the money market account are given by the following diffusion equation:

$$dS(t) = S(t)\left[rdt + \sigma dW^Q(t)\right] \quad (6)$$

$$dB(t) = rB(t)dt \quad (7)$$

2.3 Dynamics of Financial Assets Prices under *P*

Since the investor optimizes her utility under the real world probability measure, we change the measure from the risk neutral probability measure Q to the real world probability measure P. The following Girsanov theorem is used to change measures. The proof can find in Kusuoka (1999).

Girsanov Theorem. *A probability P is equivalent to Q, if and only if there exists progressively measurable, R-valued process λ and a predictable process ε, such that*

1. $E^P(L(T^*)) = 1$, where

$$L(t) := L_1(t)L_2(t)$$

$$L_1(t) := \exp\left\{\int_0^t \lambda dW^Q(s) - \frac{1}{2}\int_0^t \lambda^2 ds\right\}$$

$$L_2(t) := \exp\left\{\int_0^t ln(\varepsilon)dH(s) - h^Q\int_0^{t\wedge\tau}(\varepsilon-1)ds\right\},$$

2. $\frac{dP}{dQ} = L(t)$

Where the process $W^P(t) = W^Q(t) - \int_0^t \lambda du$ is a G-Brownian motion under physical measure P and the process $M^P(t) = M^Q(t) - h^Q \int_0^t \varepsilon(1 - H(s))du$ is a G-martingale under the physical measure P. $\varepsilon = \frac{h^P}{h^Q}$, h^P is intensity under P.

By applying Girsanov theorem to (5) and (6), we obtain the dynamics of the price process for the stock and defaultable bond.[1]

$$dS_t = S_t[(r + \sigma\lambda)dt + \sigma dW(t)] \tag{8}$$

$$dp(t, T_1) = p(t-, T_1)\left[\left(r + \delta - h^Q - h^Q(\varepsilon - 1)(1 - H_t)\right)dt - dM^P(t)\right] \tag{9}$$

3 Optimal Asset Allocation Solution

Assume that the investor's initial wealth is W_0, investment horizon is $[0, T]$ and $T < T_1$. The trading strategy is $\pi(t) = (\pi_s(t), \pi_P(t))'$, $t \in [0, T]$ where $\pi_s(t)$ is the fraction of her wealth in stock and $\pi_P(t)$ is the fraction of her wealth in defaultable bond. The percentage of wealth invested in the money market account is given by $1 - \pi_s(t) - \pi_P(t)$. The trading strategy is restricted to be self-financing. As a result, the wealth dynamics can be written as

$$dW(t) = \pi_s(t)dS(t) + \pi_P(t)dp(t, T_1) + (1 - \pi_s(t) - \pi_P(t))dB(t) \tag{10}$$

Substituting (7), (8), and (9) into (10) we can derive:

$$dW(t) = W(t-)\begin{bmatrix} [r + \pi_S(t)\sigma\lambda + \pi_P(t)(\delta - h^Q + h^Q(1-\varepsilon)(1 - H(t)))]dt \\ + \pi_S(t)\sigma dW^P(t) - \pi_P(t)dM^P(t) \end{bmatrix} \tag{11}$$

The investor in this economy tries to maximize her von-Neumann-Morgenstern utility over the terminal wealth by dynamically allocating her wealth into these three financial assets. She has no human-capital income to support her purchase of financial assets. Assume investor with a constant relative risk aversion (CRRA) utility function:

$$U(W) = \frac{W^\gamma}{\gamma}, \quad 0 < \gamma < 1$$

[1] The dynamics of a savings account has the same representation under both measure Q and P since it is non-stochastic.

Let $A(W_0) = \{\pi(t) \in \mathrm{R}^2 : W(t)>0\}$ be the set of admissible trading strategies. Now the optimization problem the investor faces can be formulated as

$$\max_{\pi(t)\in A(W_0)} EU(W(T))$$

$$\text{S.T.}\begin{cases} dW(t)=W(t-)\begin{bmatrix} \left[r+\pi_S(t)\sigma\lambda+\pi_P(t)(\delta-h^Q+h^Q(1-\varepsilon)(1-H(t)))\right]dt \\ +\pi_S(t)\sigma dW^P(t)-\pi_P(t)dM^P(t) \end{bmatrix} \\ W^\pi(0)=W_0 \\ dH(t)=h^P(1-H(t))dt+dM^P(t) \end{cases}$$

We use stochastic control method to solve this optimization problem. Following Merton (1971), define the indirect utility function as

$$J(t,W,H) = \max_{\pi(t)\in A(W_0)} EU(W(T)|\mathrm{F}_t)$$

The Hamilton-Jacobi-Bellman (HJB) equation for this indirect utility function is as follows

$$\begin{cases} \max\limits_{\pi(t)\in A(W_0)} D^\pi J(t,W,H,) = 0 \\ J(T,W,H,) = \dfrac{W^\gamma}{\gamma} \end{cases}$$

where

$$D^\pi J(t,r,W,H)=J_t+W\left[r+\pi_S(t)\sigma\lambda+\pi_P(t)(\delta-h^Q+h^Q(1-\varepsilon)(1-H(t)))\right]J_W$$
$$+\frac{1}{2}W^2[\pi_S(t)\sigma]^2J_{WW}+\{J(t,W(1-\pi_P(t)),1)-J(t,W,0)\}h^P(1-H(t)).$$

Solving HJB equation, we can get the the optimal investment strategy:

$$\pi_s = \frac{1}{1-\gamma}\frac{\lambda}{\sigma}$$

$$\pi_P^*=\begin{cases} 0, t\in[\tau,T] \\ 1-\begin{bmatrix} \left(\dfrac{\delta-h^P}{h^P}\right)^{\frac{1}{1-\gamma}} e^{\left(-\frac{h^P}{1-\gamma}+\left(\frac{\delta-h^P}{h^P}\right)\frac{h^P\gamma}{1-\gamma}\right)(T-t)} \\ +\left(e^{\left(-\frac{h^P}{1-\gamma}+\left(\frac{\delta-h^P}{h^P}\right)\frac{h^P\gamma}{1-\gamma}\right)(T-t)}-e^{-\frac{\gamma^2 r}{1-\gamma}(T-t)}\right)\dfrac{h^P(1-\gamma)}{h^P(\gamma-\frac{h^P}{\delta-h^P})+\gamma^2 r\left(\frac{h^P}{\delta-h^P}\right)} \end{bmatrix}^{-1}, \quad t\in[0,\tau) \end{cases}$$

$$\pi_B^* = 1-\pi_s^*-\pi_P^*$$

The optimal strategy for the stock is constant irrespective of pre-default or post-default. The reason is that the stock has no correlation with the defaultable bond, which means there is no need to hedge for the default. Thus the optimal strategy for the stock is invariant to the default event risk. The optimal strategy for the stock depends on the risk aversion γ, the market price of risk for the stock λ and the coefficient the volatility of the stock return σ. Assume that γ and λ is constant, utility function is CRRA, thus the optimal strategy for the stock is independent of the investment horizon, so-called "myopic" effect.

The optimal strategy of the defaultable bond is not a continuous function because of jump risk. The value of the defaultable bond after default is assumed to be zero. So, the post-default optimal strategy for defaultable bond is zero. The pre-default optimal strategy for defaultable bond is an increasing function of the credit spread. That is, holding other factors constant, the investor purchases more defaultable bonds when the credit spread is greater. From the analytical result it is clear that the pre-default optimal strategy of the defaultable bond depends on the investment planning horizon. The investor allocates more when she has longer planning horizon, if the defaultable bond dos not default, which means that the optimal strategy of the defaultable bond is not "myopic". The pre-default optimal strategy for defaultable bond is a decreasing function of the default intensity. The greater default intensity the higher possibility of default, holding other factors constant, and the investor allocates smaller amount of wealth to the defaultable bond.

4 Numerical Analysis

In this section we analyze the behavior of the pre-default optimal strategy of the defaultable bond in particular. From the Sect. 3 we can know that pre-default optimal strategy of the defaultable security is a function of the credit spread, the default intensity, risk-free rate, the risk aversion coefficient and the time to maturity. We centre on the relationship between the credit spread, the default intensity, and pre-default optimal strategy of the defaultable security. Assume that the credit spread is 1–3%, the default intensity is 0.2–0.5%, risk-free rate is 2.25%, the risk aversion coefficient is 0.5, the time to maturity is one year (Table 1).

Figure 1 shows that the investor buys more defaultable security as the credit spread increases. The more credit spread, the more investment on defaultable bond, because the defaultable bond high yields are attractive to investors. Note that the optimal investment in the defaultable bond is increasing with a decreasing rate

Table 1 Parameters' values

δ	h^P	r	γ	$T-t$
1–5%	0.2–0.5%	2.25%	0.5	1

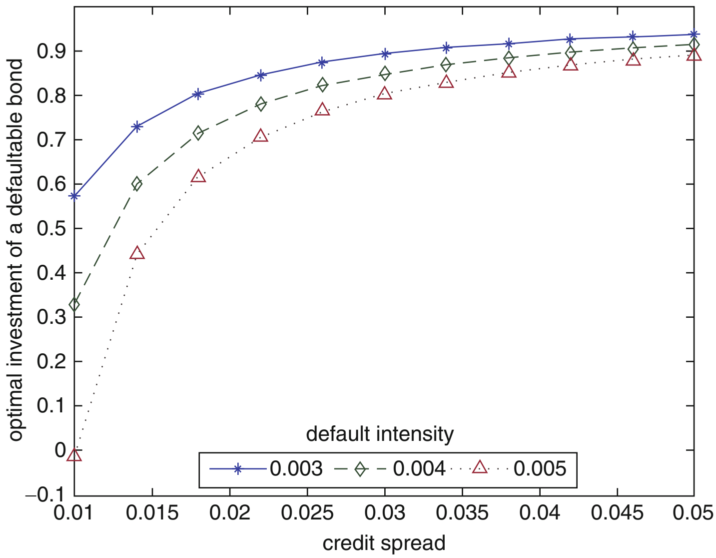

Fig. 1 Optimal investment of a defaultable bond versus the credit spread

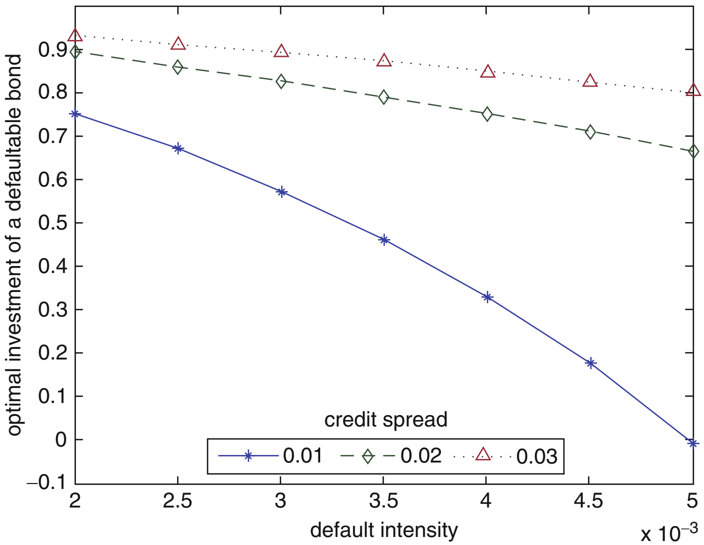

Fig. 2 Optimal investment of a defaultable bond versus the default intensity

when the credit spread increases. In Fig. 1, we also observe that if the default intensity is large then the investor responds more to the increase in the credit spread. As the default intensity decreases, however, the investor still enjoys the high credit spread, but with much care.

Since the higher default intensity the higher possibility of default, the optimal investment in the defaultable security shows a decaying pattern. Figure 2 indicates that when the default intensity is high the investor decreases the investment in the defaultable security, but still invests more compared to the case of high credit spread as the default intensity increases.

5 Conclusion

In this paper we address the optimal asset allocation problem with credit risk. Assume that defaultable bond is the only securities in the portfolio subject to credit risk. Because we assume that the investor invest a defaultable bond, there is jump risk in defaultable bond. Bring the jump risk into the investment portfolio is key innovation of this paper. We adopt the reduced-form approach to model defaultable bond, and give the dynamics of defaultable bond. Assume that the investor's utility is CRRA; using stochastic control methods we obtained closed form solutions for the optimal strategies for a default-free bank account, a stock, and a defaultable bond. We find: the optimal strategy of the defaultable bond is not a continuous function because of jump risk. The post-default optimal strategy for defaultable bond is zero, and the pre-default optimal strategy for defaultable bond an increasing function of the credit spread, and a decreasing function of the default intensity.

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Analysis of the Factors Influencing Credit Risk of Commercial Banks

Tao Aiyuan and Zhao Sihong

Abstract In this paper, the specific data about some Chinese major listed commercial banks, combined with our country's macroeconomic variables factors, were used to analyze the influence of these factors on the credit risk of commercial banks by mixed effects model. According to our analysis, we arrived at the conclusions: the credit risk of commercial bank is not only influenced by the bank itself, but also significantly affected by the others macroeconomic factors; mixed effect model can explain the differences and changes of the inter-bank credit risk. In the end of the paper, we pointed out: commercial banks should be reasonable to adjust the region and magnitude of credit and decentralize loads in the time, so as to effectively avoid the feasible serious consequences leaded by economic cycle, which could guarantee their revenue in effect, improve ability of withstanding risks, and enhance competitiveness.

Keywords Credit Risk · Mixed-Effects Model · NPLR

1 Introduction

The profit constitution of overseas first-class commercial bank is multiple, among which the non-interest return proportion take up a considerable part of the total. Such as, the non-spread revenue share of total income for Americas Bank was 43.3% and Citibank was 46%, the Morgan Chase was 47.2% in 2003. In addition, the proportions of non-interest return appear an ascendant trend. However the domestic commercial bank's profit mainly depend on the spread income, and the handing charge and the commission net income, the investment yield and other operating net income make up only a small section of the bank income. From Table 1 related data of Industrial and Commercial Bank of China (ICBC) and

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Table 1 The income source for ICBC and SDB Unit: billion Yuan

	2006	2007	2008
Net interest income	163.542	224.465	263.037
	7.000	9.606	12.598
Fee and commission income	16.344	38.359	44.002
	0.422	0.521	0.851
Investment yield	1.376	2.040	3.348
	0.100	0.201	0.422
Other operating net income	0.784	0.277	0.293
	0.113	0.165	0.114
Net profit	49.436	81.990	111.551
	1.412	2.650	0.614

Data source: Chinese finance yearbook
(Note: The first row data of each belong to Commercial Bank of China, the second row belong to Shenzhen Development Bank)

Shenzhen Development Bank (SDB) in 2005 and 2006, we may see this singleness of our country commercial bank's profit pattern.

Because of this, the credit risk of commercial banks in China is mainly reflected through the non-performing loan ratio. Based on this fact, in order to promote the profit ability, it is essential to control strictly the non-performing loan ratio for the domestic commercial banks. However, what factors on earth can influence the proportion of the non-performing loan of commercial bank, as well as how is the influence extent of these factors? All these are especially cared about by every commercial bank. In this article, we attempt to do some exploring research on this field.

Relevant factors that we consider include the commercial bank own factors such as the credit scale, asset-liability ratio, income tax and total profit, etc. and relevant macro economy variable factors, where we consider gross domestic product index, total values of imports and exports and CPI. The five grades classification system had not been carried out until 2002, so we only choose the data since 2003 for this restraint. Nine listed commercial banks had selected to implement our analysis. In order to fully explore the information implicated in the data, to find out influence factors and the impact extent of these factors on the proportion of the non-performing loan, we adopt the mixed effects model in the statistical methods, because this model does not expect much in the number of the data of single bank, and especially does not require identical in length of the data of each bank.

2 Related Studies

The proportion of non-performing loans of commercial banks is not only relative to the management of the bank itself, but also involves the credit risk of debtor. A more crucial factor of credit risk is the default rate, and now a lot of foreign literatures in the credit risk field take into account the impact of macroeconomic factors on default rates.

Pesaran and Schuermann (2003) utilized stochastic simulation method to gain macroeconomic model and generate the conditional loss distribution. They analyzed the impact of a shock to set of specific macro economic variables on that loss distribution, and found that shock asymmetry and disproportion, which showed the credit risk model nonlinear.

Koopman and Lucas (2005) used data of real GDP, credit spread and business failure for US economy to analyze the dynamic behavioral of credit risk factors in their relation to real economy. They empirically showed positive relationship of spreads and business failure rates and negative of GDP.

Petr Jakubik (2006) employed data over the time period from 1988 to 2003 of the Finnish economy to build linear vector autoregressive models, and examine how significant macroeconomic indicators determined the default rate in the economy. They thought that models can be used for default rate prediction or stress testing by central authorities.

There are a few researches on the relationship of macroeconomic cycle and credit risk in mainland. The researches mainly concentrated on describing and comparative analysis and seldom touched upon quantitative analysis for the restriction of data capture. Sun (2005) proposed that the suitable risk mitigation techniques should apply to the commercial banks for decreasing pro-cyclicality of credit risk of banks. Jia derived that the credit action of the domestic commercial banks possessed evident pro-cyclicality with the different years credit data.

On the basis of the domestic data state, we have no way of obtaining the data of the default rate of single debtor, so we are unable to make use of the foreign scholar's method to analyze the relation of our country commercial bank credit risk and macroeconomic cycle. In order to avoid this question effectively, we set about from the proportion of the non-performing loan of commercial bank in the macro level to quantify the relation of the commercial bank credit risk and macro economy variable utilizing mixed effects model; in addition, we may give some considerations to the difference among different banks at the same time.

3 Relevant Concepts and Models

3.1 The Definition of Non-performing Loans

A non-performing loan is a loan that is in default or close to being in default. In other words, the non-performing loan refers to the loan that its debtor fail to repay the loans and interests of the commercial bank on time according to the originally contract, Or there are signs that the debtor can not to pay off the loan principal and interest in line with the scheduled loan agreement with commercial banks. According to "general rule of the loan" released by People's Bank of China on July 27, 1995 (tentative implementation), the non-performing loan contained overdue loan, idle loan and bad loan.

The overdue loan refers to the exceeding time limit loan (Include the maturity after the renewal duration) that can't be returned (without including idle loan and bad loan).

The idle loan means that the loan has expired 2 years and the above and can not to be returned (Include the maturity after the renewal duration), or the loan is less than 2 years expiry and yet not due, but the production and management of invested firms have stopped operating and the projects with loan have been suspended (in addition to the bad loan).

The bad loan include: the loan fail to pay off after the debtor and guarantor declare bankruptcy in accordance with the law and be carried out liquidation; its debtor passes out or be proclaimed the missing or death in line with "general rule of the civil law of the People's Republic of China", which lead to the loan fail to pay off after discharging with his property or legacy; the debtor suffers the great natural calamity or contingency and incurs enormous loss which can not obtain insurance to compensate, and really can not to repay some or all loans, or after discharging with the insurance, the loan still can not be affordable; the inadequate segment of the gains through handling collateral, hypothecated material by the creditor in accordance with the law to be made reparation the mortgage and hypothecated loan; the section of the cancelled after verification with the approval of special project of the State Council.

The system of classifying the quality of loans into five grades loan has been practiced in an all-round way in our country since 2002, and be implemented formally on January 1, 2004. This system divides bank credit assets into five kinds according to the risk intensity of the loan: normal, attention, subordination, suspicion, loss. The non-performing loan mainly means the subordination, suspicion, and loss loan. Among them:

The normal loan means that the debtor can fulfil the contract and repay capital with interest normally all the time. The any negative factor that influences full repayment of loan principal and interest in time does not exist. The bank has abundant certainty on the debtor's repayment in full amount about the principal and interests of loan on time. Lost probability of the granted loan is 0.

The debtor has the ability to repay loan and interests at present, but some existing adverse factors may produce the negative effects in repaying, if these impact factors keep going, then the debtor's repayment ability will be influenced. This loan is the attention loan whose loss probability will not exceed 5%.

The subordination loan means that the refund ability of debtor appears obvious problem, and the debtor is unable to repay loan and interests in full amount if he entirely relies on his normal business income, and the debtor need to refund and pay the interest by dealing with the assets or external financing and even carrying out collateral mortgage. The probability with lost loan is in 30–50%.

The debtor is unable to repay loans and interests full-amount, and even by carrying out mortgages or guarantee, partial of loan is sure to incur loss too. For some uncertain factors, such as debtor recombination, merger, amalgamation, dealing with mortgage and unsettled lawsuit, the losing amount of the loan can't be confirmed yet and the lost probability of the loan is between 50 and 75%. This loan is called the suspicious loan.

The loss loan means that its debtor has already no possibility to repay the principal and interest of the loan. No matter what measure is taken and what procedure is fulfilled, the loss of loan is destined. Though few of which can be regained, its value remains next to nothing. From the viewpoint of bank, it is nonsensically and unnecessary to regard it as bank assets to keep on the account, and this kind of loan should cancel immediately after fulfilling essential legal procedure, whose loss probability is in 95–100%.

3.2 Mixed Effects Model

Models with mixed effects contain both fixed and random effects, and the regression coefficients of mixed effects models apply to each individual but not necessarily to the population. A mixed effects model might be considered to gain samples from two stages. At the first stage units are selected at random from a population and at the second stage several measurements are made on each unit sampled in the first stage. In addition, the frequency of measurements can be unequal.

In general, linear mixed effects model is as follows (Laird and Ware 1982):

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \cdots + \beta_p x_{pij} + b_{i1} z_{1ij} + \cdots + b_{iq} z_{qij} + \varepsilon_{ij}$$

where $i = 1, \cdots, M$ denote the numbers of the units and $j = 1, \cdots, n_i$ mean the frequency of measurements for each unit, and $\varepsilon_{ij} \sim N(0, \sigma^2)$ and $b_{ik} \sim N(0, \sigma_k^2)$, independently. This allows for the possibility that predictions from the fitted equation will need to cope with two sources of error, one associated with the sampling process for the units and the other with the measurement process within the sample itself.

The mixed effects model can be represented with matrix as:

$$\mathbf{y}_i = \mathbf{X}_i \boldsymbol{\beta} + \mathbf{Z}_i \mathbf{b}_i + \boldsymbol{\varepsilon}_i$$

$$\boldsymbol{\varepsilon}_i \sim N(\mathbf{0}, \sigma^2 \mathbf{I}), \mathbf{b}_i \sim N(\mathbf{0}, \Psi)$$

where

$\mathbf{y}_i$ is the $n_i \times 1$ response vector for observations in the ith unit.
$\mathbf{X}_i$ is the $n_i \times p$ model matrix for the fixed effects for observations in unit i.
$\boldsymbol{\beta}$ is the $p \times 1$ vector of fixed-effect coefficients.
$\mathbf{Z}_i$ is the $n_i \times q$ model matrix for the random effects for observations in unit i.
$\mathbf{b}_i$ is the $q \times 1$ vector of random-effect coefficients for unit i.
$\boldsymbol{\varepsilon}_i$ is the $n_i \times 1$ vector of errors for observations in unit i.

Ψ is the $q \times q$ covariance matrix for the random effects.

$\sigma^2\mathbf{I}$ is the $n_i \times n_i$ covariance matrix for the errors in unit i.

For the parameters of mixed effects model, their estimation can be gained by the Maximum Likelihood Estimate (MLE) method. The likelihood function for mixed effects model is the probability density for the data given the parameters, but regarded as a function of the parameters with the data fixed, instead of as a function of the data with the parameters fixed. That is

$$L(\mathbf{b}, \boldsymbol{\beta}, \Psi, \sigma^2|\mathbf{y}) = \prod_{i=1}^{M} \int p(\mathbf{y}_i|\mathbf{b}_i, \boldsymbol{\beta}, \Psi, \sigma^2) p(\mathbf{b}_i|\Psi, \sigma^2) d(\mathbf{b}_i)$$

where the conditional density of $\mathbf{y}_i$ is multivariate normal

$$p(\mathbf{y}_i|\mathbf{b}_i, \boldsymbol{\beta}, \Psi, \sigma^2) = \frac{\exp\left(-\|\mathbf{y}_i - \mathbf{X}_i\boldsymbol{\beta} - \mathbf{Z}_i\mathbf{b}_i\|^2/2\sigma^2\right)}{(2\pi\sigma^2)^{n_i/2}}$$

and the marginal density of $\mathbf{b}_i$ is also multivariate normal

$$p(\mathbf{b}_i|\Psi, \sigma^2) = \frac{\exp(-\mathbf{b}_i'\Psi^{-1}\mathbf{b}_i)}{(2\pi)^{q/2}\sqrt{|\Psi|}} = \frac{\exp\left(-\|\Delta\mathbf{b}_i\|^2/2\sigma^2\right)}{(2\pi\sigma^2)^{q/2} abs|\Delta|^{-1}}$$

where Δ is called a relative precision factor because it factors precision matrix, Ψ^{-1}, of random effects, expressed relative to the precision, $1/\sigma^2$, of random errors, which satisfies

$$\Delta'\Delta = \frac{\Psi^{-1}}{1/\sigma^2}.$$

Thus, above likelihood function can be expressed:

$$\begin{aligned} L(\mathbf{b}, \boldsymbol{\beta}, \Psi, \sigma^2|\mathbf{y}) &= \prod_{i=1}^{M} \frac{abs|\Delta|}{(2\pi\sigma^2)^{n_i/2}} \int \frac{\exp\left[-\left(\|\mathbf{y}_i - \mathbf{X}_i\boldsymbol{\beta} - \mathbf{Z}_i\mathbf{b}_i\|^2 + \|\Delta\mathbf{b}_i\|^2\right)/2\sigma^2\right]}{(2\pi\sigma^2)^{q/2}} d(\mathbf{b}_i) \\ &= \prod_{i=1}^{M} \frac{abs|\Delta|}{(2\pi\sigma^2)^{n_i/2}} \int \frac{\exp\left(-\|\tilde{\mathbf{y}}_i - \tilde{\mathbf{X}}_i\boldsymbol{\beta} - \tilde{\mathbf{Z}}_i\mathbf{b}_i\|^2/2\sigma^2\right)}{(2\pi\sigma^2)^{q/2}} d(\mathbf{b}_i)\ (*) \end{aligned}$$

where

$$\tilde{\mathbf{y}}_i = (\mathbf{y}_i, \mathbf{0})',\ \tilde{\mathbf{X}}_i = (\mathbf{X}_i, \mathbf{0})',\ \tilde{\mathbf{Z}}_i = (\mathbf{Z}_i, \Delta)'$$

The exponent in the integral of $(*)$ is in the form of a squared norm or, more specifically, a residual sum-of-squares. We can determine the conditional modes of the random effects given the data, written $\hat{\mathbf{b}}_i$, by minimizing this residual sum-of-squares. This is a standard least squares problem for which we could write the solution as

$$\hat{\mathbf{b}}_i = \left(\tilde{\mathbf{Z}}_i'\tilde{\mathbf{Z}}_i\right)^{-1}\tilde{\mathbf{Z}}_i'\left(\tilde{\mathbf{y}}_i - \tilde{\mathbf{X}}_i\boldsymbol{\beta}\right)$$

Thus, through further simplifies the following result may be obtained (Pinheiro and Bates 2000):

$$L\left(\mathbf{b}, \boldsymbol{\beta}, \Psi, \sigma^2|\mathbf{y}\right) = \frac{1}{(2\pi\sigma^2)^{N/2}}\exp\left(\frac{-\sum_{i=1}^{M}\left\|\tilde{\mathbf{y}}_i - \tilde{\mathbf{X}}_i\boldsymbol{\beta} - \tilde{\mathbf{Z}}_i\hat{\mathbf{b}}_i\right\|^2}{2\sigma^2}\right)\prod_{i=1}^{M}\frac{abs|\Delta|}{\sqrt{\left|\tilde{\mathbf{Z}}_i'\tilde{\mathbf{Z}}\right|}}$$

This expression could be used directly in an optimization routine to calculate the maximum likelihood estimates for $\mathbf{b}, \boldsymbol{\beta}, \Psi, \sigma^2$. The parameters estimate is generally implemented with EM algorithm (Laird and Ware 1982).

In order to compare the quality of the fitted model, the likelihood ratio test can be used to select a best model. The statistic of likelihood ratio test is

$$LR = 2[\log(L_2) - \log(L_1)]$$

where $\log(L_2)$ and $\log(L_1)$ denote respectively the logarithm likelihood value of general model and restricted model. With k_i denoting the numbers of parameters of the ith model, under condition of null hypothesis be true, the LR's large sample distribution follows approximately chi-square distribution with degrees of freedom $k_2 - k_1$.

After getting the best mixed effect model through test, we can utilize it to predict the proportion of non-performing loan next year. In fact, the prediction being given for the random effects are best linear unbiased predictors.

4 Empirical Analysis

Considering the convenience of gaining data, nine listed commercial banks (expressed respectively by letters A, B, C, D, E, G, H, I, J) were selected to carry out our analysis. The data are from financial terminal station of Wind information, and contain concretely the Non-Performing Loan Ratio (NPLR), total loans (TL), Assets Liabilities Ratio (ALR), Income Tax/Total Profit (ITTP), total value of imports and exports (TVIE) etc. As to the macro economy variable, we choose GDP Index (GDPI), the total value of imports and exports and CPI (come from China statistical yearbook), among which GDPI is the Gross Domestic Product

Index calculated at the fixed price taking 1978 as 1 and CPI is the fixed base Consumption Price Index taking 1978 as 100. The unit of total loans is 100 million Yuan. In order to increase the comparability of the relevant annual data, TL is processed with CPI. The visual of data, the estimate of model parameters and the related test are implemented with the aid of S-PULS software.

With the assumption of the independent observations, the pool data can be executed regression analysis. However, this is likely to give reasonable estimates of the regression coefficients, but overstate their significance (Venables and Ripley 2002). So we don't analyze the pool data regression, but consider directly how to construct the suitable mixed effects model. Firstly, we draw out the scatter plot of GDPI and non-performing loan ratio for each commercial bank (see Fig. 1).

The proportion of non-performing loan in each bank displays the approximate linear relation with GDP index and exhibits a decrease trend as GDPI increase. Next, we build the simple linear regression model of non-performing loan ratio in each bank and GDPI, and the results are shown in Table 2. The absolute values of all t value in Table 2 are very big, so we think that all regression coefficients are highly significant, which verify the significant impacts of GDPI on proportion of non-performing loan of each bank. Especially, the difference of intercept and slope for each bank is very distinct, which indicates the inconsistent influence of GDPI on non-performing proportion in different bank.

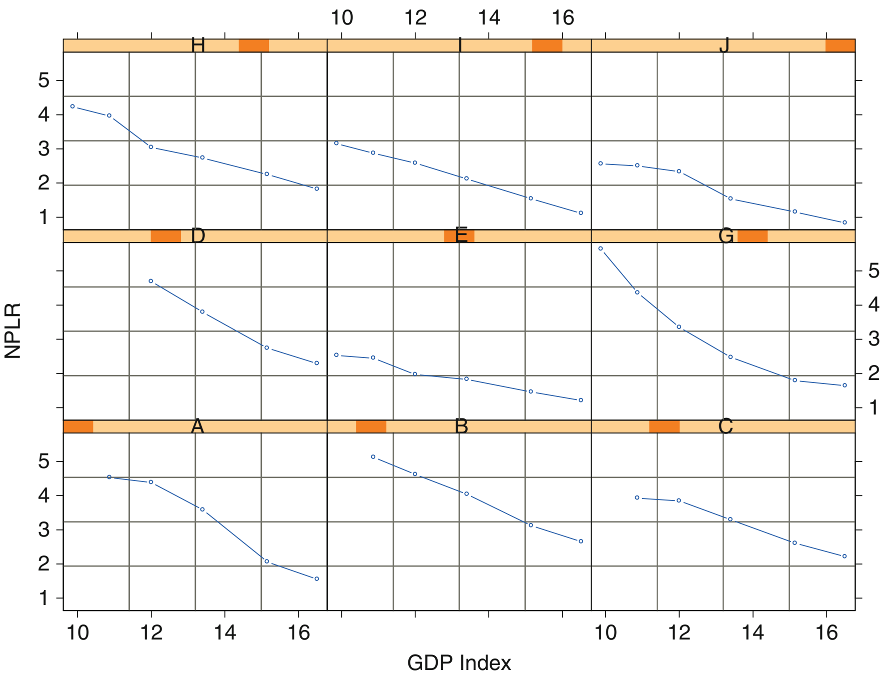

Fig. 1 The relation of NPLR and GDPI for every commercial bank

Table 2 Regression results

	A	B	C
Intercept	11.1237	9.9912	7.6044
t Value	15.4839	13.9074	10.5852
Slope	−0.5815	−0.4474	−0.3261
t Value	−11.1255	−8.5601	−6.2393
	D	E	G
Intercept	11.1139	4.5533	10.8362
t Value	11.0552	8.2287	19.5831
Slope	−0.5421	−0.2039	−0.5880
t Value	−7.7505	−4.8561	−14.0043
	H	I	J
Intercept	7.7270	6.2216	5.5418
t Value	13.9642	11.2978	10.0151
Slope	−0.3640	−0.3101	−0.2872
t Value	−8.6694	−7.3865	−6.8392

For building the accurate relation of every bank non-performing loan and GDPI, let's firstly fit the following simple mixed effects model.

Model 1.

$$NPLR_{ij} = \beta_0 + \beta_1 GDPI_{ij} + b_{i1} + b_{i2} GDPI_{ij} + \varepsilon_{ij} \; i = 1, \cdots, 9; \; j = 1, 2, \cdots$$

Using S_PLUS software, we can gain respectively the MLE of β_0 and β_1, 8.2937 (10.0985) and −0.4049 (−8.9494), and figures in the parentheses are t values. The results illustrate that the impact of GDPI on non-performing loan ratio is significant with the assumption that the influence of GDPI is random. The estimations of variance components are $\hat{\sigma} = 0.2386, \hat{\sigma}_1 = 2.3205, \hat{\sigma}_2 = 0.1237$. The values of AIC, BIC and log likelihood are 59.4303, 70.7812 and −23.7151, and we generally prefer to the model with lower AIC and BIC, but higher log likelihood.

In order to further improve the fitting ability of model, the related data of every commercial bank are added into model, such as total loans, income tax/total profit, total value of imports and exports and asset liability ratio, etc. We build the model 2 and 3, where the random effects in intercept and GDPI are considered, and the results are given in Table 3. The impact of the asset-liability ratio on the bank non-performing loan ratio is not significant in model 2, so we remove this variable to build model 3, and then each independent variable in model 3 is significant under 5% significance level. The negative sign in front of variable GDPI shows that the increase of GDPI will reduce the proportion of non-performing loan, which explains that the good economic situation will lead to the decrease of the non-performing loan ratio. Credit scale expansion is able to enlarge the non-performing loan ratio that this is also obviously in line with common practices. The increase of the total value of imports and exports can reduce the non-performing loan ratio. The variable, income tax/total profit, evaluates the revenue quality of bank, however its coefficient in model 3 is positive sign. For this situation, we believe that the revenue of these domestic commercial banks mainly come from the interest rate difference

Table 3 Fitting results of mixed effects models

	Model 2	Model 3
Intercept	9.7646 (3.8467)	7.5476 (8.2993)
GDPI	−0.3084 (−4.5108)	−0.2958 (−4.4909)
TL	0.0121 (4.0597)	0.0115 (4.1624)
TVIE	−2.5626 (−2.6942)	−2.5616 (−2.6626)
ITTP	0.0164 (2.3482)	0.0165 (2.5489)
ALR	−0.0216 (−0.8937)	–
$\hat{\sigma}$	0.2145	0.2240
$\hat{\sigma}_1$	2.4728	2.3862
$\hat{\sigma}_2$	0.1391	0.1295
AIC	49.07891	47.2484
BIC	67.9971	64.2748
Log likelihood	−14.5394	−14.6242

Table 4 Analysis of variance table

Model	DF	LL	Test	LR	P
1	6	−23.7151			
2	10	−14.5394	1 vs 2	18.3514	0.0011
3	9	−14.6242	2 vs 3	0.1696	0.6805

of deposit and loan, and the better quality of earnings for banks may be too high margin of deposit and loan, thus so high loan interest can increase the pressure on debtor to repay and lead to the growth of debtor default, which cause the increase of the proportion of the non-performing loan of commercial bank.

For three fitted mixed effects models, we choose the best model according to analysis of variance, and the analysis results are shown in Table 4, so based on that the simplicity principle of model and the results of likelihood ratio test, the model 3 is selected finally.

According to the QQ plot of residuals (Fig. 2), we think the assumption of normality we made is fairly reasonable. In order to get an accurate explanation, we need to carry out further the formal residual test of normality. We know that Jarque-Bera test statistic follows the chi-square distribution with 2 degrees of freedom under the condition that the null hypothesis is true. Here, the observation of statistic is 1.9072, and the corresponding P value is 0.3853, so we can not refuse null hypothesis that the residuals follow normal distribution. Based on the graph for the observations and fitted values of non-performing loans ratio (Fig. 3), we can see the fitting effectiveness of model 3 is fairly good (we move horizontally the fitting value a bit to the right in graph in order to compare with actual observed value).

We can examine the out of sample forecasting by utilizing model 3. If we know the data of CPI, GDP index, total value of imports and exports, and credit scale and income tax/total profit for every bank next year. In fact, these data can be estimated through combining the operation of bank with overall economic situation, in this way we may make use of model 3 to implement the prediction of the non-performing loan ratio for every commercial bank. Such as with the assumption that only GDP index increase by 8% next year, the non-performing loan ratio of all

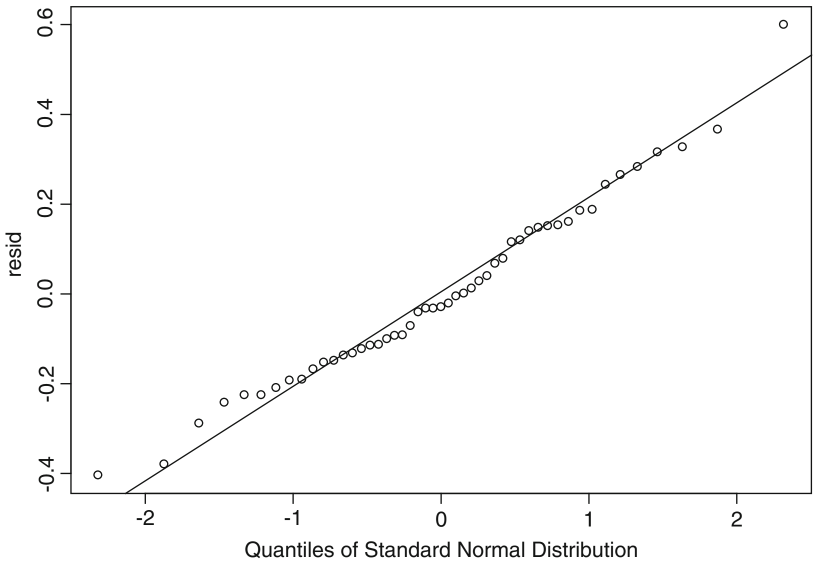

Fig. 2 QQ plot of residuals for Model 3

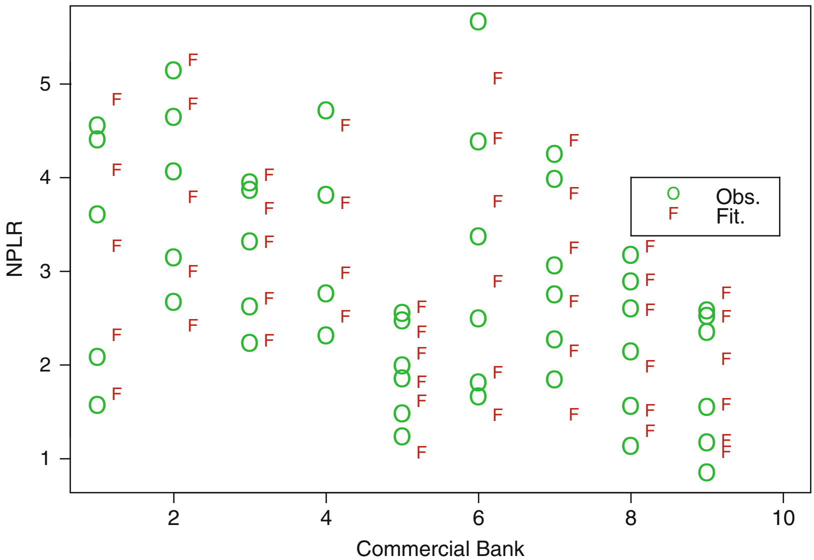

Fig. 3 The fitting values and observations of NPLR

banks can be predicted and showed in Table 5. From which we can obtain that although the effect of GDP index on the non-performing loans ratio of different banks are not exactly the same, with the increase in GDP index which can reflect the

Table 5 Impact of the GDP index changes on NPLR

Banks	A	B	C	D	E	G	H	I	J
NPLR (−5%)	2.04	2.77	2.51	2.81	1.13	1.79	1.69	1.42	1.16
NPLR (5%)	1.30	2.05	1.97	2.19	0.97	1.12	1.22	1.14	0.95
NPLR (8%)	1.08	1.83	1.81	2.01	0.92	0.92	1.07	1.06	0.89

Table 6 Impact of the TL changes on NPLR

Banks	A	B	C	D	E	G	H	I	J
NPLR (−5%)	1.67	2.37	2.20	2.45	1.04	1.45	1.45	1.27	1.05
NPLR (5%)	1.68	2.44	2.28	2.55	1.06	1.45	1.46	1.29	1.06
NPLR (10%)	1.68	2.48	2.33	2.60	1.07	1.45	1.46	1.30	1.07

macroeconomic situation good or bad, namely the macroeconomic situation is getting better, all the bank's non-performing loan ratio decline, and this decline trend is the same. If the GDP index reduces, the economic situation goes bad, then all bank's non-performing loan proportion increases.

Similar, if we only consider the changes of the different Commercial bank credit total amount and assume that TL reduce separately 5%, grow 5% and 10%, we carry on the predict to the non-performing loan ratio of these commercial banks. The results are showed in Table 6.

Some results can be concluded from Table 6, that is: the impact of different banks total credit growth on their proportion of non-performing loans is not exactly the same, although with the increase of the credit scale NPLR increase on the whole. Bank of Beijing (A) and Bank of Nanjing (G) have almost no growth in non-performing loan ratio, while the state-owned commercial banks, such as Bank of China (B), China Construction Bank (C) and Industrial and Commercial Bank of China (D) have relatively large growth, which indicates that credit management of the smaller commercial banks are superior to large state-owned commercial banks. Its mainly reasons are large-scale of state-owned commercial banks cause low management efficiency and high management costs, in addition to these state-owned banks sometimes have to face large and medium-sized state-owned enterprises in trouble.

Obviously, non-performing loan proportions of commercial banks vary evidently with the changes of credit scale and GDP index, which also explains that the credit risk of commercial banks may significantly be affected by these factors.

5 Conclusion

From the above analysis, we conclude that the insufficient data question about non-performing loan of Chinese commercial banks may well be overcome and the relatively ideal prediction of the non-performing loan ratio can be gained by utilizing mixed effects model. Based on the fitted model, we know that the proportion of non-performing loan for commercial bank depend on itself credit scale and quality of revenue, also significantly depend on the quality of the economic situation. So, it is essential to the commercial bank for holding suitable credit scale in order to control effectively the proportion of non-performing loan. More importantly, because the non-performing loan ratio depend significantly on GDP index, that is, there are close relations between credit risk and economic situation, so as to effectively avoid the serious consequences that may caused by economic cycle, the commercial banks should diversify the credit business from the time in order to ensure the level of their revenue.

The model built and the thinking of modelling can be used by every commercial bank, that is, the banks may contrast their business scope, industry and the present economic situation to adjust the direction and scale of credit in order to maximize their returns and strengthen their competitive power.

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The Credit Risk Measurement of China's Listed Companies Based on the KMV Model

Zhang Piqiang and Zhou Hancheng

Abstract Based on the credit risk measurement of a variety of technical and historical review, this paper focuses on the KMV model. The authors select a wide range of sample data and calculate one by one, and use the results to analyze the applicability of the model in China from the perspective of micro level and macro level. It is cited that the model can be used to distinguish different risks of business, and the model results can be associated with indicators of corporate credit risk, and the macroeconomic data also be used to validate the model. It is concluded that the model can be used to distinguish different credit risks of China's Listed Companies, also cited to match with China's current credit rating system. A useful suggestion is put forward that Chinese government should strengthen to supervise China's credit risk and create a fair and transparent credit market for every companies.

Keywords Credit risk · KMV model · Listed companies · Measurement

1 Introduction

The Chinese securities market began to develop, till the end of September 2010, there are altogether 1976 listing companies in China's domestic stock market, total value of stock market reach to RMB 2,387.4036 billion and is about amount to 70% of total GDP in 2009. And the daily average transaction volume reach to RMB

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232.526 billion.[1] The stock market has taken more and more important role in China's financial markets.

However, with the quick development of the stock market, some new problem has hampered the healthy development of the stock market, such as lacking of law and regulatory rules, governance structures, financial fraud, and how to control the credit of listing companies is becoming a urgent issue to the regulatory authorities. And also because of the information asymmetry, and made us difficult to pass through direct observation for risk assessment.

Therefore, it is necessary to establish a set of measures and improve credit risk management system to help the supervision of enterprises and investors on the credit risk and accurately identified. The KMV model is based on the options of the theory of the credit risk model, the measurement is simple and quick to have observation data and it has gained widespread use good results. It is meaningful in our country to achieve quick, efficient and to quantify the credit risk management goals. We need to establish a set of credit risk measures and management system to provide a tool for the stock market participants.

2 Literature Review

2.1 The Credit Risk and KMV Model Study in the Western Countries

As to the study of credit risk, it has taken years in the western countries. Here in this paper we focus on modern credit risk measurement-KMV model. Foreign scholars have taken a deep study to KMV model. At first, they focus their studies on the use of KMV models to predict the real risk of default, and use the model with other sorts of credit risk model for comparison, most of the research shows that KMV model qualifies the reliable and effective measurement functions to the credit risk, Anthony Sanders thinks that KMV model is suitable for any public companies. Vasicek (1995) confirmed that KMV model could predict the change in the revenues after he tested 108 debt rights as the study sample. Jeffrey's (1999) research shows that the highest credit quality is in the enterprise, the credit rating distribution is consistent with Standard and Poor. Crodbie and Bohn founded the financial companies formed to inspect sample KMV models to indicate that the default of the major events and KMV model was expected to be effective and sensitive, the KMV model has great predictive power. Kurba and Korablev (2003) used the time span for 10 years, involving 4,000 American company's data as a sample of the system of KMV model to calculate the enterprises in different periods of the default to the actual rate agreement be fully corresponds, it is proved that KMV model is very effective measure to credit risk. Sobehart et al. (2000) and Roger M. Stein (2005)tested all the credit risk analysis and technical method

[1]The data is from the statistics data of September 2009, if you want more information, please login in: http://www.csrc.gov.cn/pub/zjhpublic/G00306204/zqscyb/201010/t20101028_185942.htm.

contrast. Roger M. Stein (2005)pointed out that some of the pitfalls of the model and provided some relevant suggestions for improvement after the careful studied to the model.

2.2 The Credit Risk Measurement and KMV Model Study in China

At present, Chinese scholars have achieved some productions in the combination and modification of KMV model. Domestic research on KMV model in China market is mainly focused on basic theory, application on the empirical studies and improved model parameters. Wang Qiong and Cheng Jinxian (2002) in his book the Pricing Method and Models of Credit and Du Bengfeng (2002) in his book Real Value Option in Theory Applied to the Credit Risk Assessment the model of a theoretical foundation introduced the model of a theoretical foundation. Zhang Ling, and Zhang Jialin (2000) made a comparative study to KMV model and other model, they found that KMV model compared to the other model is more conducive to the evaluation of the credit risk. Chen Peng and Wu Chong Feng (2002) sort enterprise into different group, and use KMV model to find that the computed the default distance can match different risk categories. Lu Wei, Zhao Hengyan and Liu Jiyun provided GARCH prediction method of the stock share volatility in china. Liu Bo (2010) thinks that the continuous return rate of assets in KMV model is most suitable to China's domestic situation.

Based on the current researching achievements, this paper tries to test the applicability and efficiency of the KMV model in Chinese market.

3 Samples and Parameters

3.1 The Calculation Process of the KMV Model

The calculation process of the KMV model usually includes the following steps.

The calculation of asset value A its fluctuation rate σ_A, according to B-S model, the relationship between asset value and liability value as following formula.

$$E = AN(d_1) - e^{-rt}BN(d_2)$$

here: $d_1 = \dfrac{\ln\frac{A}{B} + (r + \frac{\sigma_A^2}{2})t}{\sigma_A\sqrt{t}}$

$d_2 = d_1 - \sigma_A\sqrt{t}$

and: $\sigma_E = \frac{A}{E}N(d_1)\sigma_A$

here: B = ST + 0.5LT (ST-short liabilities, LT-long liabilities)

3.1.1 The Calculation of Default Distance

With standardized corporate value to a breach between the divided by the volatility of the standard deviation and asset prices up by the company's the distance, a company DD value in the period from current risk level down to the point. The large numbers represent the value of assets from the little farther, the company for breach of the smaller:

$$DD = \frac{A - B}{A\sigma_A}$$

3.1.2 The Calculation of EDF

KMV model is also called expected default frequency (EDF), it takes default liabilities as the contingent interests of enterprise, the rights of owner as call option, the liabilities as put option, assets as target assets. KMV company uses its own advantages to establish a global enterprise and the information database, the specific way is to establish a global scale large enterprise default databases. Then put all the default point 2 standard deviation enterprises together, and observe how many default times a enterprise make yearly. However, we could not get the map relationship between DD and EDF, because KMV company does not public these data.

3.2 The Sample Choosing of the Listed Company

We altogether choose 98 companies as samples for our studies in Shanghai and Shenzhen stock exchange, and 60 companies from Shanghai and Shenzhen 300 index and other 30 from special treatment companies. The formation of samples stock companies is show as Fig. 1.

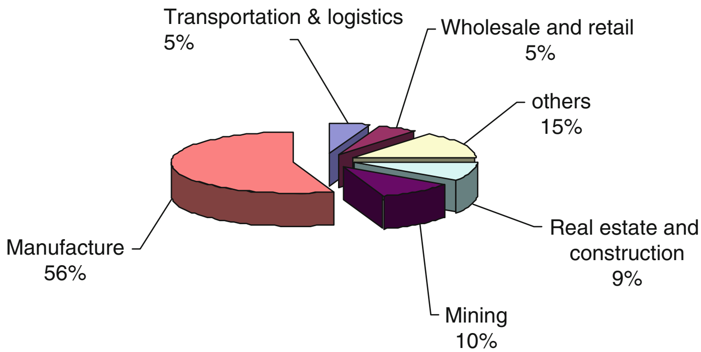

Fig. 1 The formation of samples stock companies

3.3 *Model Parameters*

3.3.1 The Determination of no Risk Rate

Here the determination of no risk rate is based on 1-year fixed deposit rates which is officially determined by the People's Bank of China (see Table 1).

3.3.2 The Determination of Default Point

For the determination of default point is based on experience, KMV reach a empirical formation through long and large of statistics, so we take KMV's proposals in accordance with the flow of long-term debt plus half of the debt. That is DP = CL + 0.5LL, such as Wuhan Still, according to it's 2008 annual report, its current liabilities RMB 29,089.4528 million, and its long-term liabilities is RMB 16,509.8027 million, thus the determination of default point of Wuhan Still is DP = 2,908,945.28 + 0.5*1,650,980.27 = RMB 37,344.3542 million.

3.3.3 Listed Companies

Since the stock segmentation reform has been basically completed in the end of 2007, so this paper directly use E = P*N as the listed company equity value, or market price of the stock multiple the number of circulation stock. In 2008 the data processing, circulation and distribution of the existence of two options exist, most documents are trying to value shares of distribution is multiplied by the stock market prices coupled with a circulation of the number of times per net assets of the product. That is E = Price*N1 + net asset per share*N2, Which N1 represented in the number of share circulation, N2 stood for in the number of share non-circulation. For example, on 7th, January, 2007, the circulation stock of Wuhan Still is 177,0480,000 shares, the non-circulation stock is 320,000,000 shares, the closing price of Wuhan Still is RMB 4.89 on that day, net assets per share is RMB 2.178,

Table 1 One-year fixed deposit rates

Adjusted time	Term deposit 1-year	Adjusted time	Term deposit 1-year
1999.06.10	2.25	2007.08.22	3.6
2002.02.21	1.98	2007.09.15	3.87
2004.10.29	2.25	2007.12.21	4.14
2006.08.19	2.52	2008.10.09	3.87
2007.03.18	2.79	2008.10.30	3.6
2007.05.19	3.06	2008.11.27	2.52
2007.07.21	3.33	2008.12.23	2.25

Source: http://www.pbc.gov.cn/

therefore, the stock value of Wuhan Still is E = 320,000,000*4.89 + 1,770,480,000*2.178 = RMB 5,420,905,440.

Market volatility is a market value of the standard deviation, here we first calculate of the yield of weekly market value, then get out the standard deviation of the yield from weekly market value, so the relationship between yearly standard deviation and weekly standard deviation is:

$$\sigma_E^{year} = \sigma_E^{week}\sqrt{52}$$

Here we use 52 transaction of the weekly market value standard deviation to measure the company's market volatility, and week yield is obtained by logarithm to the opening price and closing pricing (Table 2).

$$\sigma_R^{week} = \sqrt{\sum_1^n (R_i - \bar{R})^2/(n-1)} = 0.017437$$

$$\sigma_R^{year} = \sigma_R^{week}\sqrt{52} = 0.125743$$

3.3.4 The Company Assets Value and the Volatility

According to the previous methods, here we put share volatility, default point, no risk interest rate, stock value into formula make a number of iterations to get the property and assets volatility, finally get default point (DD). Here the iterative process is completed by the Matlab programming, we take Wuhan Still as an example (Table 3).

4 The Measurement of Credit Risk Based on the KMV Model

4.1 The Calculation of Default Distance of Samples Companies

According to the above calculation process, the default distance of listed companies are calculated as followings (see Table 4).

4.2 The Differentiation Analysis of ST Stock and Non-ST Stock

Here we altogether choose 37 ST stocks and 61 non-ST stocks to calculate their default distance in five steps (see Table 5).

Table 2 The market value yield of Wuhan Still in 2000

Date	Opening price	Closing pricing	Non-circulation stock (share)	Circulation stock (share)	Net assets per share is (RMB)	Market value of opening E0 (RMB)	Market value of E1 (RMB)	Yield R = E1/E0
2000.01.07	4.53	4.89	1.77E + 09	3.2E + 08	2.178	5.31E + 09	5.42E + 09	0.0215
2000.01.14	4.9	4.55	1.77E + 09	3.2E + 08	2.178	5.42E + 09	5.31E + 09	−0.021
2000.01.21	4.55	4.59	1.77E + 09	3.2E + 08	2.178	5.31E + 09	5.32E + 09	0.0024
2000.01.28	4.59	4.72	1.77E + 09	3.2E + 08	2.178	5.32E + 09	5.37E + 09	0.0078
2000.02.18	4.86	4.75	1.77E + 09	3.2E + 08	2.178	5.41E + 09	5.38E + 09	−0.007
2000.02.25	4.8	4.72	1.77E + 09	3.2E + 08	2.178	5.39E + 09	5.37E + 09	−0.005
2000.03.03	4.75	4.86	1.77E + 09	3.2E + 08	2.178	5.38E + 09	5.41E + 09	0.0065
2000.03.10	4.88	4.8	1.77E + 09	3.2E + 08	2.178	5.42E + 09	5.39E + 09	−0.005
2000.03.17	4.8	4.81	1.77E + 09	3.2E + 08	2.178	5.39E + 09	5.4E + 09	0.0006
2000.03.24	4.8	4.9	1.77E + 09	3.2E + 08	2.178	5.39E + 09	5.42E + 09	0.0059
2000.03.31	4.91	5.05	1.77E + 09	3.2E + 08	2.178	5.43E + 09	5.47E + 09	0.0082
2000.04.07	5.03	5.3	1.77E + 09	3.2E + 08	2.178	5.47E + 09	5.55E + 09	0.0157
2000.04.14	5.37	5.46	1.77E + 09	3.2E + 08	2.178	5.57E + 09	5.6E + 09	0.0052
2000.04.21	5.46	5.36	1.77E + 09	3.2E + 08	2.178	5.6E + 09	5.57E + 09	−0.006
2000.04.28	5.34	5.37	1.77E + 09	3.2E + 08	2.178	5.56E + 09	5.57E + 09	0.0017
2000.05.12	5.44	5.1	1.77E + 09	3.2E + 08	2.178	5.6E + 09	5.49E + 09	−0.02
2000.05.19	5.1	5.37	1.77E + 09	3.2E + 08	2.178	5.49E + 09	5.57E + 09	0.0156
2000.05.26	5.4	5.93	1.77E + 09	3.2E + 08	2.178	5.58E + 09	5.75E + 09	0.0299
2000.06.02	5.98	6.32	1.77E + 09	3.2E + 08	2.178	5.77E + 09	5.88E + 09	0.0187
2000.06.09	6.38	5.6	1.77E + 09	3.2E + 08	2.178	5.9E + 09	5.65E + 09	−0.043
2000.06.16	5.6	5.7	1.77E + 09	3.2E + 08	2.178	5.65E + 09	5.68E + 09	0.0056
2000.06.23	5.8	5.99	1.77E + 09	3.2E + 08	2.178	5.71E + 09	5.77E + 09	0.0106
2000.06.29	6.06	6.18	1.77E + 09	3.2E + 08	2.178	5.8E + 09	5.83E + 09	0.0066
2000.07.07	6.38	6.88	1.77E + 09	3.2E + 08	2.178	5.9E + 09	6.06E + 09	0.0268
2000.07.14	7	7	1.77E + 09	3.2E + 08	2.178	6.1E + 09	6.1E + 09	0
2000.07.21	7.04	7.04	1.77E + 09	3.2E + 08	2.178	6.11E + 09	6.11E + 09	0
2000.07.28	7.15	6.8	1.77E + 09	3.2E + 08	2.178	6.14E + 09	6.03E + 09	−0.018
2000.08.04	6.79	7.61	1.77E + 09	3.2E + 08	2.178	6.03E + 09	6.29E + 09	0.0426

(*continued*)

Table 2 (continued)

Date	Opening price	Closing pricing	Non-circulation stock (share)	Circulation stock (share)	Net assets per share is (RMB)	Market value of opening E0 (RMB)	Market value of E1 (RMB)	Yield R = E1/E0
2000.08.11	7.61	7.16	1.77E + 09	3.2E + 08	2.178	6.29E + 09	6.15E + 09	−0.023
2000.08.18	7.15	7.73	1.77E + 09	3.2E + 08	2.178	6.14E + 09	6.33E + 09	0.0298
2000.08.25	8	7.49	1.77E + 09	3.2E + 08	2.178	6.42E + 09	6.25E + 09	−0.026
2000.09.01	7.47	7.1	1.77E + 09	3.2E + 08	2.178	6.25E + 09	6.13E + 09	−0.019
2000.09.08	7.1	6.51	1.77E + 09	3.2E + 08	2.178	6.13E + 09	5.94E + 09	−0.031
2000.09.15	6.5	6.51	1.77E + 09	3.2E + 08	2.178	5.94E + 09	5.94E + 09	0.0005
2000.09.22	6.51	6.03	1.77E + 09	3.2E + 08	2.178	5.94E + 09	5.79E + 09	−0.026
2000.09.29	6	6.2	1.77E + 09	3.2E + 08	2.178	5.78E + 09	5.84E + 09	0.011
2000.10.13	6.18	6.06	1.77E + 09	3.2E + 08	2.178	5.83E + 09	5.8E + 09	−0.007
2000.10.20	6.05	6.1	1.77E + 09	3.2E + 08	2.178	5.79E + 09	5.81E + 09	0.0028
2000.10.27	6.13	6.11	1.77E + 09	3.2E + 08	2.178	5.82E + 09	5.81E + 09	−0.001
2000.11.03	6.09	6.2	1.77E + 09	3.2E + 08	2.178	5.8E + 09	5.84E + 09	0.006
2000.11.10	6.2	6.51	1.77E + 09	3.2E + 08	2.178	5.84E + 09	5.94E + 09	0.0168
2000.11.17	6.54	6.59	1.77E + 09	3.2E + 08	2.178	5.95E + 09	5.96E + 09	0.0027
2000.11.24	6.59	6.14	1.77E + 09	3.2E + 08	2.178	5.96E + 09	5.82E + 09	−0.024
2000.12.01	6.2	6.52	1.77E + 09	3.2E + 08	2.178	5.84E + 09	5.94E + 09	0.0174
2000.12.08	6.54	6.58	1.77E + 09	3.2E + 08	2.178	5.95E + 09	5.96E + 09	0.0021
2000.12.15	6.63	6.25	1.77E + 09	3.2E + 08	2.178	5.98E + 09	5.86E + 09	−0.021
2000.12.22	6.25	6.2	1.77E + 09	3.2E + 08	2.178	5.86E + 09	5.84E + 09	−0.003
2000.12.29	6.2	6.32	1.77E + 09	3.2E + 08	2.178	5.84E + 09	5.88E + 09	0.0066

Table 3 The default point of Wuhan Still 2000

Year	Stock value	Stock value yield volatility	Current liability (RMB)	Noncurrent liability (RMB)
2000	5,878,505,440	0.017437432	1,478,435,612	30,000,000
Default point	No risk yield	Market value	Market value volatility	Default point
162,843,561	0.0225	7.47E + 09	0.0989	7.9037

From the Fig. 2 we can find that ST companies are mainly centered in smaller DD value part, and non-ST companies' DD value are usually higher. Compare their average value, non-ST companies' DD average value (2.115) is remarkably higher than ST companies (1.516). It means that KMV model can efficiently distinguish ST companies and non-ST companies. In less than 1.5 DD value of the ST company occupy the most, in DD value is more than 2, most of them are non-ST companies, One can see that the model for DD value beyond 2 has the best resolution, but it is 1.5 to 2 DD value of the resolution to be lower.

4.3 *The Correlation Analysis Between Default Distance Value and Solvency*

4.3.1 The Correlation Analysis to the Assets Liabilities Ratio

First of all samples as the assets liabilities ratio from high to low in an arrangement and found most of the listed companies' assets liabilities ratio is below 200, remove the special listed company's data (600603-STXY-1814 and 600385-STJT-488.5), according DD value from the rest of the 96 listed company played groupings, each group of eight listed companies, and calculate each group's all the company DD arithmetic average value and the assets liabilities ratio's average value (see Table 6).

We use the statistics results to displays the following diagram by Eviews software (see Fig. 3).

From the diagram we can find that DD value with the listed company has largely negative relationship, that is, the higher DD, the lower assets liabilities ratio, this results is in accordance with the theoretic hypothesis. Meanwhile we use SPSS software doing the relevant inspection and get following result (see Table 7).

Pearson two-tailed test proves that its 99% of possibility is negative, in order to check whether DD value has relationship with assets liabilities ratio, we try to make a linear fitting to DD value and assets liabilities ratio (see Table 8).

According to The linear fitting results, the goodness of fit is not perfect, only 75% of samples can be certificated by this method. At the same time, we need to point out that it is not single company's Correlation between DD value and asset liabilities ratio. Here we only analyses one average relationship, it is revealed that

Table 4 The default distance of listed companies

Stock code	Abbreviation of listed companies[a]	Default distance (DD)	Stock code	Abbreviation of listed companies	Default distance (DD)
000002	WK A	1.5814	600050	ZGLT	2.5468
000007	STDS	1.6004	600080	STJH	1.673
000008	STBLL	1.9582	600084	STXT	1.2843
000009	ZGBA	1.4257	600089	TBDG	2.2387
000024	ZSDC	1.9059	600104	SHQC	2.238
000027	SZNY	2.5449	600127	JJMY	1.4153
000039	ZJJT	2.5752	600207	STAC	1.7606
000048	STKDE	1.823	600223	STWJ	1.1697
000060	ZJLN	1.6776	600320	ZHGJ	2.1408
000063	ZXTX	1.9278	600338	STZF	1.4837
000069	HQCA	1.5282	600362	JXTY	1.9217
000402	JRJ	1.6203	600381	STXC	1.4964
000527	MDDQ	2.0426	600383	JDJT	1.8367
000538	YNBY	2.9413	600385	STJT	1.306
000568	LZLJ	1.9263	600419	*STTH	1.4258
000605	STSH	1.2179	600462	STSX	1.602
000613	STDHA	1.4576	600489	ZJHJ	2.0232
000623	JLAD	2.0029	600519	GZMT	3.2039
000630	TLYS	2.116	600547	SDHJ	1.5436
000651	GLDQ	1.8209	600550	TWBB	1.7486
000652	TDGF	1.7156	600579	STHH	1.2913
000692	STHT	1.5488	600598	BDH	1.9412
000729	YJPJ	2.5224	600603	STSX	1.5246
000768	XFGJ	2.2896	600608	STHK	1.487
000779	STPS	1.7274	600645	STXH	2.2955
000800	YQJC	2.0304	600691	STDT	1.3417
000825	TGBX	2.1161	600699	STDH	1.3079
000839	ZXGA	1.4822	600706	STCX	1.6683
000858	WLY	2.4118	600711	STXC	1.4383
000878	YNTY	1.7694	600714	STJR	1.3502
000895	SHFZ	2.7266	600715	STSL	1.7274
000898	AGGF	2.0778	600721	STBH	1.4241
000921	STKL	1.6326	600739	LNCD	2.0049
000922	STEJ	1.3889	600757	STYF	1.2673
000932	HLGT	2.0752	600771	STDS	0.9115
000933	SHGF	1.3916	600795	GDDL	2.3707
000935	*STSM	1.384	600847	STYWL	1.7502
000937	JZNY	1.9366	600868	*STMY	1.9696
000960	XYGF	1.8874	600876	*STLB	1.5315
000983	XSMD	1.3933	600984	STJJ	1.3725
002007	HLSW	3.5139	600988	STBL	1.5017
002024	SNDQ	2.4626	601006	DQTL	2.6916
002202	JFKJ	1.661	601088	ZGSH	2.3917
600005	WGGF	2.1947	601111	ZGGH	1.8779
600018	SGJT	2.908	601168	XBKY	2.2446
600019	BGGF	2.2667	601390	ZGZT	2.5065
600028	ZGSH	2.2961	601600	ZGLY	2.1646
600029	NFHK	2.2961	601857	ZGSY	3.1043
600048	BLDC	1.8237	601919	ZGYY	1.9809

[a]It is tough to translate and give a short meaningful abbreviation to the listed companies, here we only use the first capital letter of Chinese abbreviation form of the listed companies to show its name. If you want to get more information about the Chinese listed companies, please login http://www.cninfo.com.cn/ or http://www.p5w.net and input the stock code or the four abbreviation letters. Same as Table 12

Table 5 The default distance of the listed companies

Default distance (DD)	ST company	Non-ST company
(0,1)	1	0
[1, 1.5)	19	5
[1.5, 2)	16	21
[2, 3)	1	32
dd > 3	0	3
DD average	1.516240541	2.115114754

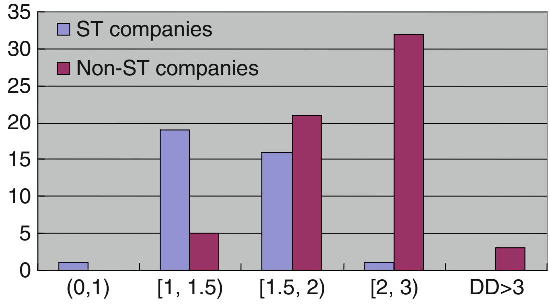

Fig. 2 The statistics of the default distance of the listed companies

Table 6 The average DD and assets liabilities ratio of listed companies

Group	Average DD	Average assets liabilities ratio
1	2.9581	33.0175
2	2.469675	47.6725
3	2.2706625	56.16
4	2.115975	62.3375
5	1.9889125	54.395
6	1.9025375	56.745
7	1.777975	69.76625
8	1.671975	65.79125
9	1.5547	77.03625
10	1.4620875	83.16875
11	1.3899875	64.5675
12	1.22395	108.2025

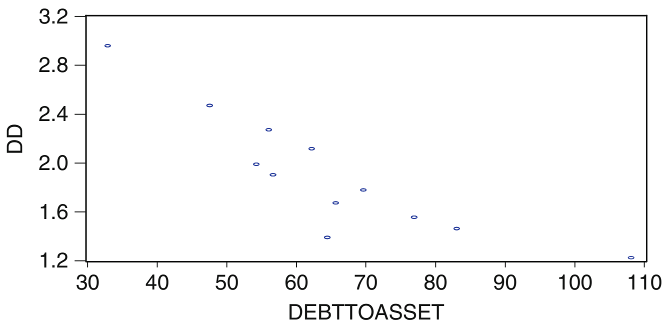

Fig. 3 The average DD and assets liabilities ratio of listed companies

Table 7 The correlation test of average DD and assets liabilities ratio

Correlations			
		DD	Debttoasset
DD	Pearson Correlation	1	−0.870**
	Sig. (2-tailed)		0.000
	N	12	12
Debttoasset	Pearson Correlation	−0.870**	1
	Sig. (2-tailed)	0.000	
	N	12	12

**Correlation is significant at the 0.01 level (2-tailed)

Table 8 The linear fitting to average DD and assets liabilities ratio

Dependent Variable: DEBTTOASSET
Method: Least Squares
Date: 04/06/10 Time: 20:39
Sample: 1 12
Included observations: 12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DD	−33.09662	5.935717	−5.575842	0.0002
C	127.7515	11.62147	10.99271	0.0000
R-squared	0.756632	Mean dependent var		64.90500
Adjusted R-squared	0.732295	S.D. dependent var		18.95886
S.E. of regression	9.809352	Akaike info criterion		7.555561
Sum squared resid	962.2339	Schwarz criterion		7.636379
Log likelihood	−43.33337	F-statistic		31.09002
Durbin-Watson stat	2.337033	Prob (F-statistic)		0.000235

when average DD value rise 1, the average assets liabilities ratio fall 33.09 in the situation of grouping.

According to the above we can similarly compare and analyze the other solvency indicators and DD. Next we are considering is the correlation among DD, current ratio and interest covered ratio. In theory, the higher of current ratio and interest covered ratio, the stronger solvency of an enterprise, it means smaller probabilities and larger DD.

4.3.2 The Correlation to the Current Ratio and Interest Earned Ratio

We first sort sample enterprises in the order of from big to small according to DD indicators, then remove those its current ratio and interest covered ratio are remarkably beyond the normal standard to lower the statistical noise interruption. Of this two indicators, we remove 5 abnormal data, and the other 90 samples data can be divided into nine groups, each group has ten companies (see Table 9).

Table 9 The average DD, current ratio and interest covered ratio in sample companies

Group	Average DD	Current ratio	Interest covered ratio
1	2.67327	116.935	17.83868
2	2.27307	104.812	10.94002
3	2.07916	109.889	13.9323
4	1.93519	135.565	15.38415
5	1.76328	136.244	7.23229
6	1.61314	95.898	4.12212
7	1.48324	51.76	3.20045
8	1.38873	84.953	2.31957
9	1.24478	51.466	−2.99254

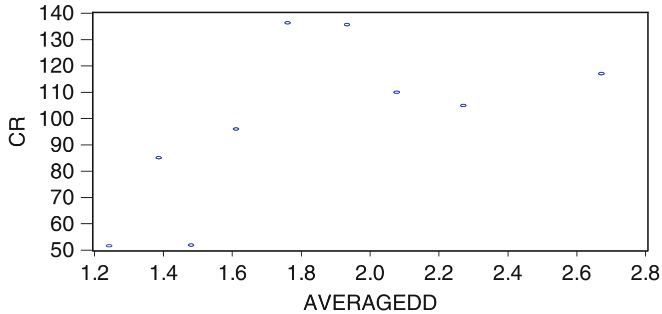

Fig. 4 The diagram of average DD-CR

Here we use Eviews to take average DD as X axis to make diagram (see Fig. 4). We found that CR has positive relationship with average DD. That is when the average DD becomes higher, CR will becomes higher too. It is in accordance with what we have predicted in theory.

And from the calculation of its correlation data, we can get the following results (see Table 10).

We found average DD and CR has positive relationship, but it could not be shown clearly in statistics, when the company's Average DD is between 1.8 and 2, its current ratio is the largest, it may has the relation with the company's assets quality. The company in the value may has a higher current ratio, such as catering industry.

Next we analyses the relationship between Average DD and ICR. According to financial theory, the higher ICR demonstrate its higher solvency of issuing bonds, thus the lower credit risk and lower default distance (see Fig. 5).

The diagram reveals has a better positive correlation, and only when DD is between 1.9 and 2.3, there is a relative fluctuation. We continue to make correlation test to the results (see Table 11).

In conclusion, the DD value which we calculate from KMV model can be able to distinguish between different credit risk enterprises, at the same time it also can be matched with the relevant credit risks of financial statements of companies, it has foundation to be used in China.

Table 10 The correlation of average DD and current ratio

Correlations			
		Average DD	CR
Average DD	Pearson Correlation	1	0.631
	Sig. (2-tailed)		0.069
	N	9	9
CR	Pearson Correlation	0.631	1
	Sig. (2-tailed)	0.069	
	N	9	9

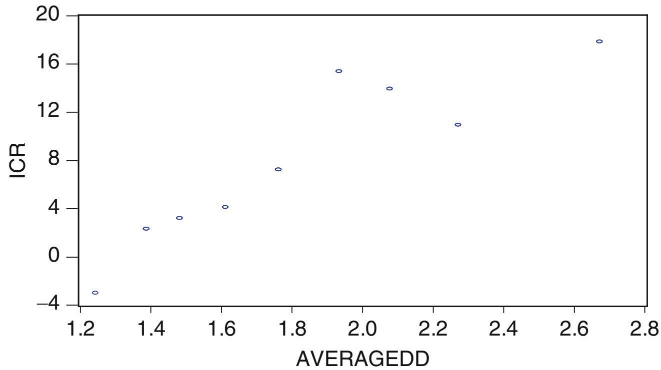

Fig. 5 The diagram of average DD and ICR

Table 11 The correlation of average DD and ICR

Correlations			
		Average DD	ICR
Average DD	Pearson Correlation	1	0.913**
	Sig. (2-tailed)		0.001
	N	9	9
ICR	Pearson Correlation	0.913**	1
	Sig. (2-tailed)	0.001	
	N	9	9

**Correlation is significant at the 0.01 level (2-tailed)

4.4 The Relationship Between DD and the Real Loan Cost of Companies

Strong payment capacity is high default distance and means the lower risks. According to risks and gains in accordance with the corresponding principle of rationality, the rational lenders will have a low yield requirements, that is to say, if the market is an effective, and the enterprise have the greater the distance DD indicators which means lower credit risk, the market price for the loan should be lower, it will lower the financing costs and financial data to the same for funds to finance the costs will be lower. Whether the reality is not consistent with what we do this, we can use this mechanism for further studies to explore.

Because it is difficult to find a listing of the actual cost of debt indicators, the financing conditions vary, here we define a rate of a rough indicator of the debt, or using financing expenses to debt, and this index calculation method is to use the financing expenses divided by the company's total debt

$$\text{FETD} = \text{FE}/\text{D} \quad \text{FE} \\ -\text{ financing expenses, D} - \text{ the company's total debt}$$

If A company is facing a larger default risk, so the financing loan for the payment of interest rates should be larger, the opposite of its financial expenses and total debt ratio would be more appropriate. As part of the company limited, a total of 98 annual report data listed company has nine enterprises for the financial costs to statistics, the elimination of two FETD distinct from normal value proportion of listed companies to reduce the noise, the last remaining in the 87 listed company to list the following data (see Table 12).

Here we use the above data and Eviews software to make a scatter diagram as DD stand for lateral axis, FETD for longitudinal axis (see Fig. 6).

Data more difficult to get accurate observation of a quick conclusion, but we can distinguish a large negative in the framework, the associated with our hypothesis about the same, to further analysis, we use SPSS software doing the relevant inspection to the results are as follows (see Table 13).

The above tested results shows DD and FETD is negative, and there is 99% of probabilities to the statistics meaning, next we continue try to use linear regression to study their relationship (see Table 14).

The goodness of fit is not particularly attractive, but good correlations shows that there is definite negative relationship between them. This we can be interpreted as interest rates in China is particularly commercial bank interest rates in most of the pricing was an expert evaluation and simple rating, and pricing method. So in accordance with the existing way of pricing, we only take a rough judge to the credit risk. Because of Lacking of efficient pricing means, the credit risk could not be matched with the pricing of risks, risks effectively reduce the effectiveness of a market, that reminds us of introducing the pricing models limited risks in china's is emergency. Overall, a testament to the test results is in accordance with what we have deduced in theory, it also reveals that in reality the calculation of default distance of corporate debt costs determination also have great reference value to us.

Table 12 The statistics of samples companies' DD and FETD

Stock code	Abbreviation of listed companies	DD	FETD	Stock code	Abbreviation of listed companies	DD	FETD
000002	WK A	1.5814	0.02003	600084	STXT	1.2843	0.1232362
000007	STDS	1.6004	0.13084	600089	TBDG	2.2387	0.0512369
000009	ZGBA	1.4257	0.03941	600104	SHQC	2.238	0.1050606
000024	ZSDC	1.9059	0.0025	600127	JJMY	1.4153	0.0398895
000027	SZNY	2.5449	0.05873	600207	STAC	1.7606	0.0533677
000039	ZJJT	2.5752	0.0195	600223	STWJ	1.1697	0.139213
000048	STKDE	1.823	0.07117	600320	ZHGJ	2.1408	0.0058532
000060	ZJLN	1.6776	0.12914	600338	STZF	1.4837	0.0970816
000063	ZXTX	1.9278	0.07792	600362	JXTY	1.9217	0.0464423
000069	HQCA	1.5282	0.03091	600381	STXC	1.4964	0.0693597
000402	JRJ	1.6203	0.00256	600383	JDJT	1.8367	0.019683
000527	MDDQ	2.0426	0.08349	600385	STJT	1.306	0.2164804
000538	YNBY	2.9413	0.00826	600419	*STTH	1.4258	0.2249413
000568	LZLJ	1.9263	0.01418	600462	STSX	1.602	0.1705386
000623	JLAD	2.0029	0.30868	600489	ZJHJ	2.0232	0.0417477
000630	TLYS	2.116	0.05325	600547	SDHJ	1.5436	0.076284
000651	GLDQ	1.8209	0.03278	600550	TWBB	1.7486	0.0392219
000652	TDGF	1.7156	0.05771	600579	STHH	1.2913	0.0958325
000692	STHT	1.5488	0.08848	600598	BDH	1.9412	0.0428522
000729	*STHT	2.5224	0.06304	600603	STXY	1.5246	−0.003019
000768	YJPJ	2.2896	−0.0054	600608	STHK	1.487	0.0709261
000825	TGBX	2.1161	0.05066	600645	STXH	2.2955	−0.078481
000839	ZXGA	1.4822	0.03927	600691	STDT	1.3417	0.3234904
000878	YNTY	1.7694	0.07895	600699	STDH	1.3079	0.1156646
000898	AGGF	2.0778	0.02257	600706	STCX	1.6683	0.0638889
000921	STKL	1.6326	0.06691	600711	STXZ	1.4383	0.087634
000922	STEJ	1.3889	0.09582	600714	STJR	1.3502	0.1456117
000932	HLGT	2.0752	0.04763	600721	STBH	1.4241	0.2030696
000933	SHGF	1.3916	0.04457	600739	LNCD	2.0049	−0.000884
000935	*STSM	1.384	0.06872	600757	STYF	1.2673	0.1295945
000937	JZNY	1.9366	0.03361	600771	STDS	0.9115	0.1374744
000960	XYGF	1.8874	0.07952	600795	GDDL	2.3707	0.0311458
000983	XSMD	1.3933	0.04004	600847	STYWL	1.7502	0.0525595
002024	SNDQ	2.4626	−0.0302	600868	*STMY	1.9696	0.1257604
002202	JFKJ	1.661	0.01642	600876	*STLP	1.5315	0.0769899
600005	WGGF	2.1947	0.02895	600984	STJJ	1.3725	0.2340781
600018	SGJT	2.908	0.0382	600988	STBL	1.5017	0.1795694
600019	BGGF	2.2667	0.03853	601088	ZGSH	2.3917	0.0520476
600028	ZGSH	2.2961	0.03824	601111	ZGGH	1.8779	0.0098433
600029	NFHK	2.2961	−0.0143	601168	XBKY	2.2446	0.0311465
600048	BLDC	1.8237	−0.0015	601390	ZGZT	2.5065	0.088239
600050	ZGLT	2.5468	0.10313	601600	ZGLY	2.1646	0.0320804
600080	STJH	1.673	0.22145	601857	ZGSY	3.1043	0.0178145
601919	ZGYY	1.9809	0.02488				

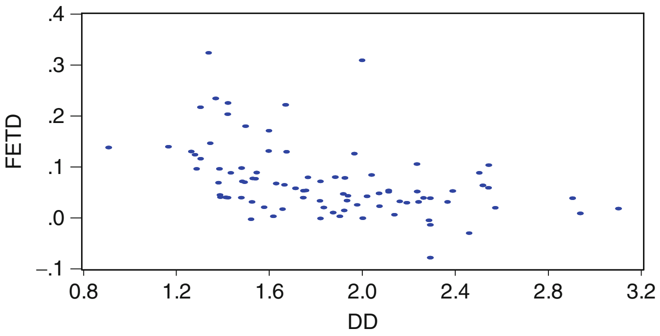

Fig. 6 The scatter diagram of DD and FETD

Table 13 The correlation between DD and FETD

Correlation			
		DD	FETD
DD	Pearson Correlation	1	−0.446**
	Sig. (2-tailed)		0.000
	N	87	87
FETD	Pearson Correlation	−0.446**	1
	Sig. (2-tailed)	0.000	
	N	87	87

**Correlation is significant at the 0.01 level

Table 14 The linear regression to DD and FETD

Dependent Variable: IRATE
Method: Least Squares
Date: 04/07/10 Time: 11:44
Sample: 1 87
Included observations: 87

Variable	Coefficient	Std. error	t-Statistic	Prob.
DD	−0.071565	0.015571	−4.595925	0.0000
C	0.203299	0.029502	6.890987	0.0000
R-squared	0.199039	Mean dependent var		0.071309
Adjusted R-squared	0.189616	S.D. dependent var		0.069971
S.E. of regression	0.062988	Akaike info criterion		−2.669010
Sum squared resid	0.337241	Schwarz criterion		−2.612323
Log likelihood	118.1020	F-statistic		21.12252
Durbin-Watson stat	1.936851	Prob (F-statistic)		0.000015

5 The Influence of Macro Level Fluctuation to the KMV and DD

5.1 The Calculation of the Sample Enterprises' Default Distance in Different Years

In order to stand for exclusively data, here we firstly choose five leading enterprise from different industries to calculate the change of the default distance from 2000 to 2008 respectively, the calculation methods just as same as the part 4 in this paper (see Table 15).

5.2 The Relationship Between Default Distance and the Prosperity Degree Data of the Related Industries

Table 16 shows the industry prosperity degree data of the five companies and the growth rate of China.

Here in after, we analyses the relationship between default distance and its prosperity degree. Firstly, we take a close look at the relationship between WGGF (Wuhan Steel Co, ltd.) and black metal smelting. Through EXCEL we can get Straight forward impression (see Fig. 7).

Drawing an amendment to the y are the coordinates of a large place, in order to show the two sets of data change, the prosperity degree data will be divided by 10. For example, the dark metal smelting and pressing for the processing of the boom in 2000 is drawing 151.91, we shall impose a 10 its size, the diagram shows the magnitude is 15.191, of course for the process does not change the relative position of the data changed, just out of the graphical view of the more easily.

From the Fig. 7, we can see as the black metal processing industry, it 's degree in 2000 to 2002 is up, in 2002 reached its peak, then began to fall year by year, in 2005

Table 15 The statistics of samples companies' DD in different years

Stock code	Abbreviation of listed companies	2000	2001	2002	2003	2004
600005	WGGF	7.9037	17.8655	17.7784	10.2463	6.0621
600127	JJMY	2.1157	1.7818	4.3659	6.4064	4.2002
600795	GDDL	6.0765	2.4223	2.858	6.3925	3.1786
000009	ZGBA	2.0522	3.8854	2.065	4.6471	3.8876
000933	SHGF	4.6534	3.7737	6.7405	8.6253	5.8219

Stock code	Abbreviation of listed companies	2005	2006	2007	2008
600005	WGGF	8.2211	5.9301	2.3388	2.1947
600127	JJMY	4.4103	2.9918	1.6927	1.4153
600795	GDDL	6.5073	5.9341	3.0646	2.3707
000009	ZGBA	2.834	3.692	1.9288	1.4257
000933	SHGF	1.6296	3.0067	1.9663	1.3916

Table 16 The statistics of DD the related macroeconomic indicator data

Indicator	The prosperity degree data					
	Black metal and melting	Agricultural by-products	Power	Real estate	Mine industry	GDP growth
2000	151.90	119.20	148.10	122.30	106.40	8.43
2001	124.10	108.30	138.70	127.90	149.40	8.30
2002	150.60	123.90	138.50	129.50	154.40	9.08
2003	161.30	132.70	145.10	131.30	157.20	10.03
2004	158.20	133.30	139.80	132.90	162.10	10.09
2005	113.20	135.00	142.80	127.60	152.40	10.43
2006	139.90	132.00	148.70	133.70	161.00	11.60
2007	151.10	137.30	149.20	140.30	161.40	11.90
2008	52.90	118.60	106.80	101.70	100.40	9.00

Source: The state statistics bureau of China

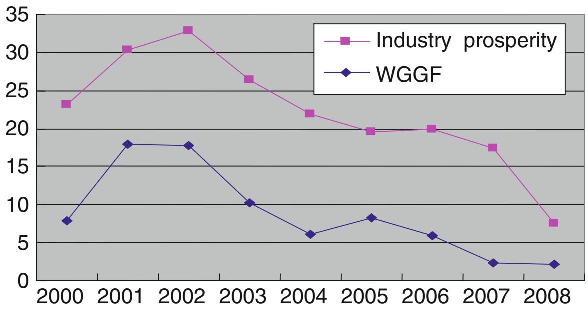

Fig. 7 The relationship between WGGF default distance and its industry prosperity degree

and 2006 keep a steady move, and have a accelerated decline in 2007. We can see from KMV model of the distance DD since 2000, in a gradual decline in 2004, to have a drop in again, and the overall trend in the form and prosperity for the indicators very is much in line with that in the dark metal processing industry, the indicators of default distance can timely and effectively reflect the change in the business environment.

Next we do the same research to agricultural by-products industry (see Fig. 8).

In Fig. 8, we can find that the agricultural by-products industry located in recession in 2001, reached its peak in 2003, then keep a steady move until 2007, after that move in with the accelerating trend. And as to DD indicator, it is generally move in the same trend with the prosperity degree data, the result shows that the DD indicator of agricultural by-products industry can also reflected industry environment.

Same as above method, we take a analysis to coal mining industry and SHGF (Henan Shenhuo Coal & Power Co., Ltd, see Fig. 9).

In Fig. 9, we can find that the coal mining industry stayed in booming process from 2000 to 2003, after its peak in 2003, it began to move down quickly, except for a slight jump in 2005. As to SHGF DD indicator, it has a better coupling with its industry prosperity degree, but it began to move down quickly from 2006.

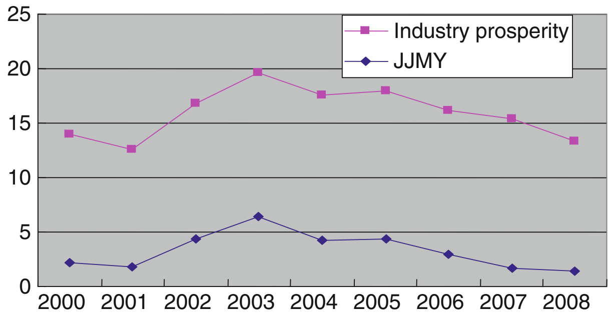

Fig. 8 The relationship between JJMY (Hunan Jinjian Cereals Industry Co., Ltd) default distance and its industry prosperity degree

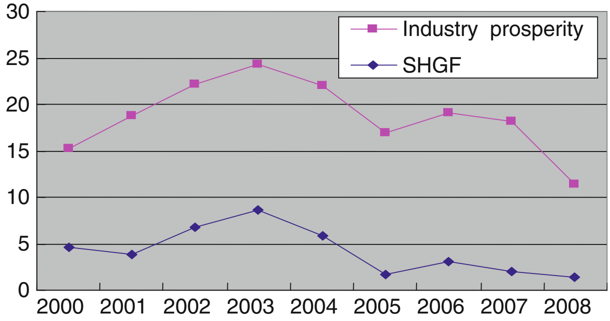

Fig. 9 The relationship between SHGF's DD and its industry prosperity degree

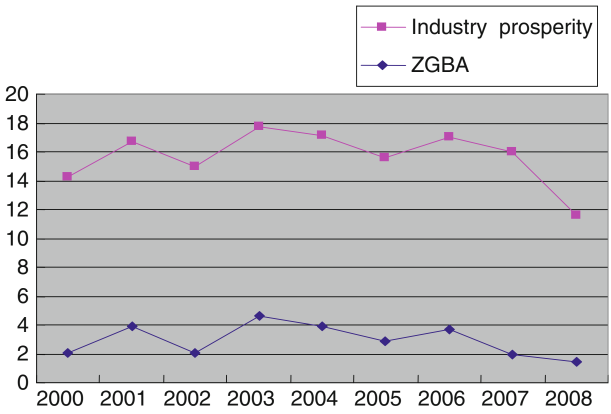

Fig. 10 The relationship between ZGBA's DD and its industry prosperity degree

We do the same analysis to real estate industry prosperity degree and ZGBA (China Baoan Group Co., Ltd, see Fig. 10). From Fig. 10, we can find that the real

Fig. 11 The relationship between GDDL's DD and its industry prosperity degree

estate industry prosperity degree began to move upward from 2000, except for a remarkable fall in 2007. ZGBA's DD can be matched better with its industry prosperity degree. But it took a great change since 2006.

Finally, we take analysis to GDDL (SP Power Development Co., Ltd) and its industry prosperity degree (See Fig. 11).

From Fig. 11 we can find that the production and supply of power began to move downward from 2000, and there was a fluctuation in 2002, it began to slow down quickly from 2006. As to its default distance, its changing trend can also reflect its industry development, but its DD began to move down in 2006.

Overall, we concluded that the default distance indicator of the five different companies which we selected can swiftly and accurately reflect their industries' prosperity degree, and be coupled with each other. It is also proved that KMV model is applicable for the China's macroeconomic situation. However, it is because of limited sample data, it is difficult to accurately describe the slight change of default distance curve, in the macroeconomic level it performed well in curve coupling, but it still has room to be improved.

5.3 The Indicator Relationship Between Default Distance of the Five Sample Enterprises and GDP Growth Rate

Here we take a close analysis to the indicator relationship between default distance of the five sample enterprises and GDP growth rate (See Fig. 12).

From Fig. 12 we can find that China has moved into quickly economic development stage since 2001, till 2007, China's economy has kept robust growth for 7 years. Because of global financial crisis in 2008, the growth rate of China's economy has lowered down sharply.

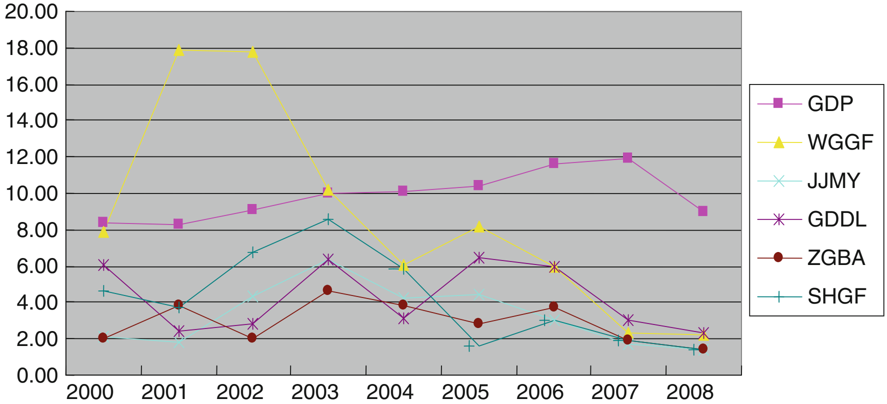

Fig. 12 The relationship of the sample enterprise's DD and GDP growth rate

However, the default distance of the five sample enterprise was not completely matched with the growth rate change before 2005. It may be related with every enterprise's development, so we could not get conclusion that the default distance of a single enterprise could not stand for the whole society's economic development trend. But the interesting thing is that the default distance of several enterprises has moved simultaneously downward greatly when the growth rate of GDP still moved upward in 2006, its change trend is quietly different with the growth rate GDP. The sharply decline of the growth rate of GDP in 2007 shows the accurate prediction of the default distance indicator. At the same time, it supports the foreign scholars' hypothesis that, KMV model has a sometimes of foresee function.

5.4 The Summary of the Default Distance of Credit Risk Measurement

The default distance which is calculated by KMV model can efficiently distinguish different risky companies. After the combination analysis among the DD value, the ratio of asset and liabilities, and the ratio of liquidity, it is found that DD value could be supported with the solvency of the enterprise's financial statement. It proved that KMV model have efficiently qualified function to the enterprises' solvency in micro level of a enterprise.

The ratio relationship between credit default distance DD value and FETD shows that there is remarkable negative relationship between DD value and real loan costs, and it does not produce a stable linear equation to make a further explanation, one reasonable statement is that KMV model can distinguish enterprise's credit risk just as the current credit loan identify method does in China. From another perspective, it is proved that KMV model is applicably to China's market. Therefore, as a methodological issue, China currently does not have a accurate pricing system to measure the credit risk, in order to improve the efficiency of credit market, it is necessary to take a quick step to introduce measurement model of credit risk to measure and control China's credit risk.

The default distance and its industry prosperity degree of the five typical enterprises from 2000 to 2008 shows that the default distance of an enterprise could be supported each other with its industry prosperity degree of an enterprise. Furthermore, after the research to the default distance and the growth rate of GDP, it is found that KMV model research results has a year forward prediction to the global financial crisis.

6 Conclusion

After an overall theoretically test to the KMV model and its' application to credit risk, it can be concluded that KMV model is meaningful and useful to China's credit management. The paper uses KMV model which is based on the options theory to test KMV model application in Chinese stock market through analyzing listed company's default distance, the indicator of debt solvency and FETD. The KMV model data is from the capital market and the listed company annual report, it is easily, timely and objectively to be used. Because of calculations with the rest of the data having a better coupled factor fit, KMV model can effectively reflect Chinese domestic market credit risk. The model not only use the historical financial data and information, and the model itself imply with the option of the enterprises, the share prices through market competition means it contains all the information of the enterprise, thus the result of the credit risk imply the enterprises future credit risk, so the result has certain predictability. Generally speaking, the paper gets the following research findings.

Firstly, how to make sure of default points for Chinese listed companies. Then, the paper makes use of the KMV model to do an empirical research on part of Chinese listed companies. It gets the conclusions that the KMV model can be applied in Chinese market as the basis of modified data. It is a dynamic and complete process while estimating the normal listed companies equity value and the whole company value through KMV model, which takes into account not only the up to date value of the companies, but also the development opportunities and prospect in the future. When it comes to the Special Treatment companies with financial distress, KMV model indicates that the Special Treatment companies values are more than their debts although their net assets could not refund the debts, KMV model also reflects both the net assets value and the virtual value of the Special Treatment companies, explaining why the Special Treatment stocks are highly demanded to some extent. However, KMV models are introduced in china in a primary phase, some problems and shortcomings are still needs further study and explore. The model is also need to solve many problems such as the default selection is the direct application.

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Consumer Credit Risk Research Based on Our Macroeconomic Environment

Zhu Ning and Shi Qiongyao

Abstract As the important factor that our country's sustained economic growth relies on in future, the consumer credit will play an important role in the stage of the economic transition. However, because of many uncertain factors in the macroeconomic environment, the development situation of the consumer credit is not optimistic. Therefore this paper empirically analyses the influences of the macroeconomic factors on the consumer credit, after studying the present situation of our country's consumer finance development, thus pertinently puts forward some related suggestions.

Keywords Consumer credit · Macroeconomic environment · Risk

1 Introduction

There are many definitions of "consumer credit". The Federal Reserve Board of U.S made the definition that the consumer credit is the short or medium term loan issued for personal consumption of goods and services or repayment of the debts caused from the consumption through the normal commercial channel. Besides, in the Britain's "Consumer Credit Protection Law", it refers to the credit which is provided to the natural person bearing the financing charges and only used in the trade of family for consumption not for the business or agricultural management purpose. The consumer credit theory develops gradually on the base of consumption function theory. The absolute income hypothesis of Keynes, the relative income hypothesis of Dusenberry, the permanent income hypothesis of Milton Friedman, and the life cycle hypothesis of Franco. Mordiglianl are the theories explain the facts that when the fixed income levels drop down and individual savings are insufficient, people have no choice but

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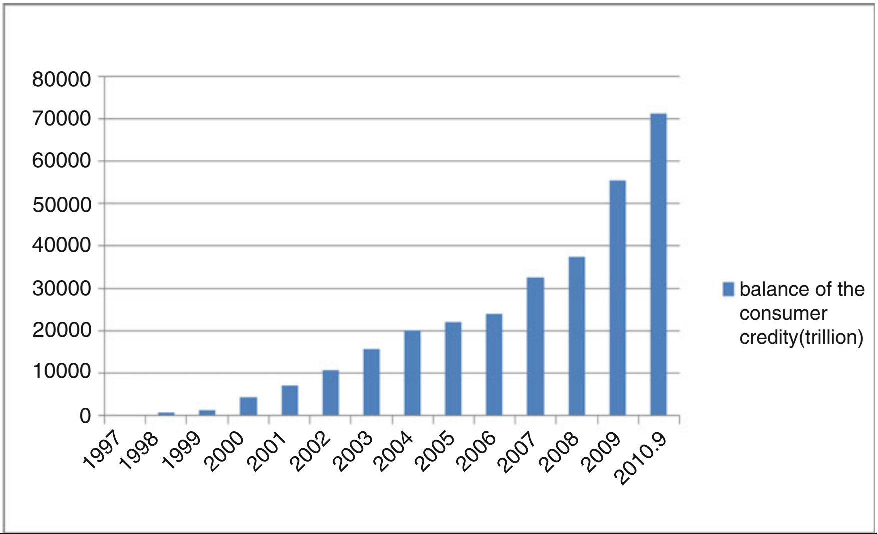
to borrow money to satisfy themselves and maintain high consumption level. Bacchetta and Gerlach pointed out that consumer credit plays the positive role in promoting final consumption after making research on the consumer credit data from five OECD countries including the United States. Domestic scholars studied the development of consumer credit from two aspects of qualitative and quantitative analysis. Huaqin (2006) did the quantitative analysis on the relationship between the consumer credit and economic development, specified the huge development space of consumer credit and finally analyzed the factors which restrict the development of consumer credit by combining some relative research achievements of institutional economics, information economics and behavioral finance. Yunfeng (2008) used the theory of consumer choice, western commercial banks' credit risk management theory, asymmetric information theory after referring to the personal consumer credit development experience of developed countries, to research on the problems in the process of our country's consumer credit development and put forward countermeasures from two aspects of internal and external financial system. Jing summarized the credit rating research situation at home and abroad, improved the explanatory variables and inspection standards of model's prediction effects to be introduced into the basic model of personal consumer credit rating, and finally proposed a new personal credit rating model: MARS-ANN two stages mixed model according to the features of different models.

As to the research on the consumer credit risk, the scholars at home and abroad make the empirical studies by the use of variety of models such as Discriminant Analysis model, Logistic Regression model, BP neural network model and so on from the aspect of microeconomic. However it is rare to study our country's consumer credit risk from the macroscopic angle according to the our country's development features after financial crisis. So this paper tries to research in the view of our country's economic environment, to analyze the influences of some macroeconomic index on the consumer credit risk in the current situation that the asset price is unstable, the CPI is very high and the credit risk of financial institutions accumulates constantly, and at last puts forward some relative proposals, hoping to provide certain reference to the development of our country's consumer finance market.

2 The Current Situation of Consumer Finance Market in Our Country

2.1 High-Speed Growth in the Credit Scale

The prototype of consumer credit appears in England and Scotland in eighteenth century when the businessmen took the means of selling on trust. Then the traditional retail business was gradually replaced by the modern one in the form of installment credit. Now in the developed countries, the proportion of consumer credit in the whole credit scale is from 20 to 40%. Take the United States as an example, the balance of consumer credit stood at 2.415 trillion dollars after



Growth rate(%)	326	92	204	63	53	48	27	10	9	36	14	49	29

Fig. 1 The balance of the consumer credit in our country. Resource: the static dates of the People's Bank of China

suffering the fourth consecutive month decline at the end of May in 2010, which increased nearly 60% compared with the year of 2001. The consumer credit in our country develops from 1980s, at the end of 1997, the balance of the credit was only 17.2 billion yuan, however with the sustainable rapid development of our country's economy, residents income and consumption level enhance gradually, and the consumer credit business enters the high growth stage. See Fig. 1. From the figure,

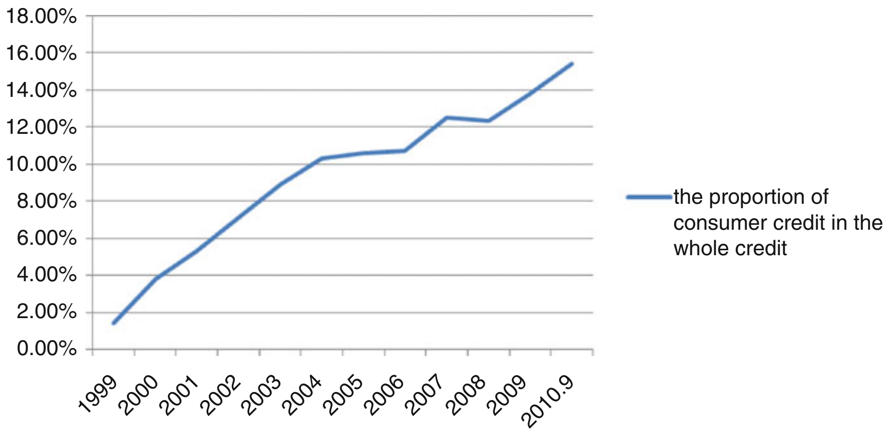


Fig. 2 The proportion of the consumer credit in the whole credit of financial institutions Resource: the static dates of the People's Bank of China

we can see clearly that after 13 years' development, the consumer credit scale has reached 7.12 trillion yuan, 414 times larger than the year 1997. Before 2005, the growth rate maintains up to 50% with the highest of 326% and declines gradually after 2005. However as the set of "expand domestic demand and stimulate the economy" strategic target and the implementation of the moderate looser monetary policy, the consumer credit in our country ushers in the new rapid growth. Besides, the Fig. 2 shows the change of the proportion of the consumer credit in the whole credit of financial institutions. The proportion has increased from 1.4 to 15.4% which is still very small compared with the rate of 70% in the United States.

2.2 *The Type of Financial Institutions Engaged in Consumer Finance Services Is Single*

In our country, the main financial institutions that offer the consumer finance services are the commercial banks which start to develop the individual housing mortgage in large scale in 1997. After that, auto finance companies become a new type of the institutions operating the consumer credit business with the "Management Measures for Auto Finance Company" cleared through the CBRC on December 27th, 2007. Besides, in view of the fact that the type of financial institutions engaged in consumer credit service is too onefold, the CBRC promulgated the "Pilot Management Measures for Consumer Finance Company" in July 22nd, 2009, hoping the new set consumer finance company can offer more services to the clients to meet their different levels of demand that the commercial banks can't satisfy. Allowing for the fact that the founded time of auto finance company and consumer finance company are very short, and the development prospect is still uncertain, the situation that the consumer credit business is centralized in the commercial banks doesn't occur the substantial change. However, some developed countries like the United States have a variety of credit institutions. See Table 1. In the Table, we can see that there are seven kinds of consumer credit institutions in the USA, among which the commercial banks, finance companies and pools of securitized assets are the top three institutions in the credit proportion. As to the trend, the proportion of commercial banks and federal government increases sharply. However the pools of securitized assets decrease gradually, especially in 2010 the decline is very large.

Table 1 The proportion of consumer credit institutions in USA

Year / Categories	2006	2007	2008	2009	2010.8
Commercial banks (%)	30.7	31.5	33.9	34.5	47.2
Finance companies (%)	22.1	22.9	22.2	19.7	21.7
Credit unions (%)	9.7	9.2	9.1	9.6	9.4
Federal government (%)	3.8	3.9	4.3	7.5	10.5
Savings institutions (%)	4.0	3.6	3.3	3.1	3.4
Nonfinancial business (%)	2.4	2.3	2.3	2.3	2.2
Pools of securitized assets (%)	27.3	26.6	24.9	23.3	5.6

Resource: Federal Reserve System

Table 2 Some consumer finance products and the proportion in the total credit of finance companies in the USA

Year		2008	2009	2010.8
Credit category				
Consumer	Motor Vehicle loans (%)	12.8	12.6	12.7
	Revolving (%)	3.9	2.8	4.9
	Other (%)	13.1	14.5	17.4
Real estate (%)		25.0	26.5	25.9

Resource: Federal Reserve System

2.3 Lake of Consumer Finance Products

In the USA, there is a variety of consumer finance products, and the credit categories in commercial banks include: (1) Installment loans. (2) Revolving credits: decide the maximum credit line according to consumers' credit status, and maintain the credit line if consumers repay the loan regularly. (3) Single-payment loans: mainly divided into secured loans and unsecured loans. In addition, the Table 2 shows some consumer credit categories and the proportion in the whole credit of finance companies in the USA. In the Table, we can see that the proportion of housing mortgage is only 25%, however the proportion of "other" category which includes student loans, personal cash loans, mobile home loans, other types of consumer goods is relatively high and takes on the trend of increase year by year. But as to our country, the main credit categories are housing mortgage and auto loan. In the end of 2008, the proportion of housing mortgage in the whole consumer credit is as high as 79.3%, whereas the balance of auto loans is only 158.3 billion yuan, and the proportion is just 4.3%. Although there are other categories such as student loans, credit card consumption loans, tourism loans, durable goods loans and medical loans, the scale of which are all very small. At the end of June, 2007, the balance of State-subsidized student loan is only 19.29 billion yuan, and the domestic credit card loan is only 90 billion by the end of 2009.

3 The Influence Effects on the Consumer Credit Risk Based on Our Country's Macroeconomic Environment

The consumer credit risk mainly refers to possibility of loss that the banks may suffer when the loans can't been paid when due. The risk is directly determined by the consumers' performance and the management of financial institutions themselves. However, considering that the national macroeconomic environment will affect consumers' ability of repayment and the operation risk of financial institutions, this paper mainly analyses from three aspects including the credit risk, interest rate risk and liquidity risk.

3.1 The Change of Residents' Capacity to Repay the Loans Influences the Credit Risk Exposures

The credit risk is one of the important risks that the consumer credit suffers. It refers to the risk that borrowers default to perform the loan contract, unable to repay or refuse to repay their debts. When financial institutions do the credit investigation, they all need to make judgment on the borrowers' property, reimbursement will and credit status, among which the capacity to repay the loans is the most important factor. And the residents' disposable income is the most basic income source, however the change of daily consumer spending will weaken the repayment ability.

3.1.1 The Influence of the Growth Rate of GDP and Fiscal Taxation on Residents' Disposable Income

The residents' disposable income refers to the households' actual cash income after paying personal income tax, mainly influenced by the national economic development situation and individual income tax level. Along with the rapid development of economy in our country, the income level of urban and rural residents have been vastly improved. See Table 3. Before the financial crisis of 2007, our country's national economy maintained double-digit growth rate. Although the rate declined during the crisis, now the 9% growth is still much amazing compared with other developed countries which is suffering the sluggish economy development. So, anyway the high-speed development of our national economy provides the basic guarantee for the raise of residents income level. Secondly, in the aspect of our country's fiscal and tax policy, during the period of 1994–2008, the proportion of the individual income tax in GDP rose from 0.15 to 1.24%, and the proportion in the whole tax rose from 1.4 to 6.4%. Individual income tax has become one of the tax categories that in high-speed growth after the reform of the tax system in 1994 and now is the first four among the whole fiscal tax. In some areas, it has leapt to the

Table 3 The situation of our economy development and urban and rural residents' per capita disposable income

Year / Item	2005	2006	2007	2008	2009
Per capita disposable income of urban households (yuan)	10,493	11,760	13,786	15,781	17,175
Per capita net income of rural households (yuan)	3,255	3,587	4,140	4,761	5,153
Urban households' per capita disposable income growth (%)	9.6	10.4	12.2	8.4	9.8
Rural households' per capita net income growth (%)	6.2	7.4	9.5	8.0	8.5
The growth of GDP (%)	10.4	11.6	11.9	9.6	8.7
The growth of individual income tax (%)	20.6	17.1	29.9	16.8	6.0

Resource: The statistics yearbooks of CNBS second place of tax revenues, being the main source of local fiscal revenue. From the Table, we can see that the growth rate of individual income tax always main the 15% level expects the year 2009, only 6%. This is one of the reasons that our residents' disposable income can't increase at a faster speed. Just as the table shows, the growth rate of per capita disposable income of urban households is always below the growth rate of GDP, excludes the year 2007 and 2009. Furthermore, both the absolute value and growth rate of per capita net income of rural households are smaller than the urban households, and always lower than GDP growth. In a word, the rapid growth of individual income tax weakens the simulative effect on the improvement of consumers' repayment capability from the rapid economic growth.

3.1.2 The Influence on the Income Source from Daily Consumption Expenditure

The change in the cost of living is one of the important factors affecting borrowers' reimbursement ability, especially to the consumers with low income level. The Engel coefficient of this group is relatively high, that is to say, the basic cost of living in the proportion of disposable income is high, so the CPI volatility will have a larger impact on its compliance capabilities. Figure 3 shows the change of CPI during the year 2000 to 2009 in our country. The CPI in 2007 and 2008 is very high and the food price index has been higher than CPI throughout the period especially in 2007 and 2008 when the index is as high as 112.3 and 114.3. In a word, the high-speed growth of the necessities' price inevitably leads to the rising cost of living, which will bring about the potential consumer credit risk.

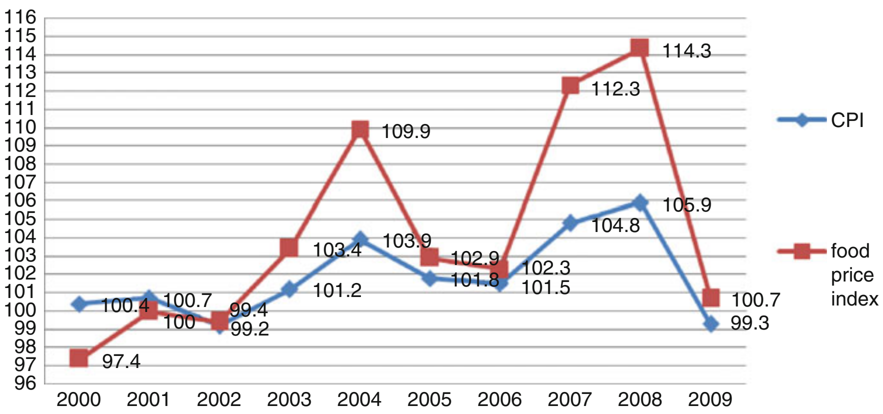


Fig. 3 The change of CPI in our country. Resource: The statistics yearbooks of CNBS

3.2 The Change of Assets-Liabilities Structure Cause the Liquidity Risk

Liquidity risk refers to the risk that financial institutions have no capacity to finance for the loss or bankruptcy coming from the decrease of debts or the increase of assets. The change of domestic monetary policy will influence the liquidity of financial institutions and finally lead to the liquidity risk. When the loose monetary policy is taken, the money of financial institutions is very abundant, and the customers' loan demand can be easily satisfied, so the liquidity risk is relatively small. Conversely, when implementing the tight monetary policy, the capital can't meet the customers' demand and the financial institutions will face the pay crisis. After going through the financial crisis and the implementation of the "Four Trillion" economic stimulus plan, our country is maintaining a relatively abundant supply of currency level to support the steady development of economy and the long-term consumption loans increases sharply. On the other hand, considering the situation that the real interest rate is negative and the nominal rate is somehow too low, the banks' financial products appear the phenomenon of lack in attraction compared with other investment products such as stocks and gold investment and the banks are now under a lot of pressure in absorbing the savings. So the consumer credit liquidity risk of financial institutions can't be neglected.

3.3 The Rise of Interest Rate Intensifies the Interest Rate Risk

The interest risk refers to the possibility commercial banks may suffer when the change of interest makes the deviation between the actual benefits or loss and expected ones, and leads to the actual income lower than expected or actual costs higher than anticipated. At present, the consumer credit term structure is as the Table 4 shows, from which we can see that the long-term consumer credit proportion is very high. However in the deposit term structure, the current deposit proportion also maintained about 40%, which leads to the whole interest rate structure with the characteristic of "short-term deposits and long-term credits". Considering the rate sensitivity of the medium-term and long-term loans is low and that of the short-term deposits is high, the match of assets and liabilities with the feature of "negative gap" will leads to the large

Table 4 The interest rate structure of financial institutions in our country

Year / Items	2007	2008	2009	2010.8
Medium-term and long-term consumer credit/the whole consumer credit (%)	90.5	88.9	88.5	87.8
(Residents' current deposits+ enterprises' current deposits)/total deposits (%)	40.9	37.7	39.3	40.7
Benchmark 1-year deposit rate during each year (%)	2.79/3.06/3.33/3.60/3.87	4.14/3.87/3.6/2.52/2.25	2.25	2.25/2.50

Resource: the People's Bank of China

interest rate risk exposure when the interest rate begins to rise. In fact, in order to solve the problem of excess liquidity and reduce the inflation expectations, the People's Bank of China raised the benchmark interest rates of financial institutions in October 10th, 2010. The benchmark 1-year deposit rate went up by 25 bps to 2.50% while 1-year lending rate reached 5.56%. Besides, the rates of which the maturity is more than 1 year were all be raised by 20 bps. It is still not certain whether the interest rate rising can curb the inflation and regulate the real estate market. However, as long as the economy maintains the steady development and the inflation pressure is still large, the formation of the rate rising channel will have a significant impact on the interest rate risk.

4 The Proposals on the Consumer Credit Risk Management

4.1 *Optimize the Finance-Taxation Policy and Improve the Reimbursement Ability*

The household income level directly decides consumption demand and consumer credit repayment ability, thereby affects its credit performance. The growth rate of residents income has been lower than the that of GDP for a long time and the income distribution favors government. However as to the main force of consumption, the group of wage earners undertakes 50% of the total amount of individual income tax. The unreasonable tax structure greatly affects our social consumption demand and the consumer credit repayment ability. So our country's fiscal policy should make some proper adjustment according to the actual situation such as reduce the tax burden of middle income consumers, strengthen the taxation on the high income group; upgrade the level of tax administration, favor the low income group through the quadratic assignment by government. So that we can under the premise of maintaining the fiscal taxation stable, narrow the gap between the rich and poor, on the other hand, enhance our consumption level and reduce the credit risk caused by the decline of repayment ability.

Besides, in the aspect of residents' daily expenditure, housing, children education, medical care has become the most important part in the households' burden. Given the price rises rapidly at present and the social security system isn't perfect, the uncertainty of the residents' expected expenditure leads to the credit risk of consumer loan. So there is need to establish a wide cover social security system containing the whole social labor members, and improve operation efficiency of the capital financed to solve the shortage of funds; promote basic medical insurance system for urban employees and the medical health system reform to further improve the unemployment insurance system. Moreover, on October 28th, the "Social Insurance law" was passed and established the social insurance system covering both urban and rural residents in the form of law. However, since there are some defects such as too much authorization and difficult to operate, it needs to be improved and perfected constantly in the implementation process.

4.2 Perfect the Credit Product Portfolio and Improve the Term Structure

In view of the fact that the consumer credit products are not sufficient, that the proportion of long-term housing mortgage loan is too high has been the main reason leads to the consumer credit risk. The financial institutions offering the consumer credit service should vigorously develop diversified consumer credit products aiming at different levels of customer base to meet their diverse needs and at the same time achieve the purpose of improving the product structure and the rate term structure of consumer credit market. Now the ongoing consumer finance company pilot which is on this aspect grounds is conducted by referring to foreign mature operation mode. The business scope of the three consumer finance companies is: provide the personal consumer loan to borrowers for purchasing agreed durable goods through dealers and personal consumption loans for general purpose. The former excludes the housing mortgage loan and auto loan. The latter mainly for education, wedding decoration, tourism, etc. consumption items. It is a good supplement to our country's consumer credit market structure which mainly includes the housing loan and auto loan.

In the process of perfecting the credit market structure, firstly, the financial institutions should strengthen the market research and customer segments, only through the clear position of the target groups can develop the products pertinently. At present, the new founded consumer finance companies have launched some novel credit products, for example, BeiYin consumer finance company launches the "emergency loan" which is designed to satisfy the self-employed individuals' need and provides credit to the university graduates who have already obtained the appointments from employing units to meet their needs of purchasing the electronic products, clothing and household goods. All these products will help to satisfy more requirements of customers and promote the enlargement of the consumer credit market scale, on the other hand, will improve the current credit category structure.

Secondly, the financial institutions should pay more attention to the development of the credit products with the characteristic of flexible term and interest rate, because the design of the term and interest rate will directly affect the interest rate risk of the whole consumer credit market. Take the consumption financing product that ZhongYin consumer finance company launches in the form of current loan. The term of the product has a wide range, among which the shortest one is only 2 days, however the longest can be 5 to 6 years. Besides, there is a great innovation in the interest rate design. A floating rate mechanism which is according to the customers' credit status is established and the interest rate will be adjusted every 3 months. The similar products is still relatively scarce, hence it is necessary to do some reasonable design on the term and interest rate.

4.3 Pay Attention to the Term Mismatch of Assets and Liabilities and Beware of the Liquidity Risk

As to the financial institutions, the mismatch of the long-term loans and short-term deposits is the main reason of causing the liquidity risk. Since the financial crisis, our credit amount expands rapidly in a period, especially along with the financial assets price rising sharply, the increase of the consumer credit such as the housing mortgage and auto loans will lead to the potential liquidity risk. However, owing to the fact that the regulation on the real estate market is still tight and other consumer credit demand is not strong, liquidity flood will make the financial institutions face the risk of promptly satisfying the capital demand without affecting the daily operation and financial status. So the financial institutions like commercial banks should pay more attention to the systemic risk caused by the term mismatch of assets and liabilities and strengthen the comprehensive management of the assets and debts. On one hand, in the situation of the negative real interest rate, financial institutions should strengthen their own financial product development, continuously consolidate the customer base, increase the stability of the deposits and maintain the savings deposits absorption channel unblocked. On the other hand, the institutions should improve the cash ability of the loan, perfect the credit term structure, compress the non-performing loans, establish an effective constraint system, strengthen the scientific mortgage loan mechanism and make the establishment of the security and compensation mechanism. In addition, each financial institution shall establish a sound liquidity risk warning mechanism, pay attention to the pressure test of the liquidity risk according to the supervisors' request and conduct the pressure test work at least quarterly in accordance with the complex degree of their own business. Then create monthly average loan statistics system according to which monitor the liquidity level and discard the assessment practices based on the data counted at the end of the month or the quarter.

5 Conclusion

With the in-depth development of consumer credit business, the uncertainty factors of macro economy will have an important impact on the credit risk, thus hinders the development of our consumer market. So this paper tries to analyze the inherent relation between the specific economic factors existed and the credit risk and thus puts forward some proposals such as optimize the finance-taxation policy and improve the reimbursement ability; perfect the credit product portfolio and improve the term structure; pay attention to the term mismatch of assets and liabilities and beware of the liquidity risk, hope to provide certain reference to our consumer credit development and risk management.

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Wealth Effects of the Creditor in Mergers: Evidence from Chinese Listed Companies

Zhihui Gu and Xiangchao Hao

Abstract We examine wealth effects of the creditor in mergers with data of Chinese listed companies. The previous method is highly dependent on the bond price so that it is not feasible in undeveloped markets like China. To overcome this problem, we develop a new method based on option pricing approach. Our findings show that creditors of the ST can obtain significant wealth effects in the merger, while creditors of the healthy obtain negative wealth effects. We argue the reasons can be ascribed to the agency conflictions and information asymmetry between the primary creditor and the new controlling shareholder.

Keywords Merger · Creditor · Wealth effects · Agency confliction · Information asymmetry

1 Introduction

In the past 10 years, there emerged, in China, a great many mergers and acquisitions, which played a critical role in the Asian financial market. Those merger and acquisition activities of China have attracted intensive attention and studies from many researchers both at home and abroad. They focused mainly on the wealth effects of shareholders, and found that share holders of target companies didn't obtain significant wealth effects in a short term (Hong and Shen 2001), what is more, in the long run, the wealth effect would whither (Feng and Wu 2001). These researches show that mergers have significant effects on the wealth of shareholders, how do they affect other stakeholders like the creditor? In other word, our question is can those creditors of the target company obtain wealth effects? If so, can they obtain the same effects with the shareholders? If not, why?

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Some literatures explore these questions with merger cases in USA. The creditors they choose are the bondholders of target or acquiring company. Empirical results indicated that the evidence of wealth effects of creditors of acquiring companies[1] and target companies[2] is mixed. Billett et al (2004) argue that there are three factors affected the finding of researches with insignificant wealth effects for the creditor. Firstly, the size of sample is very small due to the difficulty of obtaining bond price data. Secondly, even those data that is available is still not qualified because most bonds do not have published transaction prices, and many of them reported are matrix prices which is reported when a bond does not trade and dealer quotes are unavailable. And the last, most of mergers took place during the period of 1960s to 1970s, in which there are actually no excess returns. Billett et al (2004) construct a data from 1979 to 1997, and group bonds into investment grade and below investment grade. They report a significant excess return in the mass, but point out that it is highly dependent on the grade of the target's bond.

This aim of our paper is to investigate whether there are wealth effects of the creditor in mergers of Chinese listed companies. At the beginning of our research, we try to collect data of mergers according to the excess return method which is used in those researches, but find that it is not feasible. We find that the excess return method require data of merger to meet two basic conditions: acquiring companies or target companies should own issued and publicly traded bonds on one hand, and they should be capable of gaining an adequate and qualified bond price on the other hand. This is viable in those developed financial markets like USA, but not in China. As we know, up to the end of 2007, the total value of the Chinese bond market came to 500 billion CNY (over 70 billion dollar), accounting for only 2% or a little bit more of the GDP. Furthermore, the limited and publicly exchanged bonds on the market now are issued mainly by those large state-owned enterprise not listed. Therefore, we can't get bond price information about mergers or acquisitions, and consequently there is no way for us to measure wealth effects of the creditors.

We argue that the way to overcome those problems is to redefine wealth effects of the creditor and develop a new measurement method. Our definition of wealth effects is based on the change of the value of bond before and after mergers. We hypothesize that, it is difficult for the acquiring company to materially restructure the target company and the assets of the target company would not change anyway in a relative short time, so that the change of the value of bond before and after the

[1]For the bondholder of acquiring firms, Eger et al. (Eger 1983) report significant positive excess returns, but Kim and McConnell (1977), Asquith and Kim (1982) find it insignificant, while Dennis and McConnell (1986), Asquith and Wizman (1990) reports negative excess returns.

[2]For the bondholder of target firms, Marais et al. (1989) find excess returns are tiny. But Warga and Welch(1993) reports significant negative excess returns, and positive relationship between the rank of bonds and their muture time. Cook and Martin (1991) find it is the same with managerial buyout mergers.

merger should be ascribed to the influence of the merger itself. According to this logic, if the value of bond has increased after the merger, then there are surely wealth effects; if not, there aren't. Thus, our definition can be applied to both the credit and the equity.

When evaluating the value of bond, we adopt the option pricing model. By adopting such a model, we can easily break down the constraints upon bond price in the previous empirical research, and what we need is no more than share price. The deduction of the value of bond, to a large extent, followed the price formula of Leland (1994), however, we softened the pricing conditions of the indivisibility, insufficient liquidity and the impossibility of fictitious transaction of credit. Finally, we deduce the option pricing formulas of debt, equity and the total value of companies respectively. In these formulas we find that the former two and the last one are in a inverse relation.

As required by our option pricing measure method, we collect data of mergers of Chinese listed companies during the period 1997 to 2007 and construct a sample of 251 mergers which contains 212 mergers of healthy target and 39 of ST. We are surprised to obtain similar findings with Billett et al (2004) which employ the bond price method and divide the bond risk grade of target into investment grade and below investment grade. The creditor of ST companies experiences an increase of credit value and obtains significant wealth effects in the merger activity, while the creditor of healthy companies experiences a decrease of credit value and obtains significant negative wealth effects. Furthermore we discuss the reasons for the decrease of credit value and ascribe them to the agency conflictions and information asymmetry between the creditor and the new controlling shareholder.

The remainder of the paper is organized as follows: Sect. 2 is about option valuation modeling, and deduces the valuation formulas of equity, credit and total corporate value. Section 3 designs an empirical model and constructs a sample. Section 4 is empirical analysis and discussions. Section 5 is our conclusion.

2 Methodology and Valuation model

2.1 Basic Logic of Valuation Model

Following Leland (1994), we assume that the value V of asset follows a diffusion process with constant volatility σ_a of rate of return:

$$dV = \mu(V,t)Vdt + \sigma_a VdW \tag{1}$$

where W is a standard weiner process, $\mu(V,t)$ is the expected return of asset. Following Kamien and Schwartz (1981) about the analysis on dynamic stochastic model optimization, the value $F(V,t)$ of a claim that pays a nonnegative outflow C is the solution of the stochastic control problem following:

$$F(V,t) = \max E\int_{t_0}^{T} e^{-rt} f(V,t)dt \tag{2}$$

s. t. $dV = \mu(V,t)Vdt + \sigma_a VdW$ and $V(t_0) = V_0$
where r is the discount rate. Following Leland (1994), when securities have no explicit time dependence, the term $F(V,t) = 0$, and according the Bellman equation, such asset's value must satisfy the partial differential equation:

$$\frac{1}{2}\sigma^2 V^2 F_{VV}(V) + \mu(V,t)VF_V(V) + f(V,t) = rF(V) \tag{3}$$

We can obtain the analytical solution of $F(V,t)$ by solving the stochastic partial differential equation. We assume that the investor is risk neutral, and short sale and long purchase are allowed in the market, if $r = \mu(V,t) = r_f$, we can acquire the solution of a claim according to (2) and (3), which is like that of Black-Scholes-Merton. Assuming the decision model of investor is as follows:

$$F(V,t) = \max E\int_{t_0}^{T} e^{-rt} C dt \tag{4}$$

s. t. $dV = \mu(V,t)Vdt + \sigma_a VdW$ and $V(t_0) = V_0$

And when the discount rate and the return of asset of investor are all equal to free risk rate, which means $r = \mu(V,t) = r_f$, so we have:

$$\frac{1}{2}\sigma^2 V^2 F_{VV}(V) + r_f V F_V(V) + C = r_f F(V) \tag{5}$$

According the way of solving equations by Black and Cox, the solution is

$$F(V) = K_0 + K_1 V + K_2 V^{-\beta_f} \quad \beta_f = \frac{2r_f}{\sigma_a^2} \tag{6}$$

However, it is not satisfied for the assumption $r = \mu(V,t) = r_f$ if short sale and long purchase are not allowed. Barron and Jensen who suggest a method to solve equation above under the assumption of risk neutral, made $r = \mu(V)$, and obtained the solution like (6). Given capital structure, the weighted cost of capital r_a equals the expected return of asset, that is $\mu(V) = r_a$. So the (6) can be rewritten as follows:

$$F(V) = K_0 + K_1 V + K_2 V^{-\beta} \quad \beta = \frac{2r_a}{\sigma_a^2} \tag{7}$$

2.2 Valuation of Debt, Equity and the Firm

In generally the claim for the debt is prior to the equity, so the latter is actually a residual claim. Therefore, we should valuate the debt first, and acquire the valuation of equity by subtracting the former. Following Leland (1994), the valuation of claim that pays a nonnegative outflow C is

$$D(V) = K_0 + K_1 V + K_2 V^{-\beta} \quad \beta = \frac{2r_a}{\sigma_a^2} \tag{8}$$

Let V_B denotes the level of asset value at which bankruptcy is declared, and a fraction $0 \le \alpha \le 1$ of value will be lost. Under the boundary conditions of bankruptcy and health, we can obtain the solutions of K_0, K_1 and K_2, so $D(V)$ is

$$D(V) = \frac{C}{r_b} + \left[(1-\alpha)V_B - \frac{C}{r_b}\right]\left[\frac{V}{V_B}\right]^{-\beta} \tag{9}$$

Where r_b is the capital cost or the expected return of creditor. By the same way we can valuate bankruptcy cost $BC(V)$ and tax benefit $TB(V)$:

$$BC(V) = \alpha V_B \left[\frac{V}{V_B}\right]^{-\beta} \tag{10}$$

$$TB(V) = \frac{\tau C}{r_b} - \left[\frac{\tau C}{r_b}\right]\left[\frac{V}{V_B}\right]^{-\beta} \tag{11}$$

where τ is tax rate. So the valuation of a firm can be described as follows:

$$v(V) = V + TB(V) - BC(V) = V + \frac{\tau C}{r_b}\left[1 - \left(\frac{V}{V_B}\right)^{-\beta}\right] - \alpha V_B \left(\frac{V}{V_B}\right)^{-\beta} \tag{12}$$

And the equity valuation is

$$E(V) = v(V) - D(V) = V - \frac{(1-\tau)C}{r_b} + \left[\frac{(1-\tau)C}{r_b} - V_B\right]\left[\frac{V}{V_B}\right]^{-\beta} \tag{13}$$

2.3 Definition of Wealth Effects of the Creditor

Assuming that the announcement time issued is time 0. Considering the two close period before and after the announcement, which respectively are [−T, 0] and

[0, T]. Assuming the range of T is so small that the assets and capital structure of the target company do not change remarkably, and the major change is the potential controlling shareholder. We define D^{pre} as the value of bond before merging and D^{post} as the value of bond after merging, then we can define the wealth effects of creditors:

$$W = D^{post} - D^{pre} \tag{14}$$

Based on the definition in (14), two more deductions can be perceived:

1. If $D^{post} > D^{pre}$, $W > 0$, then the creditor can obtain wealth effects and their benefits can be protected effectively.
2. If $D^{post} \leq D^{pre}$, $W \leq 0$, then wealth effects do not exist and the merging activities would lead a loss to the creditor.

From this point of view, we understand that the definition of wealth effects should be based on two important parameters: r_b and β. Differentiating D, v, and E with respect to r_b and β separately, we can get:

$$\begin{aligned}
\frac{\partial D}{\partial r_b} &= -\frac{C}{r_b^2}\left(1 - \left[\frac{V}{V_B}\right]^{-\beta}\right) \leq 0\\
\frac{\partial v}{\partial r_b} &= -\frac{\tau C}{r_b^2}\left(1 - \left[\frac{V}{V_B}\right]^{-\beta}\right) \leq 0\\
\frac{\partial E}{\partial r_b^2} &= \frac{\tau C}{r_b^2}\left(1 - \left[\frac{V}{V_B}\right]^{-\beta}\right) \geq 0
\end{aligned} \tag{15}$$

$$\begin{aligned}
\frac{\partial D}{\partial \beta} &= \left[\frac{C}{r_b} - (1-\alpha)V_B\right]\left[\frac{V}{V_B}\right]^{-\beta} \ln\left(\frac{V}{V_B}\right) \geq 0\\
\frac{\partial v}{\partial \beta} &= \left[\frac{\tau C}{r_b} + \alpha V_B\right]\left[\frac{V}{V_B}\right]^{-\beta} \ln\left(\frac{V}{V_B}\right) \geq 0\\
\frac{\partial E(V)}{\partial \beta} &= -\left[\frac{(1-\tau)C}{r_b} - V_B\right]\left[\frac{V}{V_B}\right]^{-\beta} \ln\left(\frac{V}{V_B}\right) \leq 0
\end{aligned} \tag{16}$$

here (15) and (16) indicate that parameter r_b and the total value of firm as well as the value of bond are in a negative correlation, but parameter β are in a positive correlation with them, which means if r_b decreases and β increases, then the merger activity reduces the value of equity, which means the shareholder of target company gains no wealth effects, but the value of bonds and the total value of the company increases, which means the creditor of target company obtain wealth effects. On the contrary, if r_b increases while β decreases, then the merger activity increase the value of equity, suggesting the target company would gain wealth effects, but the value of bonds and the total value of the company would decrease, which means that the creditor gains negative wealth effects and its magnitude is larger than that of the shareholder. Therefore, in a merger activity, the range of variation in the value of bonds is different from that of the value of equity. According to the option pricing model, parameter r_b and parameter β depend on the changes of share prices before and after the merger, therefore, empirical test of the above-mentioned deduction is feasible.

3 Empirical Study Design and Sample Selection

3.1 Empirical Study Design

To test the deduction mentioned above, this paper has gone further in designing and implementing empirical analysis. Since the most critical parameter in valuating wealth effects in this research is β, the focal point of this empirical model design is how to design a proxy measure for it. According to the basic principle that measures the company capital costs, we can get:

$$E(\tilde{r}_a) = (1 - L)(1 - \tau)r_b + Lr_e \tag{17}$$

$$\sigma_a^2 = L^2\sigma_e^2 \tag{18}$$

where L is the capital structure of company, denoting the proportion of equity capital, r_e is the equity financing costs. Solving L from (18) and substitute it into (17), we get:

$$r_e = -\frac{(1 - L)(1 - \tau)}{L} r_b + \frac{1}{2} L\beta\sigma_e^2 \tag{19}$$

Then let $\alpha_0 = -\frac{(1 - L)(1 - \tau)}{L} r_b$, $\alpha_1 = \frac{1}{2} L\beta$, here we get the final empirical model:

$$r_e = \alpha_0 + \alpha_1\sigma_e^2 + \varepsilon \tag{20}$$

where α_0 is negatively correlated with r_b, and $\frac{\partial r_b}{\partial \alpha_0} < 0$; $\alpha_1$is positively correlated with β because of $\frac{\partial \beta}{\partial \alpha_1} > 0$. We use α_1^{post} and α_1^{pre} to denote the parameter estimations before the merger announcement, α_0^{post} and α_1^{post} to denote the parameter estimations after the merger announcement, and r_b^{pre}, r_b^{post}, β^{pre}, β^{post} to denote r_b and β before and after the merger respectively. In the time range of [−T, T], where the value of T is so small that the assets and capital structure would not change remarkably within the range, then we can get three following testable hypotheses:

1. If $\alpha_0^{pre} < \alpha_0^{post}$ and $\alpha_1^{post} < \alpha_1^{pre}$, then $r_b^{post} > r_b^{pre}$, $\beta^{post} < \beta^{pre}$, $D^{post} < D^{pre}$, $E^{post} > E^{pre}$, which means the creditors can not obtain wealth effects in merging, but the shareholders can get tremendous wealth effects.

2. If $\alpha_0^{pre} > \alpha_0^{post}$ and $\alpha_1^{post} > \alpha_1^{pre}$, then $r_b^{pre} < r_b^{post}$, $\beta^{post} < \beta^{pre}$, $D^{post} < D^{pre}$, $E^{post} > E^{pre}$, Which means the creditors can obtain wealth effects in the merger, but the shareholders can not.
3. If $\alpha_0^{pre} = \alpha_0^{post}$ and $\alpha_1^{post} = \alpha_1^{pre}$, then $r_b^{pre} = r_b^{post}$, $\beta^{post} = \beta^{pre}$, $D^{post} = D^{pre}$, so the value of bond and equity would change remarkably, both the creditors and shareholders can not obtain significant wealth effects.

3.2 Data Sources and Sample Selection

Data of mergers are draw from tow sub-data of *China Center for Economic Research* (CCER). The first sub-data is the equity transfer agreement data of listed companies which supplies time of announcement, amount, industry distribution, state and other information of mergers. The second is the stock price return data of listed companies which supplies the daily return data of target companies.

From the equity transfer agreement data of listed companies of CCER, we got 471 cases which succeed in finishing equity trade. However, we found that equity transfer of some mergers is done by the way of administrative allocation.[3] The merger and acquisition we consider are assumed to be some kinds of marketing behaviors, so we rule those companies out of the samples. In addition, some equity transfers lack such information as the price and method, and we rule them out of the samples as well. Finally, for those companies that had been involved in equity transfer for more than one time in the sample, we only retain their first transfer in our paper. According to the above selection standards, we select 251 case mergers eventually, among which 212 ones' target companies are healthy, indicating their operation and financial state are normal, 39 ones' target companies are ST,[4] indicating their operation and financial state are too bad to be taken special treatment by *China Security Stock Exchange*.

Table 1 reports the industry[5] distribution of all, healthy and ST companies. We find that Consumer Discretionary and Industrials industry have the most mergers and energy industry the least instead. We have to point out that most of the mergers

[3]This is special for some Chinese stated-owned (SO) listed companies in the privation process. For these companies equity are transferred from on SO company to another SO one by central or local government or the parent company owned by them. So the trade has no compensation and we couldn't get its price or valuate it appropriately. It is a kind of non market behavior and violate the assumptions of our model.

[4]When the finance of those companies get too worse, the securities exchange of Shanghai or Shenzhen can impose limits on their stock exchange. These are so call special treatment companies.

[5]The industry classification is based on the global industry classification system which is more suitable for investors.

Table 1 The industry distribution for the all sample, healthy sub sample and ST sub sample

Industry	Full sample		Healthy		ST	
	Obs	Percent	Obs	Percent	Obs	Percent
Energy	1	0.40	1	0.47	0	0
Materials	39	15.54	32	15.09	7	17.95
Industrials	44	17.53	38	17.92	6	15.38
Consumer Discretionary	54	21.51	42	19.81	12	30.77
Consumer Staples	21	8.37	18	8.49	3	7.69
Health Care	26	10.36	24	11.32	2	5.13
Financials and Real estates	24	9.56	18	8.49	6	15.38
IT	31	12.35	28	13.21	3	7.69
Utilities	11	4.02	11	5.19	0	0
Total	251	100	212	100	39	100

Overall sample includes 251 mergers during the period 1997 to 2007. The sample is divided into two sub samples according to the financial state when the merger occurs. Targets in mergers that financial state is good belong to the healthy sub sample, and those that are taken special treatment by the Securities Exchange of Shanghai or Shenzhen belong to the ST sub sample. The industry classification is based on the Global Industry Classification System which is more suitable for investment

Table 2 Merger exchange amounts in million CNY

Financial State	Obs	Mean	STD	Min	Max
Overall	251	142.89	239.05	1.00	3150.00
Healthy sub sample	212	156.41	256.18	1.00	3150.00
ST sub sample	251	142.89	239.05	1.00	3150.00

Most of them are calculated out by exchange price plus the volume; few are directly obtained the exchange amounts. Some special mergers contain more than contracts in one exchange, so the amounts is the total for them

Table 3 Share ratio of the largest shareholder after the merger finished successfully

Financial state	Obs	Mean	STD	Min	Max
Overall	251	30.78	12.11	5.95	70.00
Healthy sub sample	212	30.28	12.11	5.95	69.06
ST sub sample	39	33.51	11.89	13.58	70.00

The share ratio is denoted by percentage

in financials and real estate industry belong to the later, because there is few financial listed companies during the sample period in China's stock market.

Table 2 reports the average total value of mergers and Table 3 reports the share proportions of the largest shareholder after the merger. These results indicate that the transaction amount of those healthy target companies is larger than that of the ST target companies, yet the former ones possess a smaller proportion of shares than the latter ones on the contrary. We argue that it is the good financial state that makes the share exchange of the healthy in a high price, and the poor performance of the ST that makes the share exchange in low price.

4 Empirical Analysis

4.1 Descriptive Statistics of Samples

In this paper, time 0 is assumed to be the merger announcement day, and as the stock equity transfer would have been finished within 60 days or 2 months after the merger announcement. Therefore, we set up a continuous 40-day (including the announcement day) as the sample, then the time range T = 39 and the two sub periods are [−39, 0] and [0, 39] respectively.

Table 4 reports the statistics of average values of daily return and volatility in each period. We find that the average 40-day daily return before the merger is significantly higher than that after the merger, and the average 40-day daily return of the healthy is also higher than that of the ST. But the average 40-day volatility of return before and after the merger varies insignificantly, and it is the same even for sub samples of the healthy and the ST. Table 5 provides the results of testing the average stock return r_e and its volatility of return σ_e^2, which further support the conclusion drawn above. The t test result for r_e is 4.68, which is significant in the level 0.01, and that of σ_e^2 is only 1.05, which is not significant in the level 0.01 and 0.05. The t tests indicate that the return is variable while the volatility is stable, which prove the assumption of model with constant volatility is reasonable for the merger fact. In fact, what has been changed in the merger is the asset expectancy of

Table 4 Daily return and volatility of target share equity for the pre-merger and post-merger

Variable	Overall sample		Healthy		ST	
	Obs	Mean	Obs	Mean	Obs	Mean
Pre-merger						
r_e^{pre}	251	0.22	212	0.22	39	0.19
σ_{epre}^2	251	7.55	212	7.64	39	7.05
Post-merger						
r_e^{post}	251	0.00	212	0.01	39	−0.02
σ_{epost}^2	251	7.18	212	7.29	39	6.58

The sample is divided into two sub samples: the healthy and the ST. Mean value is denoted by the percentage. r_e^{pre} and σ_{epre}^2 denote the daily return of pre-merger, r_e^{post} and σ_{epost}^2 denote the daily return of post-merger

Table 5 The t test of the daily return and volatility of target share equity for the pre-merger and post-merger

Assumption	t Statistics		
	Overall sample	Healthy	ST
$r_e^{pre} - r_e^{post} = 0$	4.68***	4.44***	1.57*
$\sigma_{epre}^2 - \sigma_{epost}^2 = 0$	1.05	0.09	0.87

r_e^{pre} and σ_{epre}^2 denote the daily return of pre-merger, r_e^{post} and σ_{epost}^2 denote the daily return of post-merger. ***, ** and * separately denote t test is significant at the level of 0.01, 0.05 and 0.10

different shareholders, but the nature of assets has not been changed and the volatility would not vary too much.

4.2 Regression Results and Explanation

Table 6 reports regression results of the daily stock earnings and their volatility. The second and third column of it provide regression results of overall sample companies. As a whole, the pre-merger coefficient α_0 is -0.12 and the post-merger is -0.22, all significant at least at the level of 0.05. This suggests a decline trend around the merger, i.e. $\alpha_0^{post} < \alpha_0^{pre}$. And according to $\alpha_0 = -\frac{(1-L)(1-\tau)}{L} r_b$, we can further infer $r_b^{post} > r_b^{pre}$. For α_1, we find all the coefficients are also significant at the level of 0.01, and the post-merger estimation is smaller than the pre-merger, that is, $\alpha_1^{post} < \alpha_1^{pre}$. Therefore, if the capital structure does not change in a short time, we can draw the conclusion that β^{post} is smaller than β^{pre}, suggesting parameter β decreases in the merger. According to the deductions draw from valuation model, the value of equity of those target companies would increase after the merger, suggesting the shareholders can obtain significant wealth effects.[6] Meanwhile, as the value of debt D is positively correlated with β, so the merger activity increases the equity value of shareholders of target companies but decreases the value of debt, suggesting the creditors of target companies obtain negative wealth effects. This is our first new finding.

The last four columns report the regression results when the sample are divide into two sub sample, the health and the ST, by the financial state of merger companies. The fourth and fifth column of Table 6 report the estimation results

Table 6 Estimation results of daily return and volatility for the pre-merger and post-merger

Coefficient	Overall sample		Healthy		ST	
	Pre-merger	Post-merger	Pre-merger	Post-merger	Pre-merger	Post-merger
α_0	−0.12	−0.22	−0.12	−0.19	−0.69	−0.66
	(−2.38**)	(−4.51***)	(−2.42**)	(−3.57***)	(1.09)	(−4.67***)
α_1	0.04	0.03	0.05	0.03	0.03	0.10
	(8.37***)	(5.60***)	(8.49***)	(4.60***)	(2.55**)	(5.06***)
Obs	251	251	212	212	39	39
Adjusted R^2	0.22	0.09	0.26	0.08	0.15	0.40
F test	70.13***	31.38***	72.15***	21.16***	6.48**	25.55***

α_0 denotes the constant of estimation and α_1 denotes the coefficient of volatility. We run the regression for overall sample and then for the two sub samples of healthy and ST. the value in the bracket is the t test of coefficient. ***, ** and * indicate t test is significant separately at the level of 0.01, 0.05 and 0.10

[6]This finding is consistent with Moran and Betton (2004) based on option premium. According to the abnormal returns, they found that premium existed in merger option.

for the healthy sub sample, which are very similar with that of the general results. The coefficients of two parameters are all significant statistically, and $\alpha_0^{post} < \alpha_0^{pre}$ and $\alpha_1^{post} < \alpha_1^{pre}$. Therefore, we can draw a similar conclusion that for mergers of healthy target companies, their shareholders obtain significant positive wealth effects, but their creditors suffer the loss of debt value decrease and so obtain negative wealth effects.

The last two columns provide the regression results of those ST sub sample. Different with overall sample and the healthy sub sample, we find that the pre-merger α_0 remains significant statistically while the post-merger not. The pre-merger α_1 is 0.027, significant at the level of 0.05, the post-merger one is 0.098, significant at the level of 0.01, suggesting the pre-merger is not larger but smaller than the post-merger, i.e. $\alpha_1^{post} > \alpha_1^{pre}$. Therefore we can infer that the pre-merger β is also smaller that the post-merger β. According to our models, the increase of β means the decrease of equity value but increase of debt value. Therefore we can conclude that the merger cannot bring wealth effects to the shareholder but to the creditor in the case of the ST sub sample.

Therefore, the empirical results above have provided convincing supportive evidences for the model of this paper, and echo to the research of Billett et al (2004) at a distance. They find bondholders of the target companies obtain significant wealth effects during the announcement which are highly dependent on the risk of the bond. In particular, the bondholder of investment grade target bond experiences a mean excess return of −0.80% while those of below investment grade experiences a mean excess return of 4.30%. In their paper they divide the bonds into investment grade and below investment, while in this research, we divide the sample companies into healthy companies and ST companies according to their financial statement. As the performance of healthy companies is much better than that of ST companies, so if being rated, the grades are naturally higher. The ST companies are always performing poorly and many of them are on the edge of bankruptcy, so in general their rating grades are lower. In this sense, the way of dividing the sample companies here is similar to that of Billett et al (2004), that is to say, the healthy companies in our research can be seen as the investment grade companies, and the ST companies can be seen as below investment grade companies. Clearly, the two researches adopted totally different methods and logics, but we achieved strikingly similar results.

However, Billett et al (2004) just revealed the reasons for the existence of wealth effects in below investment grade bonds, and they attributed that to the coinsurance effects. Their conclusion can also be applied to the ST companies in our research, because restructuring poor-performance companies is always regarded as a redemption measure. Therefore, such merger activities are usually beneficial for creditors of target companies, but the shareholders are possible to suffer potential loss if the redemption can't work well. Nevertheless, when mergers involve healthy target companies, how to explain the value of bonds decline for creditors? We are going to have an exploring discussion into this question in the following section.

4.3 Discussions on Wealth Effects of Creditors and Merger Risks for the Healthy

Merger is one of the most important activities in the modern financial market, and plays an active role in flourish the market, promoting market liquidity, diversifying products of financial market, and expanding financing channels. Yet according to previous studies, merger is also a kind of high-risk financial activity, investors would benefit from it on one hand and would get a loss on the other hand. Similarly, creditors may be at risks in mergers as well. In fact, Smith and Warner had ever pointed out that, LBO increase the leverage, the value of public traded bonds will suffer damage without the protect of senior covenants. But Franks and Torous (1989) found that even if there are senior covenants, the bond right will not be supported and protected by the court. The bond will be damaged unless the return of LBO could earn a return that exceeds the potential bankruptcy cost. Therefore, mergers would bring favorable expectancy to market on one hand, but would also bring uncertain merger risks to creditors on the other hand.

The uncertainty risks of wealth effects of creditors can be summarized as two aspects. One is the agent conflictions between the primary creditor and the new controlling shareholder. Reneboog and Szilagyi (2004) propose that this kind of conflict includes assets portfolio restructuring and financial restructuring. Asset portfolio restructuring refers to the activities of spin-offs and asset sell-offs which will reduce the bondholder or creditor wealth by expropriating collateral and increasing cash flow volatility. Financial restructuring refers to leverage finance in the case of cash flow shortfalls which will exaggerate the debt loan and threaten the safety of firm's finance and the credit. They argue that the credit value is not only dependent on the post-restructuring performance, but also on the capital structure and cash flow volatility which have a direct impact on the default risk. These are ex post factors in nature. As a matter of fact, successful mergers are not very common, but unsuccessful cases are too numerous to mention one by one. In this respect, many studies in China have provided supportive evidence for our research. Tang and He (2005) examined the post-merger performance and found that merger activities didn't improve the performance of acquiring and target firms. Lei and Chen (2006) found that the long-run excess returns in restructuring equity transfer were negative and showed a yearly downward trend. As being seen, in China, those listed companies have not generally improved their performance after the merger, so creditors' rights can't be guaranteed well in mergers.

The second risk lies in the information asymmetry between the old creditors and the new controlling shareholders after the merger, specifically speaking, the creditors can't get adequate information about the new controlling shareholders (For instance, the ownership structure, industry experience and control motivation of new controlling shareholders) and they can hardly evaluate the integration results of the target companies by those new shareholders. For the healthy companies, the transference of controlling right implies that although the debt contract is still on the process, but debt paying ability will be determined by the new controlling shareholder. Generally speaking, the creditors usually know less about the new shareholders. So the creditors have to recollect information of them to reduce the uncertainty of future business. Thus, their costs would increase and that the influences of the information asymmetry can hardly to be eliminated. The most important supportive evidences come from researches on the ownership and control right. La Porta and Claesens investigate the ownership of companies in East Asia. They find that a big part of companies in this area are family controlled. The control power is always enhanced through pyramid and cross-hold structure. Therefore, the ownership structure becomes more and more complicated so that the real owner and its motive can be hidden and very hard to distinguish out. With the separation of ownership and control caused by the complex ownership structure the ultimate controller has the chance and motivation to expropriate the interest of small shareholders. Li et al. (2004) and Lai (2007) have found analogous evidence for the Chinese listed companies. Therefore, the creditors know finitely about the new controlling shareholders and how they manage the target company in mergers involving control right transfer, and hence will be very passive. We argue that this kind of merger would bring new uncertainty risks to creditors, which would consequently make the debt devalue.

5 Conclusions

This paper investigates wealth effects of the creditor in mergers with the data of Chinese listed companies. As we can't get enough qualified bond prices, it is impossible for us to use the measure method of wealth effect suggested by previous studies. To overcome this problem, we redefine the wealth effects. We argue that the wealth effects of creditors can be measured by the change of the bond's value, that is to say, the value increment after the merger means positive wealth effects to the creditors, otherwise not. Therefore, in order to figure out the value of bond, we introduce the option pricing model, followed the option pricing equation of Leland (1994), and eventually deduce the valuation formulas of credit (debt), equity and the total value of companies. Moreover, we provided some hypotheses of the wealth effects for testing. Then we designed an empirical model according to those valuation formulas, and test the hypotheses with the public data of Chinese listed companies Our findings show that creditors of ST companies could obtain significant wealth effects in mergers, but for those of the healthy companies, the credit value suffer a decrease. We argue that the merger activity bring good expect to the market and new uncertainty risks as well. Such uncertainty risks could be summarized as follows: one is the worry about performance improvement of target companies' performance impacted by conflictions between the old creditor and new controlling shareholder; and the other is the potential uncertainty caused by the information asymmetry between them.

Our findings are of great importance for such creditors as banks in managing their credit business. Mergers of target companies which are in financial distress would always draw intensive attention and input from banks, for banks are facing certain and clear risks in such cases. The problem is that people are always neglecting those potential or hidden risks. Our research suggests that banks should pay much attention to those healthy target companies as well. Two measures are suggested to creditors like banks:

Firstly, participating actively, making tremendous efforts to eliminate the asymmetry of information, reducing threats from ethical risks. If banks have perceived that the shareholders is likely to transfer the target companies' assets to high-risk businesses, then it is necessary for those banks to pay close attention to the operating information of the companies and to readjust their credit policies to the target companies. When needed, banks shall require the debtors to re-guarantee or sign new complementary contracts for their debts, taking precaution measures.

And secondly, reevaluating and rating the target company according to the new shareholders and other relative information right after the merger, and optimizing the post-loan management process. The loan issue decision of banks is based on such information as credit rating, assets situation and project status of target companies. If the controlling shareholder varies, the preconditions for issuing loans vary as well. Therefore, when managing the granted loans, it is necessary for banks to reevaluate them, and naturally a new credit rating is indispensable for those new controlling shareholders and the target companies after the merger.

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Part III
Risk Management in Enterprises

Research on the Economy Fluctuations with Energy Consumption of China Based on H-PFiltration

Hua Wei, Haiyan Tang, Shan Wu, and Yaqun He

Abstract The relationship between the energy consumption (EC) and the economy growth of China during the period of 1981 to 2008 was studied with the application of co-integration approaches base on H-P filtration. The results show that a stationary positive relationship between the total energy consumption and gross domestic product (GDP) exists, and the main reason of the rising energy consumption is the continuous growing of GDP.

The characteristic of common trends and volatilities between the energy consumption and the economy growth was obtained after H-P filtration. From the view of trend components, a long-term equilibrium relation between the two sides was clearly proved, which explains that the growth of China's energy consumption is inevitable in a considerable period. However, it was found that in a long-term, the growth of GDP doesn't necessarily depend on the large input of energy. The economy cycle will profoundly affect the energy cycle components, and the both sides will be linked more closely in the future. However, different energy consumption cycles have a little different influencing factors. For example, in the period of 1997 to 2004, with the rapid development of economy in China the energy consumption cycle had a greater volatility under the influence of both energy structure and industry structure. Therefore, the transitions of economy development model need to be accelerated and the measures of energy-saving and cost-reducing need to be developed.

Keywords Co-integration · Economy growth · Energy consumption · H-P filtration

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1 Introduction

China is one of the countries being with the lowest quantity of the per capita energy sources tenure, but the gross of the consumption of primary energy resources in China has taken more than 17.7% of the world total quantity. According to the energy utilizing efficiency and the economy output effect of the energy resources, the energy consumption turnover of industry department is the most significant, so, studying the causality between energy consumption and economy growth as well as the relation between energy consumption changing and economy growth was the very important realistic meanings for estimating the economy performance of China energy consumption and for constituting the effective short-term policies of the energy resources restructuring and energy industry development (Zhang and Li 2004).

As a representative, American economist Renshaw (1981) examined the influence of the relative prices of the world energy on the potential GDP, income distribution, capital formation and economic welfare with above research ideas and methods. Oppositely, the other economists considered that a causal relationship between the energy consumption and economic output existed, and the capital and labor were only the intermediate factors to maintain the required energy and material of production. As a result, the study was conducted based on this hypothesis. The economy growth of the 87 departments in America in recent 100 years was empirical analyzed by Cleveland et al. (1984). The result indicated that there was a very strong correlation between the energy consumption and GDP. Such research has gradually extended to the developing countries whose per capital income is not high, afterwards. For instance, Shyamal and Rabindra (2004) conducted the research of causality between the energy consumption and economic growth in India, which obtained the conclusion that there was the double-sided causality between them. Oh and Lee (2004a, b) conducted the research of causality between the energy consumption and GDP in Korea. In addition, many other scholars studied the causality between the energy consumption and its impacting factors with the method of econometrics. Ebohon and Masih (1996; Abul and Rumi 1996) carried out the analysis on the causality between the energy consumption and economy growth, income and energy price using the theory of econometrics. Ghali and El-Sakka (2004) established the VEC model with four variables of output, labor, capital and energy to reveal the relationship between the output growth and energy consumption in Canada. The results indicated that there was a long-term stationary relationship between the four variables, and possessed the double-sides causality between the output growth and the energy consumption. In the research of the relationship between China's energy consumption and its economy, Lin (2001) examined the relationship between the electricity consumption of China and GDP, electricity price, population growth, structural change and efficiency improvement from 1952 to 2001 with Johansen co-integration method. Yuan (2006) studied the relationship between the electricity consumption of China and economy growth from 1978 to 2003 with co-integration theory, and analyzed the cycle relationship between the electricity and GDP with the joint application of H-P filtration and co-integration theory. The co-integration analysis between the total energy consummation and GDP from the year of 1985 to 2006 was conducted by He Yaqun and Lao Guohong (2008), and they found that these two factors had bi-directional causal relationship.

The great progress has been obtained in the relationship research between the energy consumption and economy growth. However, the theoretical and empirical researches should be improved. The relationship between the energy consumption and GDP of China from 1981 to 2008 was investigated with co-integration theory in the paper. The internal relations and interactions between the cycle fluctuations of China's energy consumption and cycle fluctuations of macro economy were studied with the application of H-P filtration, so as to provide the theoretical basis for the coordinated development of China's energy and economy.

2 Co-integration Analyses Based on H-P Filtration

2.1 Co-integration and Unit Root Test

A long-term stability between two variables is reflected by a co-integration sequence of the variables. From an economics point of view, a stationary proportional relationship is established by the two variables which are co-integrated, even though the each variable possesses a long-term individual fluctuation. The method of co-integration was put forward by Engle and Granger in 1978. Two random and unstable series are co-integrated if a linear combination of them with d order single sequence is stationary. The same order single sequence is the necessary condition of the co-integration to the two series. If the two time series with d order single sequence are not stationary, the co-integration regression equations are provided by an ordinary least square (OLS) regression analysis of the two variables, and then, the co-integration of the two time series are assessed by ADF examination to the residual stability of the co-integration equations. The Granger test is used to research the extent of causality influence of the two variables.

For China's economy was in a closed environment before 1980, and there were a lot differences to the current economy running and operation. Therefore, the EC and GDP over the period from 1981 to 2008 taken from the China Statistical Yearbook in 2009 have been chosen for the co-integration and causality study. The base year is 1981, and the unit of the price of GDP is 100 million Yuan RMB, the unit of EC is 10,000 tons of standard coal. Figure 1 shows the variation of the EC and GDP in China in the period of 1981 to 2008 by regression and examination.

It was found from Fig. 1 that the EC is correlated with GDP, and a long term co-integrated relationship may exist. However, the consistent conclusions are not obtained by previous studies and the co-integration and causal relationship between the EC and the GDP are influenced by the sample selection and the sample interval selection. The phenomenon that the decline of the EC came along with the stable growth of the GDP in China from 1996 to 1999 has attracted many scholars' attentions. Therefore, H-P filtration is applied to this paper.

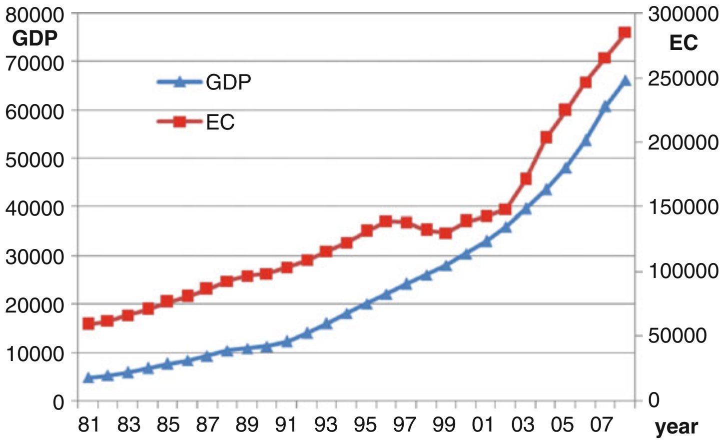

Fig. 1 The variation of the EC and the GDP in 1981–2008

2.2 The Basic Principles of H-P Filtration

H-P filtration is a time series of the decomposition method in the state space. It is equivalent to a linear filtration of the minimizing variance of volatility. It has the characteristics of unlimited samples, flexible application, without the sample loss, so, this method is widely used in academic researches. H-P filtration is used in the paper to decompose the trend components and cycle components of the energy consumption and economic growth. The basic principle is as follow.

Suppose that the economic time series is $Y = \{y_1, y_2, \ldots\ldots, y_n\}$, the trend factor is $T = \{t_1, t_2, \ldots\ldots, t_n\}$, and n is the length of the sample. In general, the trend named t_i of the unobservable components in the time series named y_i is often defined as the solution of the minimization problem, and the formula is as follow.

$$\min \sum_{i=1}^{n} \left\{ (y_i - t_i)^2 + \lambda [c(L)t_i]^2 \right\} \tag{1}$$

Where, the positive number named λ stands for the weight of the trend components and cycle components during the decomposition. $c(L)$ stands for the polynomial of the delay operator. The formula is as follow.

$$c(L) = \left(L^{-1} - 1\right) - (1 - L) \tag{2}$$

L stands for a lag operator. Make a substitution of formula (2) for formula (1), and then the problem of H-P filtration can be transformed into the minimization of the loss function, that is,

$$\min \left\{ \sum_{i=1}^{n} (y_i - t_i)^2 + \lambda \sum_{i=1}^{n} [(t_{i+1} - t_i) - (t_i - t_{i-1})]^2 \right\}$$

$[c(L)t_i]^2$ is used to adjust the trends in the minimization problem, and it increases with λ. However, a choice should be done between the similarity degree of the trend to the actual sequence and the smoothness of the trend. When $\lambda = 0$, the trend components of the minimization problem is equivalent to the series named y_i. With the increasing of λ, it is estimated that the variation of the trend relative to the actual sequence will decrease. The result is that the bigger the λ is, the smoother the trend will be. The trend will be close to a linear function when the λ becomes infinitely large. The rules of selection are as follow. When the annual data are used, the λ will be 100; when the quarterly figures are used, the λ will be 1,600; when the monthly data are used, the λ will be 14,400.

The H-P filtration is applied to decompose the trend components and the cyclical components from the series of energy consumption and real GDP. HPLGDP and HPLEC are the trend components of the EC and GDP, respectively; CLGDP and CLEC are the cyclical components of the EC and GDP. And the data of the original sequence are the sum of the trend components and the cyclical components. The results are shown in Figs. 2 and 3.

3 Discussion

As shown in Fig. 2, energy consumption curve becomes more smooth after H-P filtration, so the HPLGDP changes corresponding well with the HPLEC and they are pro-cyclical. Energy is one of the input element of the economy growth, therefore, the economy growth to the energy demand firstly or lastly can be identified as the growth of the energy demand, and the scale and pace of the economy growth will be limited by the energy shortage.

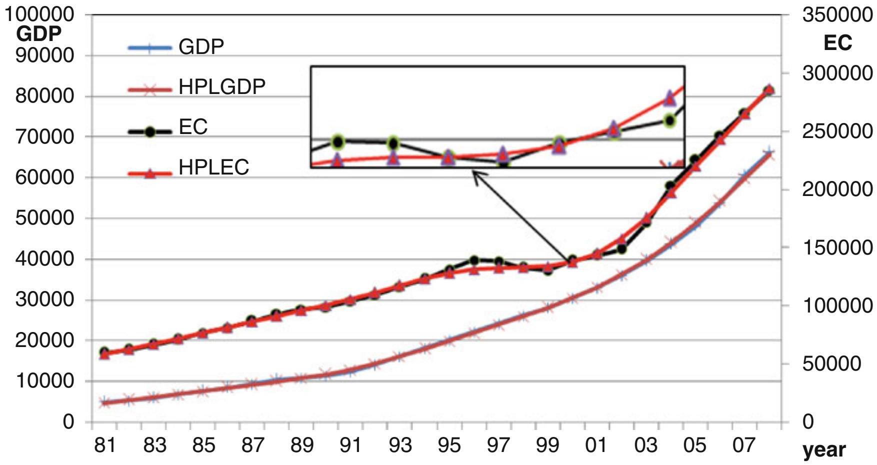

Fig. 2 The trend components of the EC and the GDP by H-P filtration

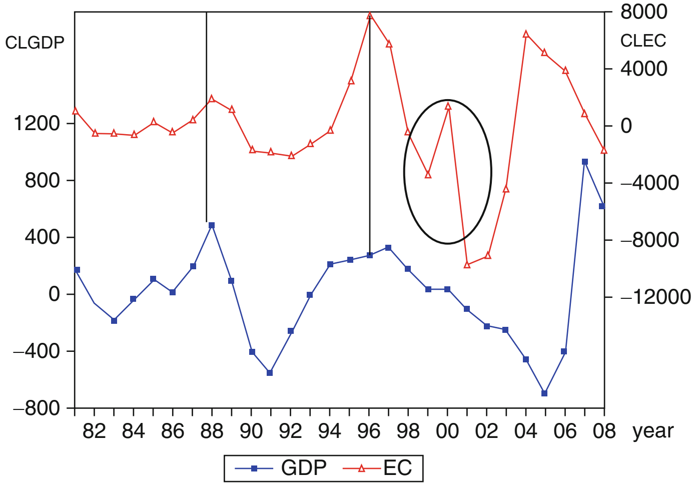

Fig. 3 The cyclical components of the EC and the GDP by H-P filtration

The cyclical components of the EC and GDP by H-P filtration almost have crest-crest and trough-trough relations such as shown in Fig. 3. So, using the crest-trough method this paper divides the cycles of the CLEC. It shows that the economic cycle has the greater influence on the energy consumption, and the amplitude of the fluctuations seems to be growing.

4 Empirical Study Based on H-P Filtration

4.1 The Analysis of Trend Fluctuations

It appears from the test results that the HPLGDP and the HPLEC are the second order integrated sequences. An OLS regression analysis for the years from 1981 to 2008 provided the co-integration regression equation for the HPLGDP and the HPLEC.

$$\mathrm{HPLGDP} = 0.2866^{*}\mathrm{HPLEC} - 14133.64366 + \varepsilon_t (R^2 = 0.9738\, F = 967.96) \quad (3)$$

Where, R^2 is the correlation coefficient, F is the value of F test, ε_t is the disturbance term of residual. The regression equation shows that a stationary positive relationship between the HPLEC and HPLGDP exists. The correlation coefficient proves that 97.38% variation of the HPLEC can be explained by the HPLGDP variation, and the main reason of the rising HPLEC is the continuous growing of the HPLGDP. The HPLEC increased 3.489 thousands tons of standard coal when the HPLGDP increased every 100 millions Yuan. It's not difficult from Fig. 4 to discover that the horizontal coordinate is the long term trends of GDP from 1981 to 2008 and the longitudinal coordinate is the long term trends of the EC. The slope represents the long-term decrease of China's energy intensity. It came to a halt at 1999 which explained the change happened of the economic growth pattern after 1999. At a certain extent, the relation between the economic growth and the energy consumption can be explained by the natural increase with the core of energy technology, and infinitely close to a long-run equilibrium relation.

In order to avoid the forged regression phenomenon, residual variance unit root test is necessary. The tagging order was set as 1, according to the AIC fixed order law. And the test results are shown in Table 1.

According to the nest test in Table 2, residuals were examined, and the test by an ADF unit root method showed that the stability existed. Further testing results showed that the HPLEC and the HPLGDP had the double-sides causality relations and had a stronger causality relationship than that of without filtration. So, it is evident that the economy growth will drive the growth of energy consumption necessarily, at the same time, the phenomena of the energy supply effecting the growth of economy appears. And then taking the process of Granger causality test in the next step, a result was obtained and shown in Table 2.

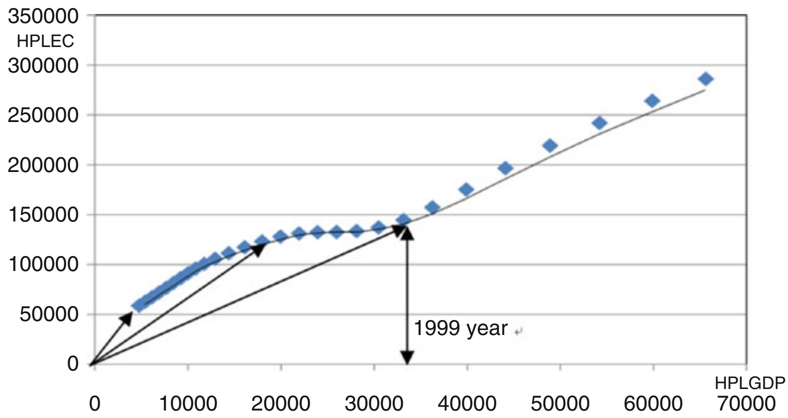

Fig. 4 Chinese economic situation of energy in 1981–2008

Table 1 Residual variance unit root test in 1981–2008 (lag: 1)

	ADF	1% significance level	5% significance level	Estimated result
Residuals	−5.72834	−3.72407	−2.98623	Stationary

Table 2 Result of Granger causality test between the HLGDP and the HLEC in 1981–2008

Sample region: 1981–2008 lagging time: 2			
Null hypothesis	Number of observed samples	F-statistic	Probability
Granger cause of the HPLGDP being not the HPLEC	26	6.29486	0.10012
Granger cause of the HPLEC being not the HPLGDP		9.9459	0.00093

4.2 The Analysis of Cycle Fluctuations

The economy cycle can be divided into three cycles, which are 1981–1988, 1989–1997 and 1998–2007 from the trend components of GDP by H-P filtration. The cycle of the energy consumption is basically similar with the cycle of GDP, but in 2000 there was an inflexion which was different from the GDP.

Firstly, the energy consumption cycle had less fluctuation during the period of 1981–1988. The energy consumption cycle was relatively stable, and the tertiary industry occupied a bigger proportion of the economic structure from 22% in 1980 to 30.5% in 1988. The proportion of the first and second industries declined obviously. The adjustment of industrial structure is the main reason for the reduction in energy intensity.

Secondly, from 1986 to 1996, the fluctuation of energy consumption cycle had become stronger. With the rapid development of the economy, the industry structure optimization ran into the bottleneck. However, the energy efficiency was improved by using of high-quality energy especially oil which was increasing from 163 million tons of standard coal in 1990 to 2,501 million tons in 1996.

Lastly, the energy consumption cycle was dramatically fluctuated from 1997 to 2004. Even though with the increase of the total continuous quantity and the proportion of oil consumption the energy intensity came to a decrease because of the expansion of high-energy-consuming industries which were promoted by the rapid development of China's economy.

Aggregate demand was turn from overheating to insufficient with the adjustment of the overheating economy, especially with the successfully Olympic bidding and joining the WTO in 2001, therefore, the deflation is the main characteristic of this economy cycle. So, the cyclical components of GDP were from positive to negative. A series of macroeconomic policies were carried out then in order to stimulate demand facing the lack of aggregate demand and caused the increasing of the energy consumption and shortage of supply. H-P filtration is applied to proclaim the stylized facts between the energy consumption and GDP. The characteristics of the volatility of the energy consumption components are shown in Table 3.

The amplitude of volatility is one of the important indexes that reflect the stability of the cyclical components of energy consumption. This value was not stationary and even dramatically changed lately in the period of 1981 and 2008. The trend of the average potential of volatility and standard deviation reflects the same

Table 3 The characteristics of the energy consumption cyclical components

Cycle time	1981–1988	1989–1996	1997–2004	2005–2008
The peak of year	1988	1996	2004	2005
Fluctuation height	1,869	7,713	6,393	5,068
The valley of year	1984	1992	2001	2008
Fluctuation depth	−651	−2,114	−9,769	−1,811
Amplitude of fluctuation	2,520	9,827	16,162	6,879
Fluctuation average potential	168	571	−1,733	1,987

problem, but the cyclical components of the EC and GDP by H-P filtration almost have crest-crest and trough-trough relations. It is evident that the same trend exists in the components trend of the energy consumption and GDP, and the cyclical components of these two series are of the same volatility characteristics. The trend components of the EC and GDP by H-P filtration belong to the integrated sequence, OLS regression analyzing for year 1981–2008 deduced the integration regression equation of the GDP and the EC as follows.

5 Conclusions

1. A stationary positive relationship between the HPLEC and the HPLGDP exists, and the main reason of the rising HPLEC is the continuous growing of HPLGDP. The total HPLEC of the whole society increases 34,890 tons of standard coal with 100 million Yuan increasing of HPLGDP.
2. The characteristic of common trends and volatilities between the energy consumption and the economy growth after filtration. However, the cyclical components of energy requirements were unstable with the trend of more and more intense from 1981 to 2008. It shows that the economic cycle has the greater influence on the energy consumption, and the relationship between them will become more complicated in the future.
3. There are double-sides causality between the trends of the energy consumption and economy growth. The stronger evidence can be obtained after filtration than former results in Granger causality tests. It indicates that the relationship between the energy consumption and the economy growth has been strengthened with removing the short-term fluctuations. So, it explains that economy growth promotes the accelerated consumption of energy, and extensive economy growth pattern has not been effectively controlled.
4. The change channels of the long-term and short-term relationship between the energy consumption and the economy growth are revealed by H-P filtration. The short-term relationship directly leads to the volatility of the long-term equilibrium. The long-term relationship will bring the both back to the stationary equilibrium status. However, its internal mechanism is more complicated and needs to be intensive studied.

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Enterprise Risk Assessment and Forecast: Based on Chinese Listed Companies in 2009–2010

Shao Jun, Wang Shuangcheng, and Liu Yanping

Abstract This paper assessment and forecast the risk of Chinese listed companies in 2009–2010 on bayesian network classification model and risk forecasting index system. The result shows that listed companies are all have certain level financial and operating risk in 2009: 11.62% have high financial risk and 21.76% have high operating risk. Looked from the industry distribution, electricity, gas and water production and supply, electronics, real estate, metallurgy, agriculture, forestry, animal husbandry and fishery, pharmaceuticals, biological and comprehensive industries have higher financial risk. Mining, electronics, real estate, textile, clothing and fur Industry, transportation, storage, metallurgy, agriculture, forestry, animal husbandry and fishery, wholesale, retail and comprehensive industries have higher operating risk. Listed companies in 2010 also have certain level financial and operating risk: 12.37% of them have higher financial risk and 18.44% have higher operating risk. electricity, gas and water production and supply, electronics, real estate, metallurgy, agriculture, forestry, animal husbandry, fishery, pharmaceuticals, biological, wholesale and retail, food and beverage and comprehensive industries have higher financial risk. Mining, electronics, real estate, mechanicals, equipment and instrument, metallurgy, wholesale and retail, servicing and comprehensive industries have higher operating risk.

Keywords Financial risk · Operating risk · Risk forecast · Risk identify · Risk management

1 Introduction

Risk management is always important, especially after the European Union, Greece sovereignty crisis as well as Spanish, the Portuguese credit rank declines anticipated, many countries pay additional attention to it. In recent years, China began to pay more

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and more attention to it and issued a series of corresponding laws and regulations to regulate its implementation. Specifically, listed companies faced the toughest challenges in 2009. For instance, after government introduces a series of regulations to curb the rapid growth of housing price, the profitability of real estate and financial industry have been adversely affected. In addition, the uncertainties about the price of big commodities, RMB currency exchange rate, the recovery of consumers' confidence and unemployment rate further increase the risk level faces by listed companies. Corresponding listed companies not only realize the existence of the risk, but also analyze the risk factors. So they are able to control risk and reduce the loss. This paper is to measure and assessment the listed companies' risk using dynamic bayesian network model. It provides a fundamental research platform for macro economics risk management and micro risk management. It also provides guidance to identify effectively, assessment and avoid the risk of listed companies (Altman 1968; Cao and Xia 2005; Coats and Fant 1993).

2 Risk Factors Identification

Among different types of risks, operating risk and financial risk are the two major risks faced by listed companies. Operating risk is the risk occurring in purchasing, production and sales. Financial risk is the possible financial loss due to various uncertain factors. The financial activities of enterprises can be divided into four parts: financing, investing, receiving and net income distribution, therefore the financial risk has four types too. They are risks associated with financing, investing, receiving and net income distribution.

2.1 Current Operation Analysis

The major factors of operating risk and financial risk of listed companies in year 2009 and 2010 are as below:

- Global financial crisis began slowing down
  Since the 2nd quarter of 2009, the impact of global financial crisis on China economy has gradually reduced. Stimulated by China government currency policy and financial regulation, especially by government RMB four trillion stimulus package, China economy began turning around and market demands began increasing. Listed companies' main operating income increased and cost decreased, leading a dramatic increase in income. Listed companies in 2009 have total operating income of RMB 12,257,408,588,300.00, increasing by 15.79% compared with that in 2008. The total operating cost is RMB 9,816,252,044,000.00, increasing by 12.92% than 2008. Operating income is RMB 1,423,323,410,500.00, decreasing by 181.92% than 2008. Total income is RMB 1,472,212,302,700.00, increasing by 106.37% than 2008. The income

goes up much more than the growth of cost. It is the main reason of the good performance of listed companies in 2009. Net income (Including minority shareholders' equity) is RMB 1,151,477,891,000.00, decreasing by 15.58% than 2008. The average earning per share of non-financial listed companies is RMB 0.32/share and it varies among different industries. Return on Equity for all the industries is 4%, but it is negative for electricity, gas and water production and supply, oil, chemical, rubber and plastics industries. The returns of some industries are over 10%, such as mining, real estate, mechanicals, equipment, instrument construction, servicing, food, beverage, information technology, pharmaceuticals and biological, etc. The average operating cash flow per each share of all the industries is RMB 0.58. The loss of listed companies' assets is reduced with the increasing of commodity price. The weight of loss of assets over the operating income on average dropped by 46%. However, the weight for some industries increased, such as electricity, gas, water production and supply, electronics, textile, clothing, fur industry, mechanicals, equipment, instrument, metallurgy, servicing, oil, chemical, rubber, plastics, pharmaceuticals, biological and paper, printing. Because loss in assets is reduced, listed companies began to make more profit and the total net income rate is over 15%.

- Increase in direct financing and the change of financing structures
  In 2009 China economics began to recover due to some government financial regulations and currency policy which stimulated demands of finance in the market. In the meantime, China Securities Regulatory Commission also restarted IPO. From June 2009 to April 2010, 242 IPOs and 154 companies are approved to refinance. The total financing amount is as high as RMB 618 billions. It helps the servicing listed companies with direct financing, developing, operation, integration and upgrading. Besides 84 listed companies went public, 56 companies implemented asset restructure with total trading amount of RMB 400 billions in 2009. In addition, 12 companies accomplished oversea merger and acquisition with amount of RMB 53 billions. Excluding financial listed companies, the total investment through financing is RMB 372.1 billions in 2009 and it's 1.26 times the amount in 2008, the total loan is RMB 4,130 billions and close to RMB 3,970 billions in 2008. The amount of bond issuance is of RMB 196.1 billions which is increased by 61% than that in 2008. Of all the financing of listed companies, 12% is coming from direct financing in 2009, increasing by 3% compared with that in 2008. With blooming of direct financing market, more and more companies raise funds by direct financing, such as selling stocks or bonds. However, approximately 90% of financing is still bank loans and it places much more pressure on listed companies. Furthermore since the beginning of 2010 the central bank has increased the reserve deposit ratio for all the banks and it will probably raise the interest rate. Under the more and more restricted currency policy, the cash flow of listed companies will become tight again and it will adversely influence operating cost.
- Increase in contribution from non-recurring gains and losses, but at decreasing rate
  According to the statistics published by China Securities Journal, non-recurring gains and losses of 1,718 comparable listed companies are approximately RMB 80 billions. It dropped by 27.02% than the same period of 2009 and only accounted for

3.85% of net income. It indicates that non-recurring gains and losses are hard to continue growing. Non-recurring gains and losses are consisted of a lot of components: government subsidies, restructure benefit, disposal of non-current assets, changes in fair value, etc. Among them, gain/loss from changes in fair value is most extraordinary. Excluding financial listed companies, annual reports in 2009 disclosed that gain/loss from changes in fair value increase from RMB (20,415,000,000) in 2008 to RMB 13,804,000,000 in 2009. Government implemented income tax reform in 2008 and relieve the income tax burden from listed companies in some way. Government also implemented some regulations to battle the economic recession and provided opportunities for listed companies. Under those policies, they are able to be qualified for income tax incentives if they are certified as high technology listed companies and national planning key software listed companies; or national torch plan key high-tech listed companies and western development listed companies. In the mean time, Development Revolution Committee and local governments also provide listed companies with some supporting subsidies, rewards, financial subsidies, free project supports, etc. Government has been insisted on it through 2009 and 2010. For instance, from the fourth quarter, 2009 to first quarter, 2010, 60 companies have received government subsidies of over RMB two billions, including energy-conserving subsidies, exporting tax refund, technology reform subsidies, etc. Those subsidies made considerable contribution to the increase in listed companies' performance.

2.2 Risk Factors Identification

- Operating risk factors identification

  When making operating plan, we look at operating risk from the company's profitability and assets management efficiency. Table 1 shows that the operating income of transportation and storage, electronics, and mechanicals equipment dramatically dropped in 2009 and total income of mechanicals equipment has adversely decreased. Some industries, transportation and storage, electronics, mechanicals, equipment, metallurgy and comprehensive Industries are more likely to have operating risk.

  Table 2 shows that inventory turnover rate in 2009 is lower than 2008, averagely decreasing by 15.7%. Accounts receivable turnover is lower than 2008 too, averagely decreasing by 3.51%. Total assets turnover rate is lower than that in 2008, averagely decreasing by 9.49%. Industrywise, the inventory turnover rates for some industries are lower, for example, mining, manufacturing, public utilities, transportation and storage, commercial trading, servicing, communication and culture, comprehensive industries, textile, clothing, paper and printing, oil chemicals, metallurgy and other manufacture. Some industries have lower total assets turnover rate, for instance, mining, manufacture, transportation and storage, information technology, paper and printing, oil chemical, electronics, metallurgy and other manufactures. Therefore, the assets management efficiency obviously is reduced.

Table 1 Growth rate of listed companies in 2009

GR			
Industry	Operating income (%)	Total income (%)	Net income (%)
Mining	44.62	11.52	7.72
Manufacture	43.37	38.71	41.29
Public utilities	942.53	3,537.59	1,542.27
Construction	97.39	94.62	108.09
Transportation and storage	−20.87	0.01	13.68
Information technology	55.97	28.19	−50.06
Commercial trading	17.06	14.11	15.7
Real estate	28.53	28.37	24.84
Servicing	46.84	41.57	41.29
Communication and culture	25.34	17.16	19.29
Comprehensive industries	24.89	21.54	26.04
Food and beverage	162.17	132.04	368.44
Textile, clothing	81.91	67.11	72.97
Wood, furniture	101.81	70.9	101.72
Paper and printing	30.08	25.82	38.65
Oil and chemical	0.43	16.24	16.57
Electronics	2,564.16	136.26	847.28
Metallurgy	−50.78	853.23	130.27
Mechanicals, equipment and instrument	−13.08	−10.71	−14.84
Pharmaceutical biological	46.83	43.78	41.79
Other manufacture	67.41	66.64	72.24
Agriculture, forestry, animal husbandry, fishery	31.56	9.27	10.26
Average	381.37	228.41	151.20

Table 2 Assets management efficiency of listed companies in 2009

Industry turnover	Inventory	Account receivables	Total assets
Agriculture, forestry, animal husbandry, fishery	2.08	11.86	0.66
Mining	7.63	40.7	0.95
Manufacture	4.11	12.3	0.85
Public utilities	9.54	9.88	0.33
Construction	4.46	7.14	1.11
Transportation and storage	23.6	14.75	0.39
Information technology	6.25	7.19	0.63
Commercial trading	7.04	34.38	1.63
Real estate	0.32	25.96	0.29
Servicing	2.5	11.68	0.39
Communication and culture	3.19	10.31	0.42
Comprehensive industries	2.14	15.85	0.52
Food and beverage	3.22	28.9	0.99
Textile, clothing	1.79	10.54	0.56
Wood, furniture	2.5	7.57	0.61
Paper and printing	3.51	8.07	0.54
Oil chemical	5.13	14.95	0.69
Electronics	4.3	7.36	0.82
Metallurgy	4.7	29.99	0.89
Mechanicals, equipment and instrument	3.99	7.98	0.92
Pharmaceutical, biological	4.23	7.68	0.87
Other manufactures	1.95	12.32	0.67
Average	4.92	15.33	0.72

Table 3 Debt paying back of listed companies

Debt paying back			
Industry	Times earned interest (EBIT/interest)	Asset-liability ratio (%)	Net cash flow from operating activities liabilities
Agriculture, forestry, animal husbandr, fishery	3.18	51.24	0.08
Mining	18.72	44.14	0.37
Manufacture	5.71	57.42	0.12
Public utilities	2.42	70.31	0.11
Construction	6.04	76.98	0.06
Transportation and storage	3.79	57.30	0.09
Information technology	11.9	51.89	0.20
Commercial trading	9.87	63.40	0.12
Real estate	10.93	65.74	0.05
Servicing	8.47	49.82	0.20
Communication and culture	6.65	43.77	0.21
Comprehensive industry	4.75	59.31	0.06
Food beverage	20.44	44.18	0.29
Textile clothing	5.22	53.15	0.11
Wood furniture industry	2.79	55.48	0.16
Paper and printing	3.65	51.81	0.10
Oil chemical	2.81	58.50	0.09
Electronics	2.38	50.67	0.05
Metallurgy	2.93	59.19	0.11
Mechanicals equipment	13.54	61.36	0.13
Pharmaceutical biology	12.94	43.34	0.23
Other manufactures	5.96	57.47	0.14
Average	7.64	57.39	0.14

Mining, manufacture, transportation and storage, textile clothing, paper and printing, other manufactures all have higher operating risk.

- Financial risk factors identification
  Table 3 illustrates that some industries have above average asset-liability ratio. These industries include public utilities, construction, commercial trading, real estate, comprehensive industries, mechanicals and equipment, etc. If a company has high asset-liability ratio and the ratio keeps going up, it is highly possible to have financial crisis when short of capital. So some industries face more financial pressure, for example, Public utilities, construction, commercial trading, real estate, comprehensive industries, mechanicals, equipment, etc. Times earned interest is 7.64 on average and is 58% more than 2008. It's 4.84 in 2008. Obviously overall solvency is enhanced. Industrywise, wood furniture, paper and printing, oil chemical, electronics, metallurgy, mechanicals equipment, pharmaceutical biological and other manufactures have above average times earned interest. They have less financial risk. In contrast, agriculture, forestry, animal husbandry, fishery, mining, manufacture, public utilities, construction, transportation and storage, information technology, commercial trading and real estate have lower times earned interest and higher financial risk. From two indexes, public utilities, construction, commercial trading, real estate, comprehensive industries apparently have financial risk.

3 Risk Assessment and Analysis

3.1 Static Bayesian Network Model on Risk Measurement

Bayesian network model is a probabilistic graphical model that represents a set of random variables and their conditional dependences via a directed acyclic graph. Generally bayesian networks can solve decision problems under uncertainty. When data is not big enough, classification techniques cannot be used to do the effective alarm due to many variables are hard to estimate. In this case, we will use clustering to do forecast. We normally forecast risk rating within time slot by static bayesian networks clustering. However, when we need gather information from different time slots, we will use dynamic bayesian networks clustering. $C, X_1, \ldots, X_n$ represent static variables and attribute variables, $c, x_1, \ldots, x_n$ is the value, D is data set, $N$is numbers in data set, $C[t], X_1[t], \ldots, X_n[t]$ $(0 \leq t \leq T)$ represent dynamic time slot variables and attribute variables. $c[t], x_1[t], \ldots, x_n[t]$ is the value.

$D[0], D[1], \ldots, D[T]$ represent different time slot data set. $N[0], N[1], \ldots, N[T]$ is numbers in data set. We combine Bayesian Network and Gibbs sampling to do the static data clustering. Assuming we can sort out unknown data through clustering with prior knowledge about data and sample, we randomly initiate the value of C and keep doing trial and test of C value until all the conditions are satisfied. In each time we do trial and test in the order of numbers in data set. For example, if $C = c_m, X_i = x_{mi}, \hat{c}_m = c_m$, variable C is possibly $c^1, \ldots, c^{r_c}$. $D^{(k-1)}$ represents the data set before the kth trial and test. $D_m^{(k-1)}$ is the data set during the kth trial and test. $D^{(k)}$ is the data set after the kth trial and test. According to Gaussian Density Function, we can obtain:

$p^{(k)}(x_{mi}|c_m, D_{m-1}^{(k)}, S) = g^{(k)}(x_{mi}; \mu_{c_m}, \sigma_{c_m}|D_{m-1}^{(k)}, S)$. $\mu_{c_m} = \dfrac{x_{1i}(c_m) + \ldots + x_{Ni}(c_m)}{N_{c_m}}$ is the mean of c_m in sample.

$\mu_{c_m}(c_m) = \begin{cases} \mu_{c_m} & c_j = c_m \\ 0 & c_j \neq c_m \end{cases}$ is standard deviation of c_m in sample. When $p^{(k)}(c_m|D_{m-1}^{(k)}, S) = 0$, $\mu_{c_m} = \mu_c$ and $\sigma_{c_m} = \sigma_c \cdot \mu_c$ and μ_c are unconditional mean and standard deviation. Standardize $p(c_m|D_{m-1}^{(k)}, S) \prod_{i=1}^{s} p(x_{mi}|c_m, D_{m-1}^{(k)}, S)$ and obtain

$$w(h) = \frac{p(c^h|D_{m-1}^{(k)}, S) \prod_{i=1}^{s} p(x_{mi}|c^h, D_{m-1}^{(k)}, S)}{\sum_{j=1}^{r_c} p(c^j|D_{m-1}^{(k)}, S) \prod_{i=1}^{s} p(x_{mi}|c^j, D_{m-1}^{(k)}, S)}, h \in \{1, \ldots, r_c\}$$

λ is randomly generated. We determine the value of C as below:

$$\hat{c}_m = \begin{cases} c^1, & 0 < \lambda \le w(1) \\ & \ldots\ldots \\ c^h, & \sum_{k=1}^{h-1} w(k) < \lambda \le \sum_{k=1}^{h} w(k) \\ & \ldots\ldots \\ c^{r_c}, & \lambda > \sum_{k=1}^{r_c-1} w(k) \end{cases}$$

If $c_m \neq \hat{c}_m$, we need adjust correspondent parameters and c_{m+1}.
Other similar variables adjustment is as below:

$$\hat{p}^{(k)}(c_m|D_m^{(k)}, S) = \hat{p}^{(k)}(c_m|D_{m-1}^{(k)}, S) - 1/N,$$

$$\hat{p}^{(k)}(\hat{c}_m|D_m^{(k)}, S) = \hat{p}^{(k)}(\hat{c}_m|D_{m-1}^{(k)}, S) + 1/N$$

Continuous attribute parameters are adjusted as below:

$$\hat{p}^{(k)}(x_{mi}|c_m, D_{m-1}^{(k)}, S) = g^{(k)}(x_{mi}; \mu'_{c_m}, \sigma'_{c_m}|D_{m-1}^{(k)}, S)$$

$$\mu'_{c_m} = \frac{\sum_{k=1}^{N} x_{ki}(c_m) - x_{mi}(c_m)}{N_{c_m}},$$

$$\sigma'^{\,2}_{c_m} = \frac{\sum_{k=1}^{N} (x_{ki}(c_m) - \mu'_{c_m}(c_m))^2 - (x_{mi}(c_m) - \mu'_{c_m}(c_m))^2}{N_{c_m}},$$

$$N_{c_m} = -1 + \sum_{k=1}^{N} N_{c_m}(c_k)$$

$$g^{(k)}(x_{mi}; \mu'_{c_m}, \sigma'_{c_m}|D_{m-1}^{(k)}, S) = \frac{1}{\sqrt{2\pi\sigma'_{c_m}}} e^{-\frac{\left(x_{mi}-\mu'_{c_m}\right)^2}{2\sigma'^{\,2}_{c_m}}}$$

$$p^{(k)}(x_{mi}|\hat{c}_m, D_{m-1}^{(k)}, S) = g^{(k)}(x_{mi}; \mu'_{\hat{c}_m}, \sigma'_{\hat{c}_m}|D_{m-1}^{(k)}, S)$$

$$g^{(k)}(x_{mi}; \mu'_{\hat{c}_m}, \sigma'_{\hat{c}_m}|D_{m-1}^{(k)}, S) = \frac{1}{\sqrt{2\pi\sigma'_{\hat{c}_m}}} e^{-\frac{\left(x_{mi}-\mu'_{\hat{c}_m}\right)^2}{2\sigma'^{\,2}_{\hat{c}_m}}},$$

$$\mu'_{\hat{c}_m} = \frac{\sum_{k=1}^{N} x_{ki}(\hat{c}_m) + x_{mi}(\hat{c}_m)}{N_{\hat{c}_m}}$$

$$\sigma'^{\,2}_{\hat{c}_m} = \frac{\sum_{k=1}^{N} \left(x_{ki}(\hat{c}_m) - \mu'_{\hat{c}_m}(\hat{c}_m)\right)^2 + \left(x_{mi}(\hat{c}_m) - \mu'_{\hat{c}_m}(\hat{c}_m)\right)^2}{N_{\hat{c}_m}},$$

$$N_{\hat{c}_m} = 1 + \sum_{k=1}^{N} N_{\hat{c}_m}(\hat{c}_k)$$

Then use the consistent of adjacent clustering variable series to check and do the trial and test. If we obtain clustering variable series in two adjacent tests are $c_1^{(k)}, c_2^{(k)}, \ldots, c_N^{(k)}$ and $c_1^{(k+1)}, c_2^{(k+1)}, \ldots, c_N^{(k+1)}$,
$sig(c_i^{(k)}, c_i^{(k+1)}) = \begin{cases} 0, c_i^{(k)} = c_i^{(k+1)} \\ 1, c_i^{(k)} \neq c_i^{(k+1)} \end{cases}$ with defined range $\eta_0 > 0$, if $\frac{1}{N}\sum_{i=1}^{N} sig(c_i^{(k)}, c_i^{(k+1)}) \leq \eta_0$, the trial and test is finalized.

3.2 *Dynamic Bayesian Network Model on Risk Measurement*

When size of sample data is not big enough, classification techniques cannot be used to do the effective alarm due to many variables are hard to estimate. The method of mixed data clustering which is combination of bayesian networks model and gibbs sampling is suitable for discrete and continuous data clustering. This method can be used to forecast the risk rating at any time slots (annually or quarterly). First it determines the range of clustering numbers according to prior knowledge and then it determines the category of clustering number. Next, it expands MDL (minimal description length) standard through penalty factor and use the expanded MDL standard and statistics to discover the best cluster of class number and finally realizes the common clustering. We use dynamic simple Bayesian Network structure to do dynamic data clustering and class variables to form first-order markov chain (also expand to first-order markov chain). Time slot attribute variables and class variables form star structures, as Fig. 1:

Gibbs sampling uses distribution $p(c[t]|c[0], \ldots, c[t-1], x_1[0], \ldots, x_n[0], \ldots, x_1[t], \ldots, x_n[t])$ to obtain sample. In this method, based on Dynamic Plain Bayesian Network Structure, we can decompose conditional probability to make sampling less complicated. According to Bayesian Network Theory and Bayesian Function, we can obtain:

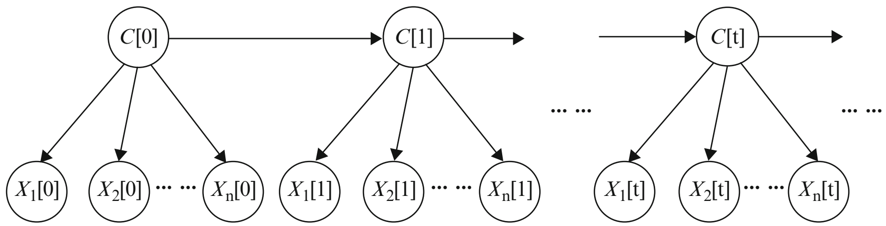

Fig. 1 Dynamic plain bayesian network structure

$$\begin{aligned}
&p(c[t]|c[0], \ldots, c[t-1], x_1[0], \ldots, x_n[0], x_1[1], \ldots, x_n[1], \ldots, x_1[t], \ldots, x_n[t]) \\
&\quad = p(c[t]|c[t-1], x_1[t], \ldots, x_n[t]) = \frac{p(c[t], c[t-1], x_1[t], \ldots, x_n[t])}{p(c[t-1], x_1[t], \ldots, x_n[t])} \\
&\quad = \beta p(c[t]|c[t-1]) \prod_{i=1}^{n} p(x_i[t]|c[t])
\end{aligned}$$

β has nothing to do with $c[t]$, $p(c[t]|c[t-1])$ is class transition probabilities, $p(x_i[t]|c[t]$ is conditional density. We need estimate $p(c[t]|c[t-1])$ by data set in current time slot and previous time slot, but for $p(x_i[t]|c[t]$, we can estimate it by current time slot. Then normalize

$$\begin{aligned}
&p(c_m[t]|c_m[t-1], D[t-1], D^{(k)}_{m-1}[t], S[t]) \\
&\qquad \prod_{i=1}^{n} p(x_{mi}[t]|c_m[t], D^{(k)}_{m-1}[t], S[t])
\end{aligned}$$

Implication of non-sequential agrees with static Bayesian Network and records as

$$v(h) = \frac{p(c^h|c_m[t-1], D[t], D^{(k)}_{m-1}[t], S[t]) \prod_{i=1}^{n} p(x_{mi}[t]|c^h, D^{(k)}_{m-1}[t], S[t])}{\sum_{j=1}^{r_c} p(c^j|D^{(k)}_{m-1}[t], S[t]) \prod_{i=1}^{n} p(x_{mi}[t]|c^j, D^{(k)}_{m-1}[t], S[t])}, h \in \{1, \ldots, r_c\}$$

μ is randomly generated, we determine the value of $C[t]$ by the following method:

$$\hat{c}_m[t] = \begin{cases} c^1, & 0 < \mu \le v(1) \\ & \ldots\ldots \\ c^h, & \sum_{k=1}^{h-1} v(k) < \mu \le \sum_{k=1}^{h} v(k) \\ & \ldots\ldots \\ c^{r_c}, & \mu > \sum_{k=1}^{r_c - 1} v(k) \end{cases}$$

3.3 Sample and Index Selection

- Sample selection
  Samples financial reports of A shares in Shenzhen and Shanghai Securities Exchange from 2008 to first quarter, 2010. There are total 1,782 companies each year in China sample. Division of industries is based on the book, guidance of categories of listed companies Industries issued by China Securities Regulatory Commission in 2001. This book divided all the listed companies into 22 types of industries. Our sample excludes financial industries. All the financial data in this paper come from WIND data base.
- Selection of index
  Listed companies' financial risk and operating risk include two parts: risk rating index and other related indexes. (1) Listed companies financial risk rating index: It has four ratings: highest risk (a), higher risk (b), medium risk (c), low risk (d). The factors influencing the financial risk rating index are gross profit margin, net income ratio, return on equity, net income over total assets, earning per share(basic), equity to assets ratio, times earned interest (EBIT/ Interest), asset liability ratio (average), cash total debt ratio, operating cash flow per share. (2) Listed companies operating risk rating index: It also has four ratings: highest risk (a), higher risk (b), medium risk (c), low risk (d). The index influencing the financial risk rating are Inventory turnover, Accounts receivable turnover, total assets turnover, Total asset growth rate, fixed assets/ total assets, operating revenue growth rate, operating income growth rate, net income growth rate.

3.4 Risk Assessment and Analysis

First we got the data related to financial and operating risk of listed companies. Then we invited 15 famous domestic experts who are famous on listed companies management, financial management and accounting to rate risk by Delphi method (after three rounds discussions by experts, the unanimous opinions is the final rating), then forecast and analyze risk rating in time slots based on bayesian networks clustering and dynamic bayesian networks classification convergence analysis of time slot clustering method. Figures 2 and 3 show that based on data set $D[2009]$, operating and financial risk forecast and clustering convergence.

By static clustering method, according to data sets in two time slots of 2009, we forecast and analyze financial, operating and comprehensive risks. Table 4 show financial and operating risk distributions. Table 4 also illustrates that all the listed companies are at the level of low risk on average: 11.62% of all the companies have highest financial risk; 21.76% have highest operating risk.

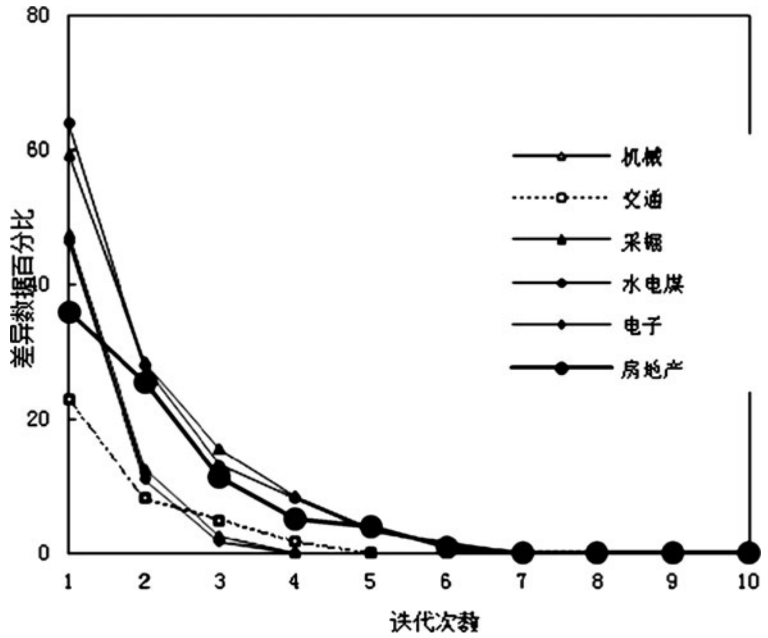

Fig. 2 Static financial risk clustering convergence in 2009

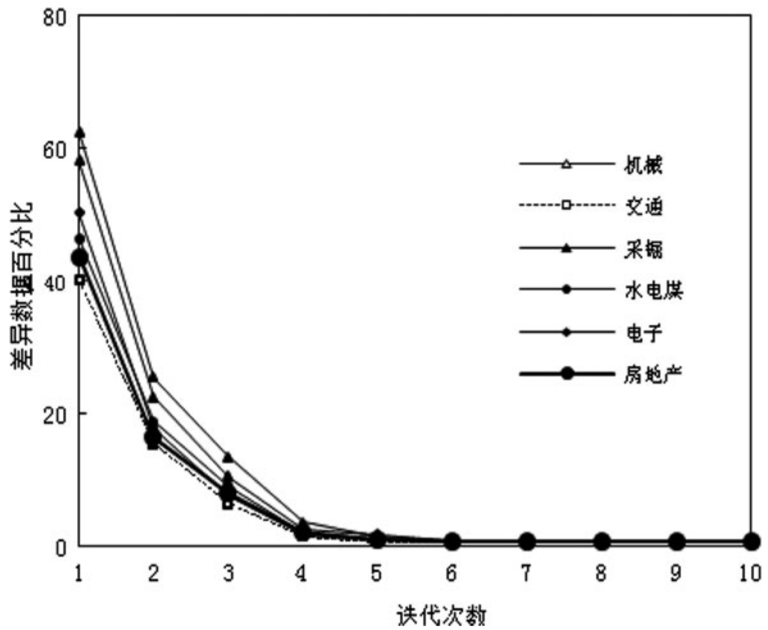

Fig. 3 Dynamic financial risk clustering convergence in 2010

Table 4 Risk distribution in 2009

Risk rating								
Industry	A		B		C		D	
	Financial (%)	Operating (%)	Financial (%)	Operating (%)	Financial (%)	Operating (%)	Financial (%)	Operating (%)
Mining	11.36	40.27	11.36	20.18	40.91	21.35	36.36	18.20
Electricity, gas and water production and supply	29.85	11.94	23.88	41.79	38.81	22.38	7.46	23.88
Electronics	20.00	38.20	20.00	24.71	28.57	28.08	31.42	8.98
Real estate	42.99	45.79	25.23	30.84	18.69	12.14	13.08	11.21
Textile, clothing and fur industry	17.64	30.88	33.82	30.88	13.23	22.05	35.29	16.17
Mechanicals, equipment and instrument	10.92	15.69	25.93	18.43	33.78	39.24	29.35	26.62
Transportation and storage	7.46	21.94	29.85	43.73	19.40	14.92	43.28	19.40
Metallurgy	34.41	25.97	25.97	38.05	16.88	18.83	22.72	17.14
Agriculture, forestry, animal husbandry and fishery	28.57	20.00	14.28	22.85	25.71	28.57	31.42	28.57
Wholesale and retail	17.82	20.79	29.70	19.80	14.85	18.81	37.62	40.59
Servicing	14.28	18.36	32.65	14.28	18.36	36.73	34.69	30.61
Food beverage	16.66	16.44	25.00	43.29	43.05	17.37	15.27	22.90
Oil, chemical, plastics, rubber	19.44	11.34	33.33	27.83	11.11	29.89	36.11	30.92
Information technology	16.17	12.50	33.82	31.61	19.85	41.91	30.14	13.97
Pharmaceutical, biological	20.17	19.28	25.43	14.91	36.84	43.85	17.54	21.92
Comprehensive industries	26.86	26.85	37.31	23.88	10.44	25.37	25.37	23.88
Average	11.62	21.76	24.02	20.11	28.48	23.58	35.86	34.54

Table 5 Risk distribution in 2010

Risk rating								
Industry	A		B		C		D	
	Financial (%)	Operating (%)	Financial (%)	Operating (%)	Financial (%)	Operating (%)	Financial (%)	Operating (%)
Mining	15.78	41.29	21.24	20.42	32.57	16.57	30.41	21.72
Electricity, gas and water production and supply	22.23	15.38	24.17	35.84	35.45	18.78	18.15	30.00
Electronics	17.30	31.15	25.84	22.87	30.26	27.39	26.60	18.59
Real estate	38.49	37.82	33.18	34.31	16.27	17.55	12.06	10.32
Textile, clothing and fur industry	20.91	19.27	25.77	28.18	18.54	27.85	34.78	24.70
Mechanicals, equipment, instrument	18.68	22.75	17.56	21.77	32.49	34.83	31.27	20.65
Transportation and storage	12.12	17.36	22.66	43.15	23.71	22.66	38.46	16.83
Metallurgy	31.74	22.83	23.58	39.47	20.17	21.17	24.51	16.53
Agriculture, forestry, animal husbandry and fishery	25.92	17.31	17.43	27.36	28.76	29.78	27.89	25.55
Wholesale and retail	20.15	21.67	25.42	20.33	17.73	22.81	36.70	35.19
Servicing	18.51	20.50	28.79	20.45	20.11	34.66	23.91	24.39
Food beverage	21.83	17.17	22.30	44.29	36.65	17.36	19.22	21.18
Oil, chemical, plastics, rubber	15.87	13.94	31.26	22.17	22.58	31.74	30.29	32.15
Information technology	20.36	15.71	38.11	33.28	25.92	36.73	15.61	14.28
Pharmaceutical, biological	18.33	18.79	29.72	17.26	33.56	41.14	18.39	22.81
Comprehensive industries	22.31	23.24	33.52	20.55	20.41	27.87	23.76	28.34
Average	12.37	18.44	26.42	19.62	30.25	26.18	30.96	35.76

4 Risk Forecast and Analysis

According to data from 2009 to first quarter, 2010, we forecast the financial risk and operating risk of listed companies in 2010 by dynamic clustering method. Below is the financial risk distribution in Table 5. Table 5 illustrates in 2010 that electricity, gas and water production and supply, real estate, textile, clothing and fur industry, metallurgy, agriculture, forestry, animal husbandry and fishery, wholesale and retail, food beverage and comprehensive industries have higher financial risk. Table 5 shows mining, electronics, real estate, mechanicals, equipment, instrument, metallurgy, wholesale and retail, servicing and comprehensive industries have higher operating risk. Table 5 also illustrates that listed companies in 2010 all have low level of risk of financial and operating risk. 12.37% have higher financial risk and 18.44% have higher operating risk.

5 Conclusion

This paper is to assessment and forecast the risk of Chinese listed companies through bayesian networks network classification model and risk forecasting index system. The results show that all the listed companies have certain level financial and operating risk in 2009:11.62% have higher financial risk and 21.76% have higher operating risk. electricity, gas and water production and supply, electronics, real estate, metallurgy, agriculture, rorestry, animal husbandry and fishery, pharmaceutical, biological and comprehensive industries have higher financial risk. Mining, electronics, real estate, textile, clothing and fur Industry, transportation and storage, metallurgy, agriculture, forestry, animal husbandry and fishery, wholesale and retail and comprehensive industries have higher operating risk. In 2010, all listed companies have low level financial and operating risk too: 12.37% have higher financial risk and 18.44% have higher operating risk. electricity, gas and water production and supply, real estate, textile, clothing and fur industry, metallurgy, agriculture, forestry, animal husbandry and fishery, wholesale and retail, food beverage and comprehensive industries have higher financial risk. Mining, electronics, real estate, mechanicals, equipment, instrument, metallurgy, wholesale and retail, servicing and comprehensive industries have higher operating risk (Deakin 1972; Ohlson 1980; Platt and Platt 1990, 2002).

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The Prevention and Control of Environmental Liability Based on Environmental Risk Management and Assessment in Enterprise

Zhifang Zhou and Xu Xiao

Abstract With the environmental deterioration, there are increasing environmental risks for enterprises, which may bear a tremendous responsibility for environmental liabilities. Based on the basic principles and techniques of environment risk assessment and management for enterprise, from the perspective of environmental whole process management, combining with assessment techniques and management procedures of environmental risk, and analysis framework of environmental damage total cost, this paper proposes the prevention and control methodology of environmental liabilities in enterprise, namely, The prevention method includes environmental materials and environmental liability insurance; The whole process control method includes Ecological Design and ISO14000 environmental management framework; The post-management method includes hazardous waste recycling and management and damage coordination and management of sudden environmental incidents. These methods can provide a good reference for the control of environmental risk, prevention of environmental liabilities in enterprise.

Keywords Assessment · Control · Environmental liability · Environmental risk · Management · Prevention

1 Introduction

During the pursuit of economic interests of enterprises, the claims of protecting our environment have driven enterprises to consider the problem of the environmental risks, which will probably cause great economic losses. And consequently, enterprises shall bear huge responsibility of environmental liabilities because of those risks. There are mainly two schools in current academic research of environmental risks and environmental management for enterprise: the first, researchers focus on

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environmental pollution and control technology of enterprise, environmental risk assessment techniques in natural sciences (Yang 1996; Zhang and Li 1999; Guyonnet et al. 1999; Enea and Salemi 2001); the second, social science researchers tend mainly to the environmental issues from the standpoint of environmental economics, environmental control theory, such as economic value assessment of environment and environmental regulations, recognition and measurement in environmental accounting, environmental information disclosure, and technological innovation, share price, investment decisions, international trade and other areas related with this research field (US WRC 1979; Xu 1998; Yuan 2010), with the research tools of theoretical analysis and empirical studies. Nonetheless, there are few researchers who carry out the research starting from the intersection point of natural sciences and social sciences, namely from the perspective of integration of environmental risk assessment techniques and control of environmental liability in enterprise.

As the environmental liability arising from environmental risks, it is considered that the analysis of environmental risks has a very important role in management of environmental risk and assessment of environmental liabilities in enterprise. Therefore, based on environmental engineering, economics, management and environmental law, with the assessment and quantification of uncertainty and probability of environmental risk, from the perspective of environmental whole process management, this paper designs the assessment and management procedures of environmental liability in enterprise by the relevant assessment and management techniques of environmental risk: (1) contaminated site discovery; (2) preliminary environmental site assessments and environmental risk analysis; (3) site sampling and testing, identification and assessment of environmental damage; (4) development and implementation of pollution control programs; (5) verification and compliance monitoring. Finally, based on what listed above, this paper proposes three kinds of prevention and control measures of environmental liabilities in enterprise, namely, prevention method, process control method, post-management method, and have made a more thorough discussion.

2 Environmental Risk: Main Driving Force of Environmental Liabilities

Risk is existed in everywhere. There are some cognitive arguments, such as “risk is possible danger”, “Risk is the likelihood of damage”. In the safety evaluation and environmental risk assessment, the risk is a loss arising from departure from actual conditions and expectations of an incident, which is characterized as “the product of the probability of adverse events and the consequences of adverse events during a certain period of time” (CSA 1995; Hu and Shen 2001). Environmental risks refer to the actual or potential threat of adverse effects on living organisms and environment by effluents, emissions, wastes, resource depletion, etc., arising out of an organization’s activities (Hamed and Brfirmy 1997). For an enterprise, the possible environmental problems and risks originated from all types of activities of enterprise can be divided into six categories:

(1) the soil pollution resulted from the waste discharges; (2) the impacts on ecosystem; (3) the water pollution; (4) the impacts on natural and cultural landscape in a region; (5) the air pollution; (6) the impacts on community life and people's health and safety.

From the above concepts, environmental risks include the two major characteristics of uncertainties of environmental risks, and the dangers on ecological environment (e.g. air, water, soil, flora and fauna, et al.) and human body. As the main body in socio-economic activities, the production and operation of enterprise inevitably result in more or less environmental pollution, and the execution of mandatory "security" standards and systems made by the administration is directly attributable to the occurrence of environmental risks and environmental liabilities of enterprise. The environmental liabilities are occurred in following areas: (1) the expenditures and obligations resulting from the activities of sustained environmental protection under the law; (2) the costs and debts coming from clean-up of contaminated projects in accordance with the legal requirements; (3) the costs and debts incurred by the claims of health and safety damage of individuals and property impairment of organization because of the pollutants discharged by enterprises; (4) the costs and debts resulting from the violations of environmental laws. The amounts of environmental costs or liabilities are great, seriously affected business performance and even survival or development of enterprise. For example, according to the estimation of U.S. Environmental Protection Agency in 1990, the clean-up cost of pollution site may be more than 750 billions from 1990 to 2020, and the polluting enterprise will responsible for these expenditures according to the U.S. "super fund".

When the enterprise's environmental risk exceeds a certain standard, that is, the capacity of enterprises, it should define the environmental cumulative risk through risk assessment techniques based on the prudence principle in the accounting system of enterprise, and then quantify the probability of risk occurrence and future losses of enterprise, which officially enters the accounting system of enterprise. Finally, it can achieve the objective of reducing environmental liability through the budget and repay of certain environmental liabilities and the management, control and prevention of environmental liabilities. Of course, it also can take the environmental risk assessment though environmental risks are not accumulated to a certain degree, but it be not confirmed and measured in corporate accounting system, only be estimated and prevented in outside system.

3 Environmental Risk Assessment and Management Technology and Its Application in Environmental Liabilities

Environmental Risk Assessment (ERA) is to assess the probability of occurrence of environmental events, and the seriousness of event consequences in different probability, and thus determine appropriate countermeasures. With the progressive development of environmental impact evaluation, environmental risk assessment is developed rapidly, and the research on environmental impacts of the possibility of occurrence of environmental risk has been gradually transferred from the normal events to accidents (e.g. Zhong et al. 1998). As a professional tool, environmental impact assessment is originated from the case study of air pollution in Leicester city (Munn 1975). Among current international issues of environmental risk assessment, they mainly focus on the environmental damage evaluation caused by unexpected disasters, namely, the accident risk assessment. Environmental risk assessment is divided into three levels in terms of its scope of evaluation: micro-risk assessment, systematic risk and national (or macro) risk assessment (e.g. Hu et al. 2000).

There are many environmental risk assessment methods in the research fields, the typical examples include (Shi and Wang 1993; Van Bardwijd 1994; Rubin 2001): the National Research Council of United States develops the four-step risk assessment procedures: (1) assessment of hazard; (2) the development of dose-response relationships; (3) exposure assessment; (4) risk characterization. The analysis of pollutant emissions in Netherlands is a practical approach in the application of environmental pollution assessment research. There are more completed for risk assessment of risk objects in the risk-wide assessment system. Fault Tree Analysis (FTA) is also common in many research methods. In addition, the environmental risk assessment procedure, which is recommended by the World Bank and Asian Development Bank, is widely used in evaluation techniques. In the environmental risk assessment technology, the first method is simple, and has wide application, but is too concentrated in long-term, chronic health risks resulting in pollutants, while less in the risk of sudden environmental pollution; other environmental risk assessment processes have the characteristics of reliability and accuracy for certain types of environmental hazards, such as Fault Tree Analysis embodies the features of systematic, accuracy and predictive originated from the studies of systematic security issues with system engineering method. However, it is not common way, and limits the wide application of its method.

Environmental Risk Management (ERM) refers to choose effective control technology, take the costs and benefits analysis to risk reduction, determine the acceptable risk degrees and acceptable damage levels according to the results of environmental risk assessment and appropriate laws, and conduct policy analysis and socio-economic and political factors, and determine and implement appropriate management measures, reduce or eliminate the risk of accidents, protect human health and safety of environmental system (Rubin 2001). The objectives of environmental risk management are: the first, to determine risk reduction level under different control programs; the second, to choose the suitable solution depending on the cost and feasibility of solutions. With a series of environmental pollution control programs are launched in developed countries, the environmental risk management ideas have been gradually recognized by the society.

At present, environmental risk assessment and management technology has been gradually developed to a policy analysis and management tool which is widely used to solve complex and difficult environmental issues, particularly in control and prevention of industrial pollution, assessment and control of environmental liability. On the one hand, it can reduce enormous potential treatment cost of environmental pollution due to technical limitations, and achieve the purpose of prevention and management of environmental liability by quantifying and assessing environmental risks; On the other hand, it can reduce future pollution control costs, and also coordinate the interest conflicts of various stakeholders which are existed in the litigation of environmental pollution, through appropriate assessment and management process of environmental liabilities. It is conclusion that environmental risk assessment and management plays an important role in control framework for the assessment of environmental liabilities of enterprise.

4 The Prevention and Control of Environmental Liability

In order to prevent the occurrence of environmental liabilities, we must adopt to a series of preventive and management measures. From the foregoing flow chart of management of environmental risk and assessment of environmental liability, we know that environmental liability divided into two parts in accounting system. The one is the environmental liability which is recorded in bookkeeping, the other one is the environmental liability which requires accountants to disclose and reveal, and it is likely to lead to potential expenditures in future and do not meet the criteria of liability recognition. For the former Liability, it can eliminate the future responsibility for enterprise by the future payments (e.g. resource tax, fine, penalty caused by environmental pollution, et al.), or pollution, damage recovery (e.g. development and implementation of environmental pollution governance programs, et al.) and other measures; The latter may occur as the future liabilities, and will affect future cash flow of enterprise and enterprise value, therefore, it should take measures for prevention and control.

Thus, quantifying the environmental liability caused by environmental risk, based on audit procedures of environmental risk and different types of environmental liabilities, this paper proposes three types of countermeasures system, namely, prevention method, process control method, Post-management method. It is showed in the following Table 1.[1]

In the possible measures of prevention and control of environmental liability in enterprise, the using of Eco-materials is the one of the best ways based on the views of prevention of environmental liabilities. Eco-materials is also known as Environmental Conscious Materials (ECM), Environmental materials or Ecological materials, and it is first proposed by professor YAMAKI ryouiti in the last century 1990s.

[1]It is worth mentioning that environmental regulations and environmental risk management of China have entered a new period because of the promulgation of environmental assessment system for public listed companies in China. This is not the voluntary measures for pollution prevention, but the expansion and financing of enterprise will has been affected dramatically by this mandatory external regulation, and can promote pollution prevention and management of enterprises.

Table 1 The possible measures of prevention and control of environmental liability in enterprise

Managerial approach	Control systems or measures	The reduction of environmental liabilities
Prevention method	Environmental Materials Environmental liability insurance	Most of the environmental liabilities
The whole process control method	Ecological Design. ISO14000 environmental management framework.	Parts of the environmental liabilities.
Post-management method	Hazardous waste recycling and management Damage coordination and management of sudden environmental incidents	Thimbleful environmental liabilities

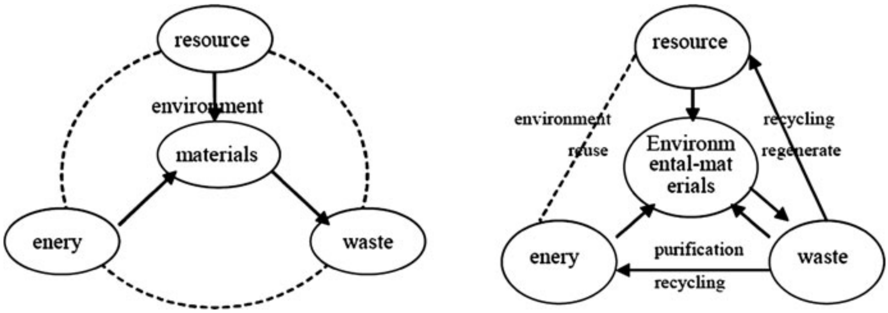

Fig. 1 The difference between Eco-materials and traditional materials

Compared with traditional materials, its impact on the environment is shown in Fig. 1 (Liu 1999).

The using of environmental materials generally can reduce the using of renewable resources, and also can reduce the existing resources, energy consumption with cost-effectively. At the same time, it reduces the amount of waste discharged to the environment in the process of regeneration recycling, and reduces the amount of sewage charges, namely, reduces the future costs of environmental liability. In addition, the using of environmental material can also enhance environmental image of company, increase economic efficiency. Therefore, manager can use environmental materials to prevent future environmental load. In general, enterprises should choose environmentally friendly materials according to environmental principle, quality principle and efficiency principle.

In addition, environmental liability insurance may also be effective in preventing environmental liabilities. It also known as environmental pollution liability insurance, environmental damage liability insurance, etc. (e.g. Gao 2000; Wang 2002). Environmental liability insurance can spread the liability of environmental damage for corporate. And the loss is transferred to other companies and society insurance through its "intermediary" role, which can avoid financial resources loss, environmental liability compensation originated from protracted litigation, etc., and avoid impact the social and economic development because of an

Table 2 The difference between traditional design and eco-design

	Traditional design	Eco-design
Cost concerns	Production cost	Life cycle cost
Type of environmental control	First pollution, later treatment	Pollution prevention
Environmental response	Passive response	Initiative
Economic benefits	The maximization of internal economic benefits for enterprise	The maximization of economic benefits for enterprise and user
Environmental benefits	Less, do not deliberately seek	To minimize life cycle environmental damage
The suitability to original paradigm	High	Low
Sustainability	Low	High

excessive burden on business or even bankruptcy of company, and it is conducive to reduce the loss and protect the victims.

The whole process control of environmental liabilities for company includes: eco-design, ISO14000 environmental management frameworks, etc. Eco-Design (ED) is an approach to design of a product with special consideration for the environmental impacts of the product during its whole lifecycle. In a life cycle assessment, the life cycle of a product is usually divided into procurement, manufacture, use and disposal.[2] The difference with the traditional design as shown in Table 2 (e.g. Wang et al. 2000).

From the table above, we know that the traditional design concerns production costs, and eco-design more focuses on life-cycle costs. Its purpose is the pursuit of the minimization of life cycle environmental damage under sustainability, and it is a proactive environmental response. From types of environmental pollution control, eco-design emphases pollution prevention, and future environmental expenses under eco-design less than those under traditional design.

Primary prevention functions of eco-design cover: (1) compared to traditional design, the amount of cost-savings is more obvious under eco-design; (2) the avoidance of possible environmental liabilities include: (1) to avoid future sewage charges, fines and paying; (2) to enjoy environment tax relief because of environmentally friendly products produced by "three wastes"; (3) to obtain interest-free loans and low-interest loans from the state-owned banks or environmental protection agency, and to get interest expense savings.

In essence, the environmental liability management in company is an environmental pollution control mode, namely, end-treatment mode. It includes the recycling and management of hazardous wastes, the damage coordination and management for sudden environmental accidents (AICE 2000; OECD 2001). The former is only explained in this paper.

[2] http://en.wikipedia.org/wiki/Ecodesign

In waste disposal and management, the related producers should bear the environmental responsibility of waste, such as toxic chemicals, waste batteries and other non-biodegradable plastic waste, which causes environmental pollution, and resulting in environmental liabilities. Therefore, to try to eliminate those environmental liabilities, manager should consider the related factor of waste recycling and management in ecol-design, and to promote waste reduction, recycling and innoxious. Producers should take appropriate actions according to the related guidance. There have two ways for waste recycling and management.

The first is mandatory recycling. It defines the product liability of producers through laws and regulations, and mandatory recycles or proper deals with wastes. Mandatory recycling can be divided into: (1) recycling responsibilities. Such as the recycled proportion of waste batteries is listed in Japan's battery recycling specifications for every battery manufacturer, so as to promote battery recycling, reduce resource consumption and protect environment (Han and Chen 2002); (2) payment responsibility. Such as the regulations of disposable plastic food containers begins to mature in Shanghai; (3) environmental tax liability; the second is spontaneous recycling. It covers two types: (1) self-recycling; (2) joint-recycling. Such as the mobile phone battery recycling activities which begins at the April 2002 in Hong Kong (HK EPD 2002).

Either from the business perspective, or from the social point of view, the method of recycling and waste management is not the best strategy. Compared to waste management, the prevention of environmental liability is a better choice, such as eco-design, cleaner production, environmental materials, etc.; it can achieve the purpose of waste reduction and environmental responsibility elimination from resource control and environmental protection. However, as the financial resources and other objective factors are limited, many companies in China are lagged behind in technology and production process, and it is not realistic to take measures to completely eliminate contamination in advance. Thus, it is feasible and necessary to reduce environmental pollution, as far as possible eliminate the environmental accountability through active waste management.[3]

[3]In addition, many environmental management system or methods can also be effective in the prevention and management of environmental liabilities which may have been already occurred in enterprise, such as cleaner production, environmental internal audit system, the mediation of court proceedings, etc. To clean production, the means include: (1) The construction of closed utilization system of raw materials and resources circulation; (2) the development of new environmentally friendly process by reforming process equipment; (3) the improvement of product system and the adjustment of product structure; (4) the application of advanced environmental management system, the strengthen of scientific management. The basic aim is to reduce waste and avoid environmental liabilities, through the minimization of waste discharges or emissions during production process which is based on energy conservation, reducing consumption and further treatment of waste, and so that the final discharges of waste can meet or better than the national standards.

5 Conclusion

From the basic drive to environmental liabilities, this paper analyzes the basic properties of environment risk and the possibility of environmental liabilities in enterprise; and from environmental risk assessment and management techniques in the environmental science, combined with whole process management of environment and accounting systems of enterprise, with real-time assessment of environmental damage in enterprise, this paper proposes three kinds of measures for management of environmental liabilities, namely, prevention method, process control method and post-management method, which provides a good reference guide for the control of environmental risk, prevention of environmental liabilities in enterprise.

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Supply Chain Risk Management Review and a New Framework for Petroleum Supply Chains

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Abstract Supply Chains have significantly increased in size and complexity due to supplier, producer and customer globalization. The quest for business efficiency has resulted in the current paradigm of lean organizations, exposing high vulnerability to disruptions and uncertainties. Supply Chain Risk Management (SCRM) has surfaced as a high potential field to foster business sustainability, flexibility and resilience. The Petroleum Supply Chain (PSC), a highly automated, investment intensive, and financial risk prone industry sees keen interest in uncertainty mitigation.

Short Biography

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The current paper develops a hierarchical SCRM framework and presents a classified review of the extant SCRM literature. The investigation then focuses on the petroleum supply chain risk management (PSC-RM), reviews the PSC and the process industry developments, develops a hierarchical RM methodology, identifying research directions and financial offerings for the PSC-RM implementation.

Keywords Framework · Petroleum supply chain · Risk management · Uncertainty

1 Introduction

Supply chain management (SCM) is the process of conducting traditional business along the supply chain (SC), in strict coordination with the member companies, aimed at improving the long-term performance of all the members of the SC. Different strategies have arisen to solve the specific characteristics of various problems, leading to the definition of mathematical formulations and algorithms. However, problems related to operations, infrastructures and other risks have been underestimated, and are now surfacing at galloping speed, presenting an excellent opportunity for research in the SCRM field.

Global SCs are subject to exchange rate, economic, political, regulatory, and market uncertainty which greatly influence their performance. As SC structures tend to get more complex, their dynamics and individual members are more fault-prone than previously assumed. Their interaction leads to several states along the SC. A proactive SCRM system that supports process design that is robust and insusceptible to disruption is a relevant success factor in SCM as it empowers its members to prepare and decide spontaneously. Effective risk management can be developed through consistent understanding of the risks and RM methodologies. Recently, many contributions have focused the SCRM, producing new scientific, conceptual and mathematical formulation methodologies. New issues have been brought into the spotlight, motivating research directions and widening its scope.

One particular stream of investigation is the process industry which includes the PSC as a special case. It is a strategic, high-value sector, whose performance is crucial to the national and world economies, as it supports almost all other activities. The PSC comprises of the upstream and downstream sector and is a long SC involving exploration, refining, transportation, storage, production and distribution. Although qualitative risk mitigation is a hot issue, there are almost no specific methodologies for quantitative RM in this sector. The present research aims at exploring this gap by developing a methodology that contributes to the measurement and reduction of risk within some business roles in the petroleum industry. This chapter continues presenting the research as outlined earlier in the abstract.

2 A Hierarchical SCRM Framework

This investigation begins with the study of former literature reviews before presenting a novel hierarchical SCRM framework. Beamon (1998) classifies SC models as per the business process and modeling approach. Vidal and Goetschalckx (1997) and Goetschalckx et al. (2002) review strategic and tactical SC models. Huang et al. (2003) present a framework reflecting the decision level, SC structure and dynamics, addressed issues and modeling techniques. Narasimhan and Mahapatra (2004) present a short categorization of decision models. Gunasekaran and Ngai (2005) review build-to-order SC for risk reduction. Tang (2006b) reviews quantitative models for managing operational SC risks. Oke and Gopalakrishnan (2008) summarize SC risk categorization and risk mitigation strategies. Peidro et al. (2008) present a three dimensional classification of SC quantitative planning methods under uncertainty. Despite the research presented in these reviews, the resurgence of SCRM as an important issue, strongly motivated the design of a new framework integrating all SCRM literature and an implementation methodology. Figure 1 presents the SCRM framework which uses two perspectives: risk identification and risk mitigation. While the former studies the risk agent and risk source, the later evolves as the planning level, management scope, mitigation strategy and modeling technique. The remainder elements, namely risk objects, risk events, consequences and payoffs, are not used for literature classification and hence will be explained later in Sect. 8 as part of the SCRM methodology implementation.

The risk identification elements express where the risks come from. The Risk Agent is a broad category, identifying who brings in the risks, for instance business or market. Risk Sources further specify the factual origin of the risks. These include demand, supply yields, lead times, capacity, supply cost, technology, production capacity, information, terrorism, disaster and financial uncertainties.

The risk mitigation elements counter the risk identification elements and indicate how and where these risks are managed. The Planning Level is first identified considering a three-tier strategic or long-term, tactical or mid-term, and operational or short-term planning. A key issue is the identification of the Management Scope which states the department responsible for RM activities. Customer, supplier, product, operation, information and finance are typical management scopes.

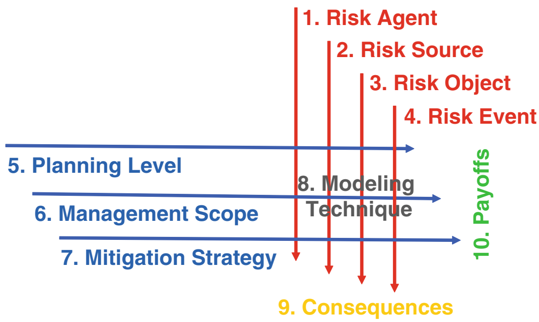

Fig. 1 A hierarchical supply chain risk management framework

Mitigation Strategies then define how the risks are mitigated under each management scope. Customer strategies include customer relationship, demand shift across time, markets and products, product substitution and product bundling. Supplier strategies involve supplier network design, supplier relationship, supplier selection, order allocation, wholesale price and buyback, revenue sharing and quantity based contracts. Product strategies handle product postponement, make to order and make to stock with or without forecast and production process sequencing. Operation strategies contemplate security, safety measures, environment, distribution optimization, inventory policy, maintenance policy, production, disruption and resilience planning. Information strategies include product information, information sharing, vendor managed inventory and collaborative forecasting. Financial strategies involve finance, insurance and value management.

Finally, the Modeling Technique may be qualitative or quantitative. The later may involve deterministic, stochastic, simulation, artificial intelligence or hybrid models. The framework provides a drilldown view by classifying the literature.

The following sections present the extant SCRM literature as per the framework's planning level, management scope and risk source. Literature classification tables are also provided, organized as matrices with risk agents and risk sources as columns and the planning level, management scope and the mitigation strategy as rows, where the modeling technique for each reference is indicated as subscript.

3 Strategic Supply Chain Risk Management

Strategic SCRM involves long-term planning, usually above a year, based on approximate and aggregated data for the decision-making process. Decisions at this level have the highest impact on risk mitigation and determine the response philosophy of the organization. Strategic decisions include the selection of manufacturing technology, location, capacity, type of manufacturing plants, partners, transportation channels, launch and retirement of finished products. Considerable research relates to strategic SCRM, mainly targeting supplier and operations management. Customer and product management are less studied, thus presenting as potential research areas. General, demand, supply yields, production capacity, disaster and financial uncertainties are focused exposing opportunity for supply cost, new technologies and information uncertainty. The risk elements under this review are kept aggregated for the sake of generality. Strategic literature is now presented in Table 1 and reviewed, concluding with a methodology analysis.

3.1 Customer Management

Chopra and Sodhi (2004) study risk categories, drivers and mitigation strategies by risk type, risk/reward relationships. Sheffi (2005) analyze mitigation by shipment

Table 1 Strategic SCRM literature

		Risk agent/risk source							
		Business		Market		Operational			Finance
	Mitigation strategies	General	Demand	Supply yields	Supply cost	Prod. capacity	Information	Disaster	Financial
Customer management	Customer relationship	187_{sd} 197_q	50_q 170_q 199_s	50_q 170_q		50_q 170_q	50_q		
	Demand shift across time/ product		106_s 180_s 207_q						
Supplier management	Supplier network design	30_s 85_q 165_q 187_s 197_q 221_q	2_s 8_s 41_s 88_s 89_s 102_s 107_s 115_s 116_s 119_s 136_s 145_s 169_q 170_q 185_s 189_s 196_d 217_s	8_s 30_s 41_s 57_q 102_s 119_s 170_q 185_s 189_s 212_a 215_a 218_m 219_q	41_s 102_s 107_s	8_s 30_s 115_s 116_s 140_a 154_s 163_q 169_q 170_q 185_s 189_s 197_m 223_s	170_q	57_q 90_s 91_s 170_q 223_s	154_s 178_s
	Supplier selection process	75_s 197_q 231_d	26_m	26_m		26_m			
	Supplier Order allocation		50_q 199_s	26_m 50_q	59_s 102_s	26_m 50_q 198_s	50_q		
	Supply Contracts	197_q	39_s 50_q 123_s	50_q		50_q 123_s	50_q		
	Wholesale/revenue sharing contracts	39_s 97_s							
Product management	Product variety	187_{sa} 197_q 222_s							
	Postponment	75_s	170_q	170_q	170_q				
	Postpone w/MT S	78_s 152_m 238_s							
	Process sequencing	30_s	170_q	30_s 170_q	30_s 170_q	170_q			
Operations management	Operations	75_s 113_q 190_q	107_s 119_s	119_s 161_s 197_m	107_s	161_s 163_q 197_m			
	Distribution optimization		26_m	26_m 161_s		26_m 161_s 164_d 198_s			
	Inventory policy		2_s 26_m 82_a 123_s 237_a 238_s	26_m 82_a		26_m 82_a 123_s			
	Maintenance policy	84_h			84_h 223_s		223_s		
	Production planning		8_s 26_m 34_h 44_s 84_h 107_s 123_s 169_q	8_s 26_m	107_s	8_s 26_m 34_h 84_h 123_s 164_d 169_q			
	Disruption planning	57_q 168_s	168_s	168_s		118_q 223_s		223_s	
Information management	Information management	162_q 197_q	123_s 170_q	170_q		123_s 170_q	170_q		
Financial management	Value, finance, insurance	13_s 128_{ds} 199_s	13_s		154_s				15_s 22_s 128_{ds} 154_s 178_s

Model technique: $_q$-qualitative, $_d$-deterministic, $_s$-stochastic, $_m$-simulation, $_a$-art.intelligence, $_h$-hybrid

visibility, improved collaboration, risk pooling, postponement, build-to-order, product variability reduction and centralized inventory. Peck (2006) define a SCRM framework and present global perspective research approaches.

Rajaram and Tang (2001) use an extended news-vendor model to analyze impact of product substitution on retail order quantities and expected profits. Iyer et al. (2003) use a two-stage capacity planning model to determine the optimal, regular and demand postponement period capacities and minimize the supplier's expected cost using a demand splitting rule. Sahinidis (2004) advocates global optimization against two-stage and probabilistic, chance-constraint formulations for uncertainty as these generate very large models due to multi-period and multi-stage decisions.

Talluri and Van Ryzin (2005) analyze demand management, single-resource and network capacity control, overbooking, dynamic pricing, auctions, customer-behavior and market-response models, revenue economics, estimation and fore-casting for revenue management with uncertainty.

3.2 Supplier Management

Weber et al. (2000) use multi-objective programming (MOP) to obtain order quantities and data envelopment analysis (DEA) to evaluate their efficiency on multiple criteria. Gaonkar and Viswanadham (2007) present a deviation management model to minimize the supplier expected operating cost and the cost variation, and a disruption planning model to minimize the expected supplier shortfall given disruption scenarios and probabilities. Puigjaner (2008) use multi-stage stochastic mixed integer linear programming (MILP) to devise a model predictive control (MPC) methodology for SC design and financial formulations.

Demand Uncertainty: Huchzermeier and Cohen (1996) develop a stochastic dynamic programming (DP) formulation to determine alternative product and network designs, production capacity, network linkages, hedging costs for switching exchange rates, fixed operating costs, factor costs and corporate taxes. Lucas et al. (2001) propose a two-stage resource allocation model for SC network capacity planning using Lagrangian relaxation and column generation to decompose the large scale mixed integer programming (MIP). Tsiakis et al. (2001) present a MILP model for multi-echelon SC network design under demand uncertainty to determine the number, location, and capacity of warehouse, distribution and transportation facilities and the production and material flow rate. Aghezzaf (2005) propose a two-stage stochastic formulation for strategic capacity planning and warehouse location. Ha (2001) develop a single supplier-buyer contract design model for stochastic and price-sensitive demand to maximize supplier profits with asymmetric costs and a buyer participation cut-off policy. Cachon and Lariviere (2005) compare revenue-sharing, buy-back, price-discount, quantity-flexibility, sales-rebate, franchise and quantity discount contracts for deterministic and stochastic demand.

Levis and Papageorgiou (2004) proposes a two-stage, hierarchical multiscenario, MILP model for long-term, multi-site capacity planning. Santoso et al.

(2005) develop a stochastic programming (SP) method for large-scale SC network design under uncertainty, integrating an accelerated Benders decomposition algorithm and the sample average approximation (SAA) method. Guillen et al. (2005, 2006) propose a two-stage MOP model for SC design under uncertainty that maximizes the net present value (NPV) and demand satisfaction and minimizes financial risk.

Supply Uncertainty: Boccara and Towler (1997) identify the independence of time and profit to the price ratio probability distribution in the petrochemical industry by comparing the residual economic function, NPV and discounted cash flow rate of return. Dasu and Li (1997) use a DP formulation to determine the optimal global production policies with linear or step function switch-over costs (exchange rates, inflation, taxes and tariffs). Sabri and Beamon (2000) develop a MOP planning model for production, delivery and demand uncertainty, that measures cost, fill rates and delivery flexibility performance. Koutsoukis et al. (2000) propose a two-stage SP decision support system for strategic planning under uncertainty.

Van der Vorst et al. (2000) develop a timed coloured Petri-nets based simulation model to evaluate benefits of alternative SC designs. Beamon and Chen (2001) propose a simulation model to derive supplier, production, inventory and transportation flow, costs and times along with operational risk measures. Truong and Azadivar (2005) build a SC model using MIP and genetic algorithms (GA) to determine strategic location, production and transportation decisions. Lieckens and Vandaele (2007) develop a MILP model for reverse logistics network design with stochastic lead times to minimize investment, process, transport, disposal and penalty costs.

3.3 Product Management

Yang et al. (2004) consider uncertainty to be high for strategic production decisions of what, when and how many and low for distribution decisions of where and whom. Likewise, Garg and Tang (1997) develop centralized and decentralized control policies for work/goods inventory using buffers. Mele et al. (2006) propose a discrete event-driven model including a GA, an oriented search and parameters optimization where agents describe SC using a collection of states and transitions.

3.4 Operations Management

Demand uncertainty: Chan et al. (2001) propose a stochastic location-routing problem formulation that uses a queuing network to generate probable demands at each service region. Gnoni et al. (2003) develop a hybrid lot sizing and scheduling MILP and simulation model for capacity constrained production planning with demand uncertainty at various sites, products and periods. Braun et al. (2003) integrate a MPC approach with information sharing, centralization and decentralization with hierarchical, real-time enterprise-wide planning. Xie et al. (2006) model demand uncertainty as fuzzy sets by serializing production and inventory structures backward from end product to raw material facilities.

Operations Uncertainty: Alonso-Ayuso et al. (2003) propose a two-stage stochastic model with branch and fix coordination algorithm for strategic SCM under uncertainty to determine product, production topology, plant size, and vendor selection. Giannoccaro et al. (2003) use the echelon stock concept and fuzzy set theory to model market demand and inventory cost uncertainty. Snyder et al. (2007) use a stochastic location model with risk pooling to optimize location, inventory, allocation decisions with discrete random scenarios and Lagrangian exact algorithm.

Naraharisetti et al. (2008) develop a MILP model for facility locations, investments, technology, production allocation, distribution, supply contracts and capital generation redesign. Neiger et al. (2009) develop the Value-Focused Process Engineering (VFPE) methodology, a multidimensional representation of risk processes, objectives and sources built on Value-Focused Thinking [VFT, Keeney (1992)] and Extended Event-driven Process Chain (e-EPC) process modeling (Scheer 1999).

Disruption Planning: Palmer and Wiseman (1999) use structural equations to disaggregate risk into managerial risk and organizational risk (income related). Craighead et al. (2007) relate SC disruption severity to its density, complexity, and node criticality design, resulting from supply base reduction, global and cluster sourcing, and recovery and mitigation capabilities. Viswanadham and Gaonkar (2008) devise a SCRM framework for risk-tolerant design and post-risk damage containment, integrating supplier failure event propagation, an integer quadratic model for deviation planning and a Markowitz model for partner selection to minimize costs and variability. SC design literature is reviewed in Klibi et al. (2010).

3.5 Financial Management

Miller and Reuer (1996) provide a correlation matrix between three downside risk measures: lower partial moments from historical returns data, downside capital asset pricing model (CAPM) beta, and lower partial moments from stock earnings forecasts. Sodhi (2005) discuss the VaR, demand VaR and inventory VaR financial concepts to devise risk exposure and performance metrics. Aseeri and Bagajewicz (2004) develop upside potential or opportunity value (OV) concept as alternative to the VaR to weigh opportunity loss versus risk reduction. Barbaro and Bagajewicz (2004) develop two-stage stochastic formulations to manage financial risk with planning under uncertainty and analyze trade-offs.

The strategic SCRM review figures qualitative risk assessment frameworks and SP quantitative models. Neural networks are used with early warning systems while two-stage, multi-scenario and MILP models are deployed for long-term, multi-site capacity planning under demand uncertainty. The resulting large-scale problems are decomposed using Lagrangian relaxations. Researchers develop MOP, MPC, GA, VFPE, VFT and e-EPC methodologies employing Poisson process and Monte Carlo simulations for probabilistic scenarios.

4 Tactical Supply Chain Risk Management

Tactical SCRM involves mid-term planning, requiring more accurate estimates, as it can extend from a few days to a year. It has significant impact on the occurrence and outcome of risks and normally based on stochastic processes as the decisions are taken prior to the knowledge of the uncertainty. Tactical decisions include lot sizing, inventory allocation, pricing, cost structure and contract quantity.

Much development can be observed for tactical SCRM within supplier and operations management and less in customer, product, information and financial management. General, demand and supply yield uncertainties obtain major attention while supply costs and production capacity are also explored. Technology, information, disaster and financial uncertainties are potential research areas. Tactical SCRM developments are presented in Table 2 and reviewed hereafter.

4.1 Customer Management

Customer management mainly mitigates demand uncertainty. The stochastic model in Dana (1999) reduces capacity costs by defining higher prices at peak times thereby shifting demand to off-peak times. Hsu and Bassok (1999) develop a downward product substitution two-stage SP model which is decomposed into a parameterized network flow problem where the random product yield and demand distributions are modeled by Monte Carlo generated scenarios. Tang et al. (2004) model the advance booking discount (ABD) program generating better sales and coordination through accurate forecasting and supply planning. Tang (2010) classify and review marketing/demand and operations/supply coordination models.

4.2 Supplier Management

Li and Kouvelis (1999) use the binomial lattice to introduce time and quantity flexibility, supplier selection and risk sharing in supply contracts to obtain optimal sourcing cost with price uncertainty. Cohen and Agrawal (1999) evaluate tradeoffs between the flexibility of short term contracts and fixed investments, and improvement opportunities versus the price certainty of long term contracts. Poojari et al.

Table 2 Tactical SCRM literature

	Mitigation Strategies	Risk agent/risk source							
		Business		Market		Operational			Finance
		General	Demand	Supply yields	Supply cost	Prod. capacity	Information	Disaster	Financial
Customer management	Customer relationship		210_q			210_q			
	Demand shift across time		58_s 211_s						
	Product substitution		99_s	99_s					
Supplier management	Supplier network design	113_q 132_s 176_s	14_s 120_s	14_s 120_s		113_q			
	Supplier relationship	53_s 162_q	206_q	206_q					
	Supplier selection process	117_q	9_a 185_s 234_s 236_s	9_a 185_s	234_s 236_s	185_s			
	Supplier selection criteria	225_a	121_a 208_s 171_h 234_s 235_s 236_s	51_s 171_h 208_s	208_s 234_s 236_s	235_s 171_h			
	Supplier order allocation	177_s	177_s	11_s 23_s 86_s 98_m 181_s 193_s	167_s				
	Supply contracts	126_s	21_s 126_s		138_s				
	Buy back contracts	126_s	126_s						
	Quantity based contracts	126_s	126_s	11_s					
Product manager	Product variety	177_s 182_q	177_s						
	Postpone w/MTO		$95_m 213_s$						
	Postpone w/MTS		17_s 18_s 78_s 95_m 133_s 202_s						
	Process sequencing	113_q	95_m 205_s 208_s 220_s	87_d 173_m 208_s	208_s	87_d 113_q 133_s 173_m			
Operations management	Operations	113_q 143_h 144_h 146_s 147_h	14_s 120_s	14_s 120_s		113_q			163_q
	Distribution optimization		206_q	206_q					
	Inventory policy	24_d 111_m 174_a 175_{hm} 205_s 226_d	24_d 174_a 175_{hm}	111_m					
	Production planning		14_s 125_s 135_s 137_s 171_h 175_{hm} 210_q	24_d 174_a 175_{hm}	111_m				
Information management	Information management	162_q	155_m 208_s	13_s 208_s	208_s	87_d			
	Information sharing		47_m 243_m	47_m					
	Vendor managed inventory		17_s 18_s						
Finance management	Value, finance, insurance		5_d 19_s 93_s 125_s	19_s	155_s	19_s			5_d 19_s 94_s

Model technique: $_q$-qualitative,$_d$-deterministic,$_s$-stochastic,$_m$-simulation,$_a$-art.intelligence,$_h$-hybrid

(2008) develops a two-stage stochastic integer programming (SIP) model for strategic SC resource allocation while calculating performance and risk measures.

Demand Uncertainty: Lariviere (1998) presents a literature review on SC contracting and co-ordination with stochastic demand. Helo (2000) use DP modeling to control surge effect and capacity limitation, study demand amplification to Forrester effect, capacity surge to Burbidge effect, capacity utilization to lead times.

Porteus (2002) study the economic order quantity (cycle stocks), and the newsvendor (safety stocks) inventory models, suggesting dynamic optimization and infinite-horizon models for uncertainty. Kumar et al. (2004) develop a fuzzy MIP model for vendor selection under variability of demand, vendor capacity, quota and purchase value flexibility, and budget allocation to minimize net costs, rejections, and late deliveries. Babich (2006) analyze supplier default risk with competition and diversification, showing advantage of increase in suppliers against retailers normal preference to single-supplier order quantities in the presence of future demand uncertainty.

Wu and Olson (2008) consider three types of risk evaluation models for vendor selection: chance constrained programming (CCP), DEA, and MOP. Component devaluation, price protection, product return and obsolescence risks are modeled. Ozelkan and Cakanyildirim (2009) use a Stackelberg interactive multistage sequential price game framework, to study the reverse bullwhip effect on retail prices due to supply cost variability. Peidro et al. (2010) optimize service, inventory and production costs using a fuzzy MILP model integrating procurement, production and distribution planning with demand, process and supply uncertainties.

Supply Uncertainty: Bassok and Akella (1991) evaluate vendor reliability with quality and capacity uncertainty, and calculate optimal production and raw material order quantities to minimize the total expected cost. Ramasesh et al. (1991) compare dual and single sourcing with reorder point, constant demand, stochastic lead time inventory models. Anupindi and Akella (1993) provide optimal order quantities to minimize backlog costs with two uncertain suppliers.

The expert system proposed in Vokurka et al. (1996) evaluates and selects potential suppliers based on the product importance, quantitative data and qualitative factors. Gong and Matsuo (1997) develop infinite-time horizon stochastic DP for production policy with uncertainty, to control the multistage work-in-process. Kouvelis and Gutierrez (1997) develop a production model with demand and exchange rate uncertainty for two plants supplying two markets. Sedarage et al. (1999) minimize the expected total cost by determining the reorder level and order-split quantities for multiple suppliers with stochastic demand and lead time.

Wu (2010) and later Wu and Olson (2010) present a stochastic efficiency analysis model based on data envelopment analysis (DEA) to characterize the supplier performance concerning risk and uncertainty measures and intangible attributes such as political, legal, economic, socio-cultural and technological features, while using the VaR approach for the vendor selection. Tachizawa and Gimenez (2010) analyze supply flexibility strategies for supplier responsiveness, delivery policy and adaptability considering demand uncertainty and switching costs.

4.3 Product Management

Tayur et al. (1998) discuss quantitative models for supply contract design and evaluation, value of information, product variety and international operations. Grossmann (2005) proposes enterprise-wide optimization (EWO) to integrate and coordinate planning, scheduling, real-time optimization and inventory control using information technology. Tang (2006a) characterize SC operation continuity with resiliency (quick recovery), and efficiency (managed operational risks) and develop a mathematical model to maximize the cost/benefit effectiveness of SCRM strategies. Varma et al. (2007) study the impact of enterprise-wide cross-functional coordination, integrating strategic and tactical decisions for control of financial, inventory and resource deployment on performance, sustainability and growth.

4.4 Operations Management

Demand Uncertainty: The VFT methodology in Keeney (1992) structures strategic objectives and operational objectives, connecting high-level organizational variables to measurable decision variables. Voudouris (1996) propose a MILP model that uses a discrete time representation to simulate scheduling policy, suggesting design improvements for SC flexibility, response time, customer satisfaction and competitiveness. Swaminathan and Tayur (1998) model delayed product differentiation using a two-stage integer program with recourse implemented with structural decomposition and (sub)gradient derivative methods. Inventory postponement strategies for random, correlated demands are analyzed in Aviv and Federgruen (2001a, b) using a Bayesian framework where prior distributions characterize parameters of future demand. Petrovic et al. (1999, 2001) develop a fuzzy analytical model to determine optimal order-up-to inventories and replenishment quantities under customer demand, supplier reliability and lead time uncertainty.

Gupta and Benjaafar (2004) model costs and benefits of delaying differentiation where common products are stocked at the make-to-stock (MTS) stage, and then customized at the make-to-order (MTO) stage, after demand is known. Su et al. (2005) evaluate delivery and differentiation postponement strategies. Leung et al. (2007) develop a multi-site production planning model to minimize overall costs. Battini et al. (2010) propose a framework and analytical model for consignment stock policy design for demand uncertainty stockout and capacity limitation.

Operations Uncertainty: Lee and Tang (1997) model delayed product differentiation strategies to reduce complexity, and increase flexibility and service level with risk-pooling. Persson and Olhager (2002) develop a simulation model to evaluate SC design through total cost, quality and lead-time to improve SC design. Ramdas (2003) develop a framework to provide variety creation and implementation decisions. Aprile et al. (2005) optimize SC configurations with different degrees of process, operations planning and logistics flexibility to respond to production and demand uncertainties. Luhandjula (2004, 2006) survey fuzzy stochastic LP models for possibilistic and probabilistic uncertainty. Liu and Liu (2003, 2005) propose a hybrid algorithm integrating fuzzy random simulations, GA and neural network to optimize minimum-risk problems using Choquet integrals. Julka et al. (2004) propose a multi-agent system (MAS) framework for SC modeling, monitoring and management. Zhao et al. (2002) and Chiang and Feng (2007) develop simulation models and show that uncertainty reduces with SC information sharing in the presence of supply, production yield and demand uncertainty.

4.5 Financial Management

Minegishi and Thiel (2000) use a simulation model to study system behavior and correct instabilities in production systems. Miller (1998) analyze integrated RM including strategic, technology, business and political risks. Agrawal and Seshadri (2000) show that contract design can induce risk averse retailers to select unique contracts, raising retailer orders to the expected value maximizing quantity, maximizing distributor's expected profit. Gupta and Maranas (2003, 2004) propose a real-options valuation (ROV) portfolio framework to hedge against external market uncertainty. Azaron et al. (2008) develop a multiobjective stochastic model for SC design to minimize the total operation cost and variance, and the financial risk which is the probability of exceeding the budget.

The tactical SCRM research focus two-stage SP, DP, MILP, CCP, MOP, MIP, MAS and expert systems, EWO and fuzzy stochastic LP models. Performance measures like VaR, ROV and NPV show substantial potential. Mitigation strategies include demand delay, ABD, supplier evaluation, refund policy, multi-currency financing, inventory control and buffers, multi-supplier, responsive pricing, demand postponement, information sharing, delayed product differentiation, MTS, MTO, risk-pooling, logistics flexibility and exposure assessment.

5 Operational Supply Chain Risk Management

Operational SCRM considers the final stage short-term planning, that involves daily planning requiring accurate transactional data. It is far easier to implement and has lower levels of uncertainty. Operational decisions include order allocations, vehicle delivery matching, task resource planning, and product sales.

Operational SCRM is widely researched, with the literature focusing operations management and gradually reducing from supplier, customer, information, product to financial management. Demand, production capacity, supply yields, general, supply cost, disaster to financial instability are modeled with varying degree of importance. Information and new technology uncertainties are less investigated, exposing a research window. The operational SCRM literature presented in Table 3 is briefly reviewed in following sections and the methodologies summarized.

Table 3 Operational SCRM literature

	Mitigation Strategies	Risk agent/risk source							
		Business		Market		Operational			Finance
		General	Demand	Supply yields	Supply Cost	Prod. capacity	Information	Disaster	Financial
Customer management	Customer	219_s	65_q 211_q 219_s	211_q				211_q	
	Customer relationship		45_s 194_h 204_q	204_q					
	Demand shift across Time		27_d 42_s 66_s 92_q 149_s 204_q	204_q		92_q			
	Demand shift acr. products		204_q	204_q					
	Product substitution	219_s	48_s 219_s						
Supplier management	Supplier	166_q	129_q 211_q	64_q 129_q 211_q				211_q	
	Supplier relationship	117_q 162_q 172_q	35_q 92_q 132_s 188_a 204_q	28_m 29_s 35_q 108_h 204_q		28_m 54_q 92_q 190_d 195_q		28_m 54_q	
	Supplier selection Approval		157_s 158_s 159_s						
	Supplier order allocation	244_s	9_a 74_s 141_a 185_s 191_s 224_s 244_s	3_s 9_a 20_s 141_a 185_s 240_s	96_s 216_s	73_a 185_s			
	Supply Contracts		27_d 204_q	204_q 245_q					
	Wholesale price contracts	36_s 37_s	12_s 36_s 37_s 55_s 56_s 97_s 127_s						
	Quality based contracts	72_s	12_s 67_s 72_s 216_s						
Product management	Postponment	216_s	204_q 244_s	204_q 239_q				239_q	
	Postpone w/MTS		17_s 18_s 78_s						
	Process sequencing	117_q 132_s	20_s 132_s 204_q	20_s 204_q		195_q			
Operations management	Operations	117_q 166_q				1_q 103_m 148_q	148_q		
	Safety measures					150_s 151_s 201_d		6_s	
	Distribution optimization	221_q	45_s 68_s 109_m 142_a 160_m 184_s 242_s	68_s 108_h 109_m 134_h 142_a 221_q		109_m 134_h 184_s 242_s			
	Inventory policy		4_s 7_s 12_s 39s 42_h 70_m 78_h 97_d 117_m 121_m 151_m 192_s 200_s 201_h 203_m 212_m 222_h 229_d 230_a 242_s	192_s 212_m 230_a	49_h 124_d	100_a 212_m 230_a 242_s			124_d 212_m

	Maintenance policy		228_s	134_h 228_s		6_s 134_h 150_s 228_s 233_s		6_s 233_s	
	Production planning	221_q	31_s 33_h 49_h 52_s 61_m 66_h 68s 184_s 185_s 228_s 229_d 232_m	33_h 52_s 60_s 61_m 68_s 108_h 134_h 185_s 221_q 228_s	49_h 77_s	32_m 33_h 52_s 60_s 62_a 114_s 122_d 134_h 184_s 185_s 228_s		61_m	
	Distribution planning		35_q 81_q 211_q 227_q	35_q 64_q 81_q 211_q 227_q 239_q		227_q		70_q 71_q 211_q	
Information management	Information	117_q 156_s 162_q	131_s 204_q 232_m	131_s 204_q	131_s		101_q		
	Short cycle product info.	72_s 105_s	72_s 96_s	96_s	96_s				
	Long cycle product info.	46_s 83_s 139_m							
	Information sharing		16_s 38_s 79_s 80_s 130_s 179_s 214_s						
	Vendor managed inventory		43_s 110_s 130_s 186_m						
Finance management	Value, finance, insurance	183_q	31_s 40_s 76_a 77_s 124_d 200_s 212_m	76_a 212_m	77_s 124_d	10_s 212_m			10_s 124_d 183_q 212_m

Model technique: $_q$-qualitative, $_d$-deterministic, $_s$-stochastic, $_m$-simulation, $_a$-art.intelligence, $_h$-hybrid

5.1 Customer Management

Emmons and Gilbert (1998) study the manufacturer-retailer relationship using the multiplicative model. Van Mieghem and Dada (2001) compare postponement strategies for capacity, production, inventory and pricing under uncertainty with a two-stage decision model. Elmaghraby and Keskinocak (2003) review literature on dynamic pricing and target strategies. McCardle et al. (2004) extend the Tang et al. (2004) ABD model to two retailers, with unique equilibrium sufficient conditions.

Chen and Lee (2004) develop a fuzzy mixed-integer non-linear programming (MINLP) MINLP model for multiechelon SC optimization with uncertain product demands and prices to simultaneously maximize conflicting objectives. Chod and Rudi (2005) find resource flexibility and responsive pricing strategies to respond to uncertain market conditions by capturing favorable demand. Bellantuono et al. (2009) present a model for optimal price discounts and order quantities with simultaneous supplier revenue sharing contract and retailer ABD program.

5.2 Supplier Management

Demand uncertainty: Yano and Lee (1993) review quantitative models for costs, lot sizing, yield and production uncertainty. Fisher and Raman (1996) propose a quick response model for demand uncertainty to plan production in response to initial demand. The DP model in Eppen and Iyer (1997) maximizes the expected profit for backup agreements which penalize backup quantity order failures.

Scheller-Wolf and Tayur (1999) develop a model using Markovian periodic review to order optimal inventory levels for each period and inventory variations as additional orders. Anupindi and Bassok (1999) analyze decentralized systems using information systems. Gurnani and Tang (1999) propose a nested newsvendor model to determine delayed order quantities at two instants for a seasonal product.

Corbett and de Groote (2000) use optimal control theory to derive the optimal quantity discount for an economic lot-sizing problem under asymmetric information. Corbett (2001) derive considerations for adopting cycle, safety, and consignment stocks, based on the order quantity/reorder point (Q, r) model. Zipkin (2000) discuss multi-echelon inventory models and performance evaluation with optimization theory, stochastic processes and DP systems. Svensson (2000) proposes a conceptual framework for vulnerability analysis, comprising disturbance categories and sources. Carr and Lovejoy (2000) devise methods to identify dominated distributions for the inverse newsvendor problem for a fixed supply capacity.

Sakawa et al. (2001) propose a fuzzy MIP transportation model that minimizes the production and transportation cost. Vlachos and Tagaras (2001) develop a periodic review inventory system that uses differed ordering with capacity constraints. Lariviere and Porteus (2001) model the wholesale price frontier based on retailer's price sensitivity and market growth variability, to maximize manufacturer and retailer profits. Lee (2002) salient the need to understand uncertainties to implement new SC strategies. Lin and Chen (2003) develop a two-stage extended GA under supply uncertainty, to control the dynamic orders and allocation to suppliers and retailers. Cachon (2003) review literature for management of incentive conflicts with contracts and Cachon (2004) study the impact of inventory risk allocation. Amid et al. (2006) convert the fuzzy supplier selection MOP into an additive fuzzy LP model.

Supply uncertainty: Agrawal and Nahmias (1998) model optimal lot sizes and supplier number in the presence of yield uncertainty. Tsay and Lovejoy (1999) study the impact of quantity flexibility contracts on forecast and order variability propagation to decide the cost of system flexibility for the greatest benefit.

Olson and Wu (2008) provide a comprehensive review of enterprise risk management (ERM) including financial, accounting, supply chain, information technology, disaster planning and project management. Braunscheidel and Suresh (2009) use structural equation modeling and partial least squares to show disruption mitigation with integration and flexibility. Zsidisin et al. (2004) suggest development of early warning systems and partner engagement to address the increased risks of failure. Blackhurst et al. (2005, 2006) presented a disruption redesign methodology to detect SC conflicts. Babich (2006) study the impact of supply default-risk and default co-dependence on purchase, production decisions. Chopra et al. (2007) suggest cheap suppliers for mitigating recurrent risk and reliable ones for disruption risk.

Operations uncertainty: Wu et al. (2007) propose a disruption analysis network, a network based approach, to model change dissemination through the SC. Methodology testing with larger SC networks using embedded agents is proposed to detect disruptions, early warning events and optimization methods to redesign product flow after disruptions. Fox et al. (2000) manage stochastic events in SCs using MAS architectures that model complex entities and activities. Cohen and Kunreuther (2007) identify co-relations between accident history data and financial information, financial and accident characteristics as valuable. Shah (2005) review process industry planning and scheduling for flexibility and responsiveness.

5.3 Operations Management

Demand uncertainty: Akella et al. (1992) develop approximate policies assuming quadratic cost functions for parts dispatch using a discrete time, multiproduct, multistage production model to minimize inventory costs. Lee and Tang (1998) model operations reversal for variability reduction with product differentiation at final stages. Janssen and de Kok (1999) present a two-supplier inventory model using a (R,S) replenishment policy. A robust optimization model solves stochastic logistic problems in Yu and Li (2000) by using scenario-based goal programming. Jansen et al. (2001) develop a simulation model to quantify performance in a multi-compartment distribution system. Hu et al. (2001) devise a fuzzy SP model for a multiagent SC orders planning problem. Nagurney et al. (2002, 2003, 2005) develop a SC network model using the finite-dimensional variation inequality theory and formulate the derived equilibrium conditions to manage supply and demand side risk.

Bonfill et al. (2004) present a two-stage SP for plant scheduling to maximize expected profit and incorporate variability measures of financial risk, downside risk, and worst-case revenue. Seferfis and Giannelos (2004) optimize SC networks using a feedback controller to maximize customer satisfaction and minimize costs.

Jung et al. (2004) consider a simulation approach using deterministic planning and scheduling models that incorporate safety stock. Ryu et al. (2004) propose a bi-level programming framework for production planning and distribution under uncertainty. Wang and Shu (2005) implement a fuzzy decision model using GA to evaluate SC performances and select inventory strategies. Garcia-González et al. (2007) present a MILP formulation for scheduling of hydroelectric generation using constraints for minimum profit and the minimum conditional VaR (CVaR).

Hung et al. (2006) present an object-oriented dynamic model to capture SC activities and Monte Carlo simulation to evaluate uncertainties. Gaalman and Disney (2006) use state space techniques to study the bullwhip effect produced by replenishment policy reacting to stochastic demands. Villegas and Smith (2006) develop a modified advanced planning system with LP to reduce bullwhip effect.

Suwanruji and Enns (2006) use simulation to compare distribution/material requirements planning, re-order point and Kanban replenishment strategies. Nair and Closs (2006) use Monte Carlo simulations and statistical analysis to test coordinated price markdown policies. Sodhi and Tang (2009) develop a SP based on asset–liability management models for SC planning with demand uncertainty. Wang et al. (2010) use an integrated production planning model to improve SC traceability and performance by optimizing the batch size and dispersion using risk factors.

Supply uncertainty: Escudero et al. (1999) propose a two-stage production planning stochastic scenario analysis based on partial recourse and decomposition. Liu and Kao (2004) develop a method for membership function for the fuzzy transportation cost to decide the cost-effective transport for an order. Choi et al. (2006) formulate multi-stage decision problems using Markovian Decision Processes (MDP) for process control and scheduling. Schmitt et al. (2010) use the newsboy fractile and single stochastic period approximation method for optimal inventory policies.

Operations uncertainty: March and Sharpira (1987) compare risk taking with choice making based on the mean expected value and variance or risk of the probability distributions over possible outcomes. A periodic review production planning model is developed by Ciarallo et al. (1994) to study the impact of external uncertainty on the production process and by Wang and Gerchak (1996) to minimize discounted expected costs with uncertainty. Denardo and Lee (1996) introduce a LP model and a convex nonlinear program (NLP) to optimize uncertainties in a serial production line. Denardo and Tang (1997) propose a proportional restoration rule for disruption recovery to estimate material flow for a stochastic production system.

Hung and Chang (1999) propose a simulation model to compute the standard deviation of production output to determine safety stocks. Bose and Pekny (2000) propose a MPC planning and scheduling framework to incorporate processing time, equipment breakdown and demand uncertainty. Lee and Kim (2002) develop a hybrid analytic model to capture stochastic operation constraints and a simulation model to obtain optimal production plans. Agrawal et al. (2002) select capacity, inventory, and shipments to maximize the retailer expected profit for a product group with supply uncertainty. Deshpande et al. (2004) propose a MAS framework for real-time new order – production task assignment using the fuzzy set approach.

Kleindorfer and Saad (2005) devise a framework for disruption management using standard logistic regression models, proportional odds from Agresti (2002) to estimate the relative change in odds of facilities. Srinivasan (2007) propose MAS, pattern recognition and expert systems to improve agility of petroleum refineries. A simulation-based SP framework and a stochastic GA are proposed in Bonfill et al. (2007) for short-term scheduling with uncertainty.

Disruption Planning: Giannakis and Louis (2010) propose a MAS framework for SCRM and disruption management. Wagner and Neshat (2010) use graph theory to measure the SC vulnerability. Yang and Yang (2010) analyze the benefits and complexity of postponement for RM. Ellis et al. (2010) use behavioral risk theory to relate magnitude and probability of risks within the purchasing domain.

5.4 Information Management

Morgan et al. (1990) present an overview of philosophical frameworks, models and methods for deriving the expected value of uncertainty. Wikner et al. (1991) use a three-echelon Forrester production system to show significant reduction of bullwhip from use of information flow. Lee et al. (1997) analyze sources of bullwhip like demand signaling, order batching, varying prices and shortage game, and mitigation strategies. Iyer and Bergen (1997) develop quick response stochastic models that suggest Pareto improving for service, price and volume commitments.

Gavirneni et al. (1999) study the value of information to compute order up-to levels using infinitesimal perturbation analysis. Johnson et al. (1999) introduce a simulation model for vendor managed inventory. Lee et al. (2000) show high value for demand information sharing with significantly correlated demands. Donohue (2000) use a two-stage newsvendor model to develop supply contracts allowing first stage uncertain forecasts, and fine tuned at the second stage. Cetinkaya and Lee (2000) develop an analytical model to coordinate inventory and transportation decisions for vendor managed inventory. Cachon and Fisher (2000) provide a simulation-based lower bound for the value of information sharing in inventory management.

Chen et al. (2000) develop a stochastic model to quantify the bullwhip using demand forecasting and order lead times. Raghunathan (2001) suggest intelligent use of available order history to eliminate the need to invest in inter-firm information systems. Aviv (2001) propose a two-stage SC model to allow forecast updates at the first stage and collaborative updating at the second stage. Li et al. (2005) simulate a SC to study the anti-bullwhip and lead-time paradox effect on information transformation with autoregressive integrated moving average (ARIMA) demand. Terwiesch et al. (2005) discuss the benefits of buyer supplier cooperation. Sahin and Robinson Jr (2005) use simulation to analyze manufacturer ordering and transportation, and vendor order fulfillment policy integration. Gilbert (2005) and Gaur et al. (2005) develop multistage models based on ARIMA time-series demands.

5.5 Financial Management

Ruefli et al. (1999) suggest CAPM beta, simple variance and variants as measures of business risk. Garcia-Flores and Wang (2002) develop a MAS to simulate the dynamic behavior of chemical SCs and evaluate decisions. Tapiero (2005) identifies the VaR approach as a unified measure for operational risks. Camuffo et al. (2007) use the agency theory to analyze buyer behavior. Andersen et al. (2007) devise a model and use simulations for high performance using strategic conduct. Lai et al. (2008) use game theory to model two deferring modes for inventory risk.

The operational SCRM research focus risk assessment frameworks, MINLP, stochastic DP, two-stage stochastic, fuzzy, MDP, MIP, MAS, ARIMA and graph theory models employing structural equations, partial least squares, log discounted total cost and Monte Carlo simulations. Mitigation strategies include ABD, responsive pricing, inventory risk allocation, order quantity/reorder point, lot-sizing and transport, early ordering, quantity flexibility contracts, supplier selection, collaborative planning, forecasting and replenishment (CPFR), supplier-managed inventory, co-managed inventory, integration and external flexibility and value of information. Supply default risk, downside risk, financial risk and worst-case revenue, CAPM, simple variance and VaR performance measures are researched.

6 Integrated SCRM and Industry Streams

An analysis of the SCRM research evidences two underlying directions. Methodologies that model the business and market risk which are mainly quantitative and those that model environmental, sustainability and obnoxious issues are mainly qualitative. Advances could come from integrating these two areas of research into unified quantitative approaches. This requires development of universal risk measures to aggregate features from other models. Secondly, integrated models are seen to produce very large intractable problems, hence the use of hybrid methodologies is seen to be as an advantage. Some features that could be considered are how to measure flexibility and resilience, how to include geographical and political data, how to integrate product development and configuration, and how to support integration of new resources, suppliers, clients, mergers and separations.

The current review provides an interesting foundation by classifying all such SCRM literature within a common framework. The classification tables identify less developed areas for potential research. While some references model various levels of planning and various types of risks, integrated RM is rapidly surfacing as an unexplored high potential research niche. Efforts in this direction are observed in recent developments. For instance Grossmann (2005) proposed enterprise-wide optimization (EWO) while Varma et al. (2007) analyze the impact of enterprise-wide cross-functional coordination. Both researches integrate strategic and tactical decisions involving control of financial, inventory and resource deployments, on enterprise performance, sustainability and growth. Other recent examples include Peidro et al. (2010) who develop a fuzzy MILP model, and Wang et al. (2010) who propose an integrated production planning model. Despite this progress, integrated SCRM using new technologies and methodologies continues to present substantial research opportunity. Specifically MILP models, neural networks and MAS could provide the right momentum for its development. The following sections consider yet another facet of this problem, namely RM for industry streams.

7 A Shift to the PSC Paradigm

Earlier sections presented the categorized review of the SCRM literature. However this research poorly characterizes vertical industries where their specific nature and requirements must be integrated. The PSC is known for its strategic investment density and rapidly changing market, thereby presenting as a risk prone industry. RM has been studied in the PSC but mainly to the qualitative extent. Hence the identification of risks, mitigation strategies and modeling techniques in specific sectors of the PSC poses as a challenge to which the current state of art does not respond. The second part of this review will provide a brief overview of existing work and pave directions for deploying the SCRM research to the PSC. A major contribution of this research is the transformation of the SCRM framework into a systematic quantitative methodology. The following sections present the PSC, its risks, review literature from the process industry, present the hierarchical RM framework methodology and discuss PSC-RM opportunities and directions.

7.1 The Petroleum Supply Chain

The PSC, being a strategic sector of the process industry, has a specific risk profile far different from the SCRM. The PSC divides into two major areas: upstream and downstream. While the former develops crude oil exploration, production and

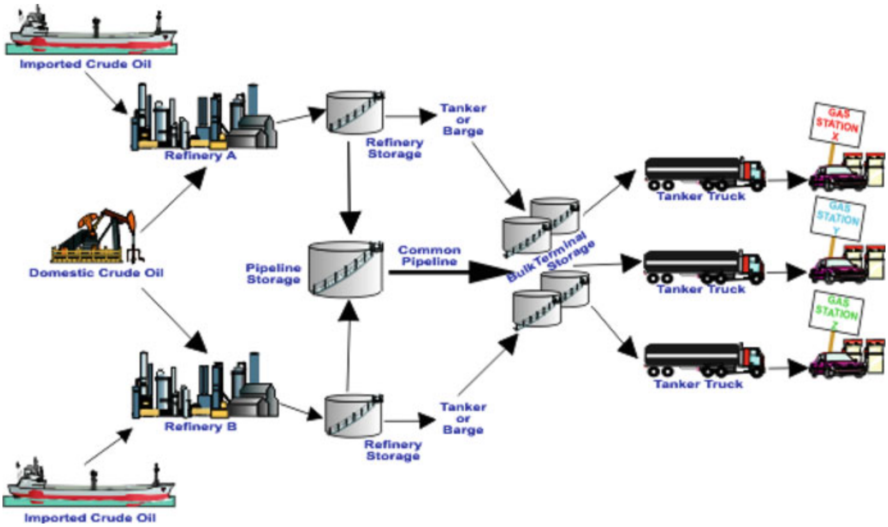

Fig. 2 The petroleum supply chain (Source: http://www.eia.doe.gov)

transportation, the later involves product refining, transport, storage, distribution and retail. These major activities aggregate thousands of processes and equipment where availability and efficient operation is of paramount importance.

The PSC comprises a vast network of tankers, barges, pipelines, railways and trucks that transport crude from the oil fields to the refineries; pipelines, trucks, vessels and wagons transport refined products to distribution centres and finally to retailers which include oil and gas stations, factories, aviation and the service sector including hotels and hospitals which may directly consume or retail the product to end consumers. Storage facilities including above and underground tanks, caverns and offshore storage are located along transportation routes allowing upsizing or downsizing of batches to match further transport mode capacities (Fig. 2).

The complexity associated with such a SC, leads to the existence of different types of risks that need to be accounted for when designing, planning and operating such systems. As the PSC struggles to shorten the business cycle and moves from make to stock to the make to order paradigm due to constant evolution of worldwide economy, an excellent opportunity lies ahead in extending the current planning models to incorporate RM, and build new methodologies for PSC-RM.

7.2 *PSC: Risk Management Challenges*

The PSC is surrounded by ample opportunity but also significant risks in the various realms of its extension. Company damage can come from negative impacts on reputation, operations, finance, safety and regulatory sources. Typical PSC

Table 4 Examples of contingencies in the petroleum supply chain

Source	Disruption	Mitigation strategy
Supply	Product shortage can lead to lower profits due to unmatched orders	Initiate contingency plan and inter-company product exchanges. Prioritize replenishment of product in shortage. Increase reserve capacity.
	Product out of specification can block significant storage capacity of an installation	Suspend reception of contaminated batch. Expedite stock to lower product specification clients. Supply demand from alternate facilities.
Dem and	Excessive demand due to air traffic or harsh winter	Optimize replenishment schedules. Optimize production shifts. Activate alternative supplies.
Operations	Strategic transport ruptures can lead to the SC's prolonged failure	Supply demand from alternate facilities. Switch to alternate mode of transport. Design contingency plan with suppliers and clients
	Safeguard system out of order leading to unsafe operation	Evaluate potential dangers, switch manual mode, strict manual checks. Initiate immediate repair.
	Energy breakdowns can disrupt refineries, storage and production facilities	Import refined product, shift production, use product exchange and insurance, postponement.
Information systems	Information systems failure leads to unavailability of customer orders	Activate redundant systems. Identify problem, initiate maintenance. Use sourcing information for alternate system in worst-case scenario.
	Communication failure due to backbone and infrastructure interruption	Activate backup communications. Initiate immediate maintenance and alternate measures.

disruption scenarios and associated mitigation strategies are identified in Table 4. This is an exploratory list of contingencies aimed at illustrating the variability and dimension of PSC-RM. Much research is needed to provide an exhaustive systematization of the risk scenarios in the wider scope of the PSC.

7.3 References from the Process Industry

As RM literature in the PSC is scarce, research from the process industry is investigated due to its affinity to the PSC. Table 5 provides a classified view of such literature. The investigation shows the use of stochastic and simulation models for demand and supply yield uncertainty, and qualitative and deterministic methodologies for production capacity uncertainty. The absence of RM methodology development for the PSC is notorious, identifying it as a potential area for future investigation. Research from the process industry and PSC is now briefly reviewed.

Table 5 The process industry RM literature

		Mitigation strategies	Risk agent/risk source						
			Business	Market		Operational			Finance
			Demand	Supply yields	Supply cost	Prod. capacity	Information	Disaster	Financial
Strategic risk management	Financial	Value, finance, insurance	13_s 128_{ds}	13_s					128_{ds}
	Operations	Logistics and distribution	123_s			123_s 164_d			
		Supply network design	41_s 89_s 107_s 115_s 116_s 169_q	41_s	107_s			90_s 91_s	
						115_s 116_s 169_q			
		Production, Process planning	107_s 169_q		107_s				
	Supplier	Supply contracts	123_s			123_s			
	Information	Information management	123_s				123_s		
Tactical risk management	Operations	Production, process planning	125_s 137_s 220_s			220_s			
		Logistics and distribution				241_m			
Operational risk management	Financial	Value, finance, insurance	125_s						
	Information	Information management				69_q 70_q 71_q			
	Operations	Safety measures				150_s 151_s			
		Logistics and distribution	152_m			1_h 122_d			

Model technique: $_q$-qualitative, $_d$-deterministic, $_s$-stochastic, $_m$-simulation, $_a$-art.intelligence, $_h$-hybrid

At the strategic level, Neiro and Pinto (2004) model integrated refinery planning, Kuo and Chang (2008) propose a MILP planning model, while Khor et al. (2008) model a two-stage SP for optimal midterm refinery planning considering market demand, price and production yield uncertainties. Kim et al. (2008b) propose a multi-product, multi-refinery MILP planning model that maximizes profits. Carneiro et al. (2010) proposes a two-stage stochastic model for oil network design under demand, supply, cost and price uncertainty to maximize expected NPV and incorporate the CVaR as the risk measure.

Lakhanawat and Bagajewicz (2008) present a refinery planning NLP model to determine crude purchase, production quantities and the final price while maximizes profit under demand and cost uncertainty. The stochastic model is seen to have better upper-bound risk curve, OV, and VaR over the deterministic one. Guillén-Gosálbez and Grossmann (2009a, b) develop a bi-criterion stochastic MILNLP for strategic planning of chemicals under uncertainty, that simultaneously maximizes the NPV and minimizes the environmental impact for a given probability level. Kim et al. (2008a) present a two-stage stochastic/deterministic MILP for network design of a hydrogen SC under demand uncertainty with multiple objectives of cost efficiency and operations safety. Iyer and Grossmann (1998) develop a bilevel decomposition algorithm to solve the master problem for optimal expansion of process networks with demand and price uncertainty in chemicals where NPV is the upper bound.

Applequist et al. (2000) devise risk premium as a measure of return and risk. Sharpe (1991) use the CAPM measure to measure risks considering security to overall market volatility ratio. Meel and Seider (2006, 2008) use Bayesian analysis with copulas to model plant-level real-time risk assessment. Adhitya et al. (2007) use MAS models to study PSC disruptions from crude oil delays, products out-of-spec, plant unavailability, and demand fluctuations. Li and Ierapetritou(2007) analyze pre and post uncertainty, preventive and reactive scheduling methods. Papageorgiou (2009) review process SC design methodologies considering uncertainty and sustainability.

Lababidi et al. (2004) develop a scenario analysis technique using stochastic modeling to control demand, market price, material cost and production yield fluctuations. Lavaja et al. (2006) present a two-stage deterministic MILP and stochastic model for product price and demand uncertainty. You et al. (2009) present a two-stage linear SP model for production and inventory levels, transport modes, shipment times and customer service levels under demand and freight rate uncertainty.

The models discussed in this section are representative of the existing quantitative RM research in process industry. Although PSC is an important industry, it is ironically directed with little research. The main reasons that alienate many investigators are its specificities and specific risk drivers. However, SCRM methodologies could be extended to the PSC-RM. The research framework and classified SCRM literature developed in this review will help investigators identify potential RM research. For example, several mitigation strategies have been identified in the SCRM for production capacity uncertainty. Not all the strategies can be applied to the PSC, but certain strategies are applicable and the SCRM framework does identify models available for that risk/mitigation combination. The research can thus build on these models by improving or extending a particular model to incorporate the specificities of the PSC. The SCRM review and the risk modeling from the process industry open new frontiers for investigation, identifying new opportunities that need to be addressed and are discussed in the following section.

8 A Risk Management Framework Methodology

The former section exposes a need of integrated quantitative modeling for PSC-RM. Fernandes et al. (2009, 2010; Fernandes and Saldanha da Gama 2008) discussed breakdown strategies for systematic risk identification, quantification and mitigation. This section describes a practical methodology that is associated with the hierarchical SCRM framework presented in Sect. 2. Its purpose is to permit the study of SCRM features and project them to the PSC-RM. Figure 3 presents an influence diagram associated with this methodology of systematic capture and modeling of quantitative data through a well-defined process. Uncertain events are represented by circular chance nodes and decision events by square deterministic nodes. The diamond-shaped elements depict the result or the expected payoff for the enterprise.

Hence, the RM process begins by considering a planning level within which the management scopes will be addressed. The risk agent stochastically influences the risk source and the management scope, which consequently direct the mitigation strategy. The risk source stochastically determines the risk objects affected which consequently undermine the occurrence of a risk event. The mitigation strategy influences the risk object and the risk event thereby reducing the risk outcome.

This SCRM framework methodology builds an information model using risk identification and mitigation processes. The risk identification process utilizes the framework to identify and hierarchically relate first the risk agents, second the risk

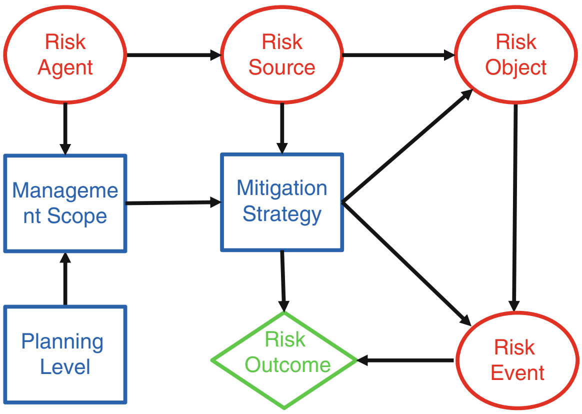

Fig. 3 SCRM framework influence diagram

sources, the risk objects and finally the risk events. Risk elements are identified by asking the following questions: Who initiates the risk? Risk agent; What are the causes of the risk? Risk source; Which resources are affected? Risk object; and How does the risk manifest? Risk event. More specifically, risk agents are the drivers of organizational risks, for example the finance area or the transport activity. Risk sources are the causes of risks, which provide a negative impetus to the risk objects thereby generating a risk. An example of a risk source is the increase in value added tax. Risk objects are resources of an organization, whose malfunctioning would originate a consequence, for example the country tax structure. Risk events are the factual occurrence of the risk thereby resulting in the effective loss, for instance reduced profits. In a nutshell, the framework indicates that the risk agent (financial area) includes a risk source (value added tax) which can affect the risk object (corporate sales) thereby generating a risk event (reduced profit).

The above risk identification process also computes the consequence for each risk agent/source/object/event combination.The remainder risk information is captured by the risk mitigation process. Each risk agent initiates a hierarchical identification of a planning level, a management scope and an appropriate mitigation strategy that could reduce the potential impacts of the risk sources. Planning level provides a timeframe for the mitigation activity, which could be strategic, tactical, operational or contingencial (post-occurrence). Management scope identifies the department within an organization that is responsible for this risk mitigation activity. Mitigation strategies are counter measures that could reduce the likelihood and the consequences of the risk events triggered by the risk sources. Payoff should be estimated for each risk source/mitigation strategy to provide the quantitative data.

The risk elements can be aggregated or decomposed based on their importance and the depth of quantitative modeling required. Considering the PSC, a risk agent α (Operation) could be sub-divided into risk agents $\alpha 1$, $\alpha 2$ and $\alpha 3$, more precisely Transport, Storage and Production operations. The transport operation $\alpha 1$ can be further divided into products transfer $\alpha 11$ and interface transfer $\alpha 12$. The product transfer $\alpha 11$ can be further sub-divided into $\alpha 111 \ldots \alpha 115$, namely, Butane, Propane, Diesel, Gasoline and Jet transfer operations. The same theory can be applied to risk sources. Analogously, the risk object storage can be decomposed into individual product subsystem. Each product subsystem could divide into tubes, tanks and spheres. Finally risk events can also be hierarchised, for instance an explosion is typified by its intensity, duration and time of occurrence. The ongoing demonstrates that the framework methodology supports a flexible and interactive risk identification and mitigation processes that constructs holistic RM information.

9 Opportunities for PSC-RM Modeling

The SCRM review and specifically the presented PSC-RM research, evidences lack of quantitative PSC-RM. The hierarchical SCRM framework and review bear special interest to the PSC as it can help identify risk agents, sources, mitigation strategies and modeling techniques that could be considered for PSC-RM. Risks come from many risk agents and manifest as risk sources such as demand, supply yields, lead times, capacity, supply cost, new technologies, production capacity, information, terrorism, disaster and financial uncertainties. These need to be countered with mitigation at the strategic, tactical, and operational planning levels.

Enterprise wide RM and the extension of SCRM modeling to the PSC-RM realm are seen as promising research areas. Development of proven models from financial, game and agency theory citing VFPE, VFT, e-EPC modeling, CPFR, supplier-managed inventory and co-managed inventory show good potential. Incorporation of well known measures like CAPM, lower partial moments, ROV, NPV and discounted total cost have significant interest for the PSC-RM.

This SCRM framework methodology helps structure the risk management information and opens new frontiers for the development of a quantitative RM model. Among various modeling approaches, stochastic DP, two-stage multi-objective modeling, scenario simulation, GA and MAS are seen as promising PSC-RM candidates. Specifically the agent-based modeling from Adhitya et al. (2007), the multi-stage model from You et al. (2009) and the MPC from Puigjaner (2008) have special interest for PSC-RM due to their proved applicability in the process industry. Similarly EWO in Grossmann (2005), Varma et al. (2007), Wang et al. (2010) and the fuzzy MILP model in Peidro et al. (2010) offer interesting integration possibilities.

Many financial concepts identified in this research, namely the net present value (NPV), opportunity value (OV), value at risk (VaR), real options value (ROV), capital asset pricing model (CAPM) beta, and lower partial moments bear prime importance to develop risk exposure, variability and performance metrics. Future research could use some of the discussed possibilities to evolve from the hierarchical framework methodology to develop integrated quantitative PSC-RM.

10 Conclusions

The current investigation adds to earlier research on methodologies and models on SCRM by developing a novel SCRM framework. The framework is used to present a classified review of the literature on SCRM and process industry RM. The PSC is analyzed identifying some challenges as well as opportunities for RM. The SCRM framework effectively identifies RM methodologies for deployment to other industry situations including the PSC. The hierarchical framework methodology systematically assesses and structure quantitative RM data for any industry. Finally, potential PSC-RM modeling opportunities and directions are considered.

The gap analysis between the SCRM and the PSC-RM identifies many opportunities for future research in PSC-RM. Some of the presented SCRM and process industry RM models are identified as potential candidates for modeling PSC-RM. Major risk agents such as business, operations and finance will be consequently targeted. This effort is directed in developing an integrated model for PSC-RM. In the wake of major changes and stiffer competition, quantitative modeling in PSC-RM could provide major impact, figuring as a business saving opportunity.

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Towards a Supply Risk Management Capability Process Model: An Analysis of What Constitutes Excellence in Supply Risk Management Across Different Industry Sectors

Kai Förstl, Constantin Blome, Michael Henke, and Tobias Schönherr

Abstract Supply risk management (SRM) is on the rise as firms face increased risks due to outsourcing and an increasingly dynamic and complex business environment. Besides, supply chain risks and resulting disruptions are not only related to temporarily enhanced cost, but may endanger the existence of a firm. Many firms from different industries intensified their efforts in SRM during the economic crises. But so far – also because of the difficulty to assess the success of risk management approaches – a process standard for SRM has not yet been defined. Hence, different approaches for SRM in terms of scope, resource intensity and formalization exist, bringing different maturity levels of SRM systems to the light.

In this paper, we contribute to prior research by illustrating a SRM process model. Based on this model we explore the status-quo of best practices across different industries. Based on insights from multiple case studies we elaborate on best practices and the maturity level of SRM processes. The eight identified SRM processes can be clustered into strategic, core and enabling processes. We investigate the supply risk strategy process, the four core practices of risk identification, risk assessment, risk treatment and risk monitoring as well as the three enabling processes establishment of risk guidelines and procedures, IT integration and employee training for supply risk management. Providing an overview over the significant spread of SRM processes proficiency we offer guidance to purchasing executives who seek to develop their SRM towards greater maturity.

Keywords Best practices · Case studies · Maturity · Proficiency · Supply risk management

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1 Introduction

In turbulent times of financial crisis not only capital markets are affected, but also supply markets. Therefore, risk management plays an ever more important role in purchasing and supply management (PSM). Supply management professionals find themselves in a challenging environment. They must contribute to corporate performance through cost savings, working capital effects, and additional key performance dimensions such as quality, flexibility, and security of supply, while they are confronted with increasing supply chain risk and resulting disruptions. The consequences do not simply include direct financial losses, but also reputational damage and loss of goodwill with customers due to interruptions of operations from supply shortages as well as reduction in product quality. In many cases the impact of supply chain risks is much higher than that of internal operational risks (Tang 2006).

As a result of the outlined circumstances and in particular its linking role between external supply markets and the internal customers, the PSM function must take actions to actively manage such organizational risk exposure. In particular, global enterprises which source from a global supply base face these challenges to a notable extent (Wagner and Bode 2006). Within this context we rely on the definition of Zsidisin et al. (2004) who defined inbound supply risk as "the potential occurrence of an incident associated with inbound supply from individual supplier failures or the supply market, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety".

In fact, legal regulations such as the COSO report in the USA, the Turnbull Report in the UK and the German legislation of the KonTraG require firms to identify, communicate, and monitor functional risks (Pausenberger and Nassauer 2000), yet these legislations overlook inter-firm risks. Therefore, these approaches only assure compliance with government legislation, but do not necessarily embrace the growing need to actively manage risks in the supply network. Still the COSO framework and other European initiatives such as the KontraG are instrumental in transforming the discipline from a finance and engineering paradigm to a more company-wide and inter-company paradigm embracing every function (MacGillivray et al. 2007).

To this point in time there is no standard for supply risk management (SRM) established neither in research nor in practice. Across industries and even within one industry, there is a strong variance in SRM process maturity. Establishing and controlling SRM processes is difficult, thus, PSM executives require guidance how to master the strategic challenges they are facing when developing risk management processes for their global supply management organization.

Therefore, we developed a model that allows comparing SRM processes across companies of different industries in order to sharpen the conception of what distinguishes initial, basic, moderate, capable and superior SRM processes. The two specific research questions to be addressed in this paper read as follows:

1. What constitutes best practices in supply risk management across industries?
2. How does the proficiency of supply risk management processes differ across firms?

By addressing these research questions, we contribute to the gradual build-up and diffusion of knowledge concerning SRM processes and standards. In the model we break down the concept of SRM into eight processes (see Fig. 1). Thus, we assess the proficiency of the following eight SRM processes: 3.1.1 supply risk strategy, 3.2.1 risk identification, 3.2.2 risk assessment, 3.2.3 risk treatment and 3.2.4 risk monitoring as well as enabling processes such as the 3.3.1 establishment of guidelines and procedures, 3.3.2 IT integration and 3.3.3 training for supply risk management.

The model allows exploration of the status-quo in SRM processes across firms of different industries displaying commonalities and differences between them. Based on the results of eight case studies from different industries we seek to provide guidance to purchasing executives who seek to develop their SRM process to enhanced maturity and effectiveness. The findings are valuable to a broad audience since we offer an overview of best practices in SRM across industries providing purchasing executives with a process benchmarking opportunity leading to the disclosure of paths for further improvement of their functions SRM capabilities.

The article is structured as follows: Firstly, the supply risk management literature will be shortly reviewed to develop the scoring grid for the SRM process capability assessment. We shortly elaborate on the multiple case study method enabling us to rate the proficiency of SRM processes of firms along the eight dimensions displayed in Fig. 1. Afterwards, we will present the results of this

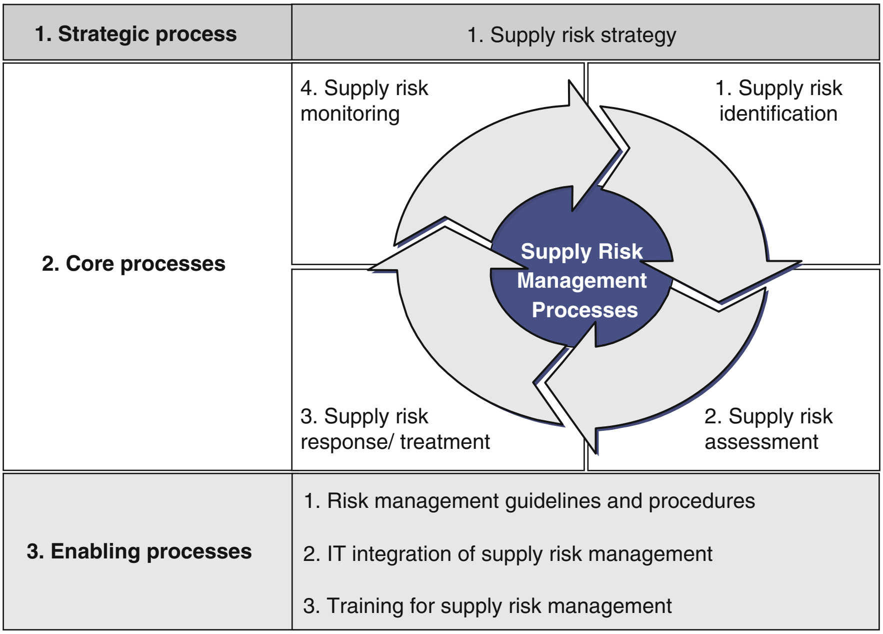

Fig. 1 The supply risk management processes

investigation focusing on the best practices across firms. After condensing our findings the paper provides implications for management practice.

2 A Review of Supply Risk Management Literature

Risk management in supply chains is of growing importance. Essentially, scholars agree on the trends for this development: supply chain risk has grown (Juettner et al. 2003), not only due to environmental uncertainty (Wagner and Bode 2006), but also due to increased reliance on supplier production as part of firms' value adding processes (Harland et al. 1999; Christopher and Lee 2004). However, the separate research stream and discussion on SRM has emerged only recently (Zsidisin and Smith 2005; Kull and Closs 2008).

Recent contributions highlight that firms must enlarge the scope of SRM beyond the risk inherent in direct or first-tier supplier relationships to the risk inherent in the entire supplier network. Despite these valuable contributions, knowledge about best-in-class SRM is not well developed for two eminent reasons: (1) Several scholars only discuss specific SRM practices of the recurring SRM process, which provide a valuable, yet scattered and less process-oriented picture of SRM. E.g. Khan et al. (2008) discuss product design as risk mitigation strategy for supply chains. Other contributions focus solitarily on supply risk assessment techniques (Zsidisin et al. 2004), early supplier involvement and risk (Zsidisin and Smith 2005) or supplier development as a supply risk mitigation strategy (Matook et al. 2009). (2) Only limited qualitative research on SRM emerged presenting detailed cases on how leading companies design their SRM processes. An exception is the contribution of Norrman and Jansson (2004) which elaborated on the whole SRM of the firm Ericsson. Also, Zsidisin et al. (2005) focused on the whole process of business continuity planning with high commonalities to a risk management process.

We recognized that an approach that allows an integrated analysis of strategic, core, and enabling SRM process prevalent in companies across multiple industrial sectors is missing. To shed light on this we build on the supply chain risk management processes by Ritchie and Brindley (2007), when defining the SRM processes (see Fig. 1). Moreover, we combine insights from the above mentioned contributions and beyond when developing the evolutionary phases of proficiency in SRM.

The concept of maturity or proficiency suggests that organizations follow an identical sequence of changes towards greater maturity, consecutively integrating the achievements of earlier stages. As they pass through these stages, functions and organizations ultimately reach maturity, which is expected to result in enhanced performance effects of the respective processes (Keough 1993; Rozemeijer 2008). We relate our work to MacGillivray et al. (2007) who developed a comprehensive benchmarking of enterprise risk management (ERM) capabilities in the water utility industry. Based on the literature review we tailored their approach to the field of PSM as presented in the following section.

3 Development of the Supply Risk Management Capability Maturity Model

In our approach we adopt the notion that a firm which adopts and invests in strategies for managing supply risks it faces will do better than firms that do not pursue an active management of supply risks. Our assessment distils SRM in a process-based framework which enables a firm to establish their current level of maturity and to identify the necessary steps to progress to a higher maturity level. Hence, the assessment according to our process-based model provides guidance to PSM managers how to better analyze supply risks leading to better risk response decisions and an effective monitoring of supply risks across the supplier portfolio. The attributes of the eight sub-processes of effective management of supply risks are below.

3.1 Strategic Process

3.1.1 Supply Risk Strategy

Firms with a formally developed and documented strategic plan consider risk in their supply network design, supplier selection and supplier order allocation. Supply risk strategy provides category management with risk tolerability thresholds, assuring congruence and integration of risk criteria in supplier management decisions. To enable aligned development and implementation of supply risk strategy with other functions purchasing needs to be a member of the highest corporate risk management board. A regular interaction between SRM interaction, ERM and internal clients assures that the PSM function effectively acts as a catalyst between internal clients and supply markets in risk management and prevents SRM in a functional silo. This process also requires that purchasing top-management considers SRM as one of their core responsibilities to be guided by a direct reporting line to ERM.

3.2 Core Processes

3.2.1 Supply Risk Identification

To identify supply risks purchasing category management should recurrently revisit risk checklists in subsequent processes. This process should be complemented by risk identification tools and techniques such as scenario analysis or brainstorming which enable risk for unforeseen risks. This process requires stakeholder involvement from functions such as R&D and manufacturing at different stages of the procurement process as not all risks might directly appear in purchasing. For instance, in the sourcing of materials and services required to develop a new product purchasing should identify risks in cooperation with R&D whereas in the recurring procurement of components for serial production it is important to involve the manufacturing plants in risk identification. The identified risks need to be documented and disseminated to the respective functions involved in handling supply risk.

3.2.2 Supply Risk Assessment

After identifying supply risks, the next step is to conduct a detailed supply risk assessment. PSM should analyze the assessment process and techniques across purchasing category management and determine responsibilities. The risk assessment may require input from other functions in order to determine a valid analysis of supply risks considering tolerability thresholds provided by top-management. This assessment is based on the likelihood and the impact of occurrence of adverse events in a supply risk matrix. The integration in IT tools such as supplier evaluation or supplier relationship management enables the timely assessment, documentation and reporting of supply risks, which in turn must be considered a success factor for timely development of response strategies.

3.2.3 Supply Risk Response/Treatment

Having derived the supply risk profile, firms must consider ways of responding to the respective risks and their damage potential. Based on cost and benefit analysis, PSM management and/or top management must decide upon a suitable reaction strategy such as risk prevention, risk reduction, risk transfer or risk bearing to bear part of the risk. These supply risk treatment options are typically executed in supplier and purchasing category management processes, but may also require the involvement of internal clients such as R&D, manufacturing or marketing.

3.2.4 Supply Risk Monitoring

The PSM function is required to monitor the effectiveness of its risk responses and the risks development over time. The response to severe supply risks tend to be managed in a project structure also including project monitoring. Supply risks have to be closely monitored by category management, but may also be part of reporting to the CPO or the risk and corporate board. Moreover, the greater the damage potential, the closer this particular supply risk must be monitored at the supplier level. Implementation of monitoring is supported by IT integration which enables timely information about the effectiveness of supply risk treatment strategies and the development of supply risk exposure over time.

3.3 Enabling Processes

3.3.1 Risk Management Guidelines and Procedures

The SRM guidelines serve as a means to define and document risk tolerability thresholds, responsibilities throughout the strategic and core processes as well as the involvement of ERM and internal stakeholders in the process. Because of the cross-functional nature of SRM, the PSM function must assure that its guidelines are compatible with ERM specifications, which is further expected to drive the acceptance of SRM throughout the entire organization.

3.3.2 IT Integration of Supply Risk Management

IT integration assures that PSM staff is not using tools and techniques which apply unique terminologies, scoring systems and ways of presentation of damage potentials and outputs. Furthermore, IT integration assures an interface between risk analysis, treatment and monitoring and improves efficiency of processes. IT integration requires user training and is ideally part of existing supplier management tools to foster establishment and implementation of risk culture and dissemination of risk assessments throughout the organization.

3.3.3 Training for Supply Risk Management

This process is important to create risk awareness among PSM employees and provide them with the necessary skills to identify, assess, treat and monitor supply risks. Such trainings may be even subject to certification. In addition, the training should be company-specific and related to the tools and techniques used in SRM. Depending on the degree of cross-functionality of SRM process, internal clients and ERM must be involved in the conception and execution of trainings.

3.4 SRM Process Proficiency Levels

We differentiate five maturity levels, which are applied to determine the proficiency of each of the eight SRM processes.

Initial (1). Unstructured and ad-hoc approach of SRM. Limited knowledge prevents processes implementation, thus the process depends strongly upon individuals.

Basic (2). A minimum understanding of the risk concept and the necessity of active risk management is established. Basic and not fully defined processes with a narrow scope are in place. These processes are repeatable which lead to the possibility of further improvement and provide opportunities to further enhance the SRM process proficiency in general.

Moderate (3). SRM processes are specific assigning clear responsibilities to PSM employees and beyond. Policies and procedures are available to all staff (also from other functions) promoting controllability of the processes. Supply risks are identified, assessed, responded to and monitored, yet the quality of individual processes is still variable. Continuous improvement is constraint by the enhanced focus on the execution of the relatively young processes. Risk management training and tools are available for designated employees.

Competent (4). A structured approach for all relevant SRM processes assures the effective and coherent implementation across category management. SRM processes are cross-functional if required involving experts from functions R&D and marketing at different stages of the sourcing and procurement processes. Advanced IT integration and risk management training foster the implementation of SRM in regular supplier evaluation processes.

Superior (5). Firm's having attained the highest maturity level, are characterized by their ability to simultaneously focus on execution excellence of all SRM processes and the adaptability of these processes to changing conditions such as the financial crisis. The PSM function learns from past experience and adapts their SRM processes accordingly. Processes reach across organizational hierarchy and across functional units at the different stages of the procurement process such as item specification, supply strategy development or supplier selection and implementation. IT governance enables effective monitoring of supply risks at supplier level. A strong risk management culture is present due to long term investments into SRM staff and processes.

4 Research Method

A multiple case study approach was selected in order to explore the process standards in SRM across firms. The cases were selected to attain insights into SRM practices of firms from different industries. Ultimately, the purchasing executives of 15 European MNCs were approached via email and follow-up telephone calls to ask for their cooperation in the project (Dul and Hak 2007). Out of these 15 firms 8 agreed to participate in our study and provided access to purchasing executives and archival data on condition of anonymity. The profile of the participating companies is provided in Table 1.

We relied on on-site visits, semi-structured interviews with purchasing executives and collection of archival data between August and November 2009. The approach appeared to be most suitable to the purpose of this study, since research on how SRM processes are structured in organizations is still in an exploratory stage. Moreover, SRM involves the coordination of complex organizational processes which sometimes required clarification and follow-up questions. The interviews with at least one high level purchasing executive responsible for SRM lasted

Table 1 Profile of respondents' organization

Company name[a]	Banking	Insurance	Fashion	Energy	Logistics	Electronics	Health care	Automotive
Number of employees at group level	>50,000	>10,000	<10,000	>50,000	>200,000	>100,000	>50,000	>200,000
Annual sales revenue in 2007 in € (billion)	>20	>5	>5	>5	>50	>10	>10	>10
Total headcount in PSM	>50	<50	>100	>500	>2,000	>100	>100	>2,000
Purchasing volume in € (billion)	>1	<1	<1	>5	>10	>5	>5	>10

[a]Original company name is disguised, but the chosen name is based on each firm's industry classification

between 1.5 and 2 h and were conducted by the same author. Notes of answers and on presented documents, such as risk management guidelines, supplier scorecards, were taken during the interviews. Right after the interviews notes were written up, data was aggregated, and stored in a coded case data base. The authors independently rated the maturity of the respective processes for each company. These observations were compared by the team of authors to assure inter-rater reliability (Gibbert et al. 2008).

5 Discussion of Firm Cases Based on Their Assessment in the SRM-CMM

We describe the observed proficiency across our sample for each SRM process. In Fig. 2, the minimum, the maximum and the median score per SRM process is depicted. Our preliminary analysis provides evidence that our sample profiles are relatively mature in the strategic, core and enabling processes. The maturity scores range from maturity level (ML) 2 to 4. Thus, all companies have achieved SRM processes beyond the initial proficiency level, yet none of these PSM functions has achieved superior SRM processes. For more profound insights at individual case level we discuss the results along the eight SRM dimensions in the subsequent sections.

5.1 Strategic Process

5.1.1 Supply Risk Strategy

The supply risk strategy provides guidance for the SRM core processes and should be coherently derived from ERM strategy and supply management strategy. Here,

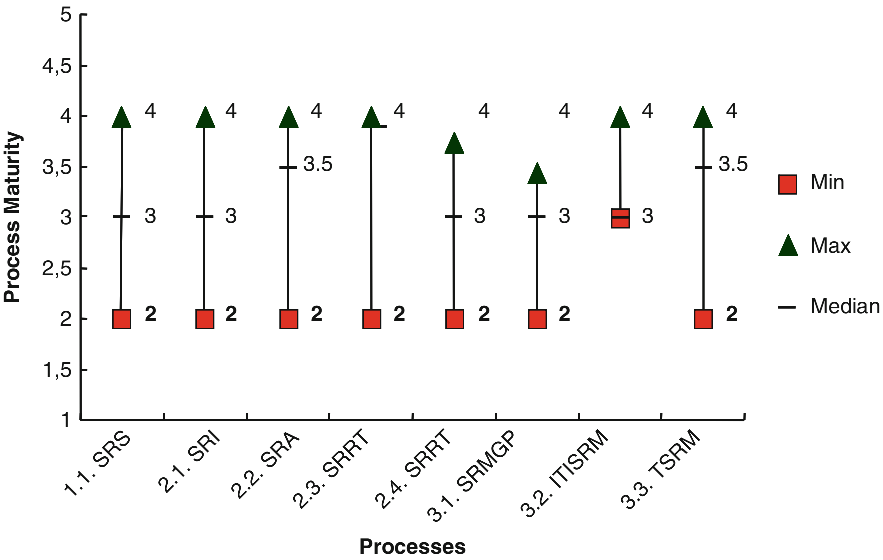

Fig. 2 Boxplot of supply risk management process maturity

we observed two firms at level two, five firms level three and one firm (ElectronicsCo) level four.

At the basic and average practice firms, the supply risk strategy is defined and disseminated to a limited group of employees. Therefore, not all employees are affected in their job, which prevents the implementation of a risk culture. Also, the limited availability of resources at top-management level to define strategy and to document subsequent processes in form of guidelines limits the ability to verify risk strategy implementation. A major improvement area is the link to the ERM system, which so far only BankingCo has proficiently established.

In our sample ElectronicsCo can be considered best practice. The firm follows an exhaustive strategy process. Strategy gives guidance across purchasing categories and provides risk tolerability criteria for the different purchasing categories At ElectronicsCo the risk strategy process is transparent and its outcome is made readily available for every purchasing employee and other parties involved in the process putting them in the position to transform strategy into practice. It enables the procurement organization to mitigate risks in a systematic manner and to ensure that different units of the procurement organization act coherently. It provides later process steps such as risk analysis and monitoring with guidance and risk tolerability criteria, which enables all affected members of the organization to interpret supply risk in a similar way – and to manage risks consistently. To achieve such coordination the supply risk strategy is derive from procurement strategy. Additionally, ElectronicsCo already has established a solid review and improvement process for supply risk strategy so that everyone in the organization is invited to contribute to the learning and professionalization of SRM processes.

5.2 *Core Processes*

5.2.1 Supply Risk Identification

Here three firms were evaluated at ML2, two firms where evaluated at ML3 and three at ML4. AutomotiveCo, the best practice firm, uses a future, present and past oriented supply risk KPI system. Based on a scorecard of 15 risk KPIs, supply risks are recurrently identified. The combination of recurrently assessed early warning indicators with brainstorming workshops beyond the pre-defined risk dimensions enables a truly proactive identification of potentially harmful incidences to the procurement function and the organization as a whole. The strong reliance on just-in-sequence production is a driver of this approach to supply risk identification. At AutomotiveCo, category management allocates time quarterly or even monthly to identify potential threats in supply markets and at specific suppliers. The data are centrally registered and disseminated to all involved parties in the procurement process. Moreover, the risk identification process is cross-functionally coordinated with R&D, production plants and logistics.

A further noteworthy process is established at BankingCo which attained close alignment of supply risk identification with ERM procedures. This fact is due to the legal obligations by banks to systematically and recurrently identify risks (Basel II). The identified risks are then centrally stored and must be closely monitored, whereas identified risks with a high operational impact must be actively managed in subsequent processes. So far, the firms of lower ML are mainly characterized by limited documentation and dissemination of identified risks and a missing link to ERM or even central supply management.

5.2.2 Supply Risk Assessment

Here we observed two firms at ML2, two firms at ML3 and four firms at ML4. Specifically, LogisticsCo, HealthCareCo, and EnergyCo provide interesting insights.

At LogisticsCo different parties are involved in the assessment of risks at different stages of the sourcing process. The cross-functional assessment allows a sound assessment as some risks might not appear to procurement professionals, but to internal clients. A very important question is how firms assess or quantify risks? HealthCareCo and EnergyCo assess risk or potential damage by the multiplication of probability of occurrence with the potential financial damage caused by the probabilistic adverse event. The financial impact caused by an adverse event is quantified (or approximated) by the purchasing volume. The probability of occurrence is usually rated on an interval ranging from one (very unlikely) to five (very likely). This assessment is usually conducted by the above mentioned experts from the involved functions.

LogisticsCo operates a slightly more sophisticated system that further develops the probability times impact assessment logic by a third measure: the ‘mean-time to repair’ which can be considered as a derivative from the failure-mode-and-effect analysis. It considers how long it will take to reinstall the state prior the adverse event.

Moreover, some of our benchmarking partners also started to look deeper into the bankruptcy probabilities of their suppliers as a result of the financial crisis. In order to detect these insolvencies as early as possible best practice firms rely on a combination of external data such as the Z-Score, Dun&Bradstreet data and internal KPIs. Especially, FashionCo and AutomotiveCo emphasize the assessment of liquidity and financial strength of their suppliers.

Firms tend to allocate more and more resources to the assessment, because they are aware that risk assessment is necessary to detect the most critical suppliers. Therefore, the assessment covers the entire risk checklist and beyond if new risks are identified or new suppliers are qualified. The firms with high proficiency in the process demonstrate that risk assessment has to be integrated in supplier relationship evaluation in order to work effectively. At the best-practice firms the risk assessment is integrated in the IT tool such as supplier performance scorecards. Thereby, risk management and in particular risk assessment becomes part of routine processes which fosters acceptance and also improves handability in terms of workload.

5.2.3 Supply Risk Response/Treatment

Identified and assessed risks need to be actively managed. The supply risk response decides whether a risk will be reduced or not. Here, we evaluated two firms at ML2, two firms at ML3 and four firms at ML4, thus half the assessed firms show competent level.

Both AutomotiveCo and ElectronicsCo rely on pre-defined responses and treatment strategies. Even though the detailed measures are decided upon by decentralised units, strategies are pre-defined according to the potential damage and the dependence on the supplier. E.g. AutomotiveCo strongly focuses on supplier development in case a high risk arises. Supplier development may be costly, yet it is a favoured strategy due to the difficulties and barriers to switch suppliers once they manufacture for serial production. If financial support in times of supplier financial distress is necessary to keep up production, AutomotiveCo provides help for strategic suppliers. But whenever possible, AutomotiveCo switches to establish back-up suppliers. HealthCareCo desist from providing direct financial support to their suppliers. They prefer to pay the short-term debt of the first tier supplier directly to the second tier in order to keep up the flow of material. Also, ElectronicsCo and EnergyCo apply risk treatment strategies after engaging in a cost-benefit analysis of possible risk management strategies that range from supplier phase-out to direct financial support to the supplier.

5.2.4 Supply Risk Monitoring

For supply risk monitoring we evaluated two firms at ML2, three firms at ML3 and three firms at ML4. Supply risk monitoring is the process guaranteeing that SRM is practiced continuously.

The mature firms show that supply risk monitoring must integrate all relevant categories and all relevant supply risks. Only if a regular check of all risks across purchasing categories is established, the SRM can function as an early warning system, increasing the reaction time in cases of short-term changes in the supply risk portfolio of the firm.

All firms show that the monitoring cycles should be related to the damage potentials. The general monitoring cycle of BankingCo is twice a year, ElectronicsCo and AutomotiveCo monitors quarterly and AutomotiveCo monthly. In case of high risks the assessments cycles are shorter. AutomotiveCo and BankingCo use the traffic light principle in order to make the monitoring intuitive for the users. As in the other core SRM processes it is important to integrate the internal clients. HealthCareCo has integrated the monitoring and reporting in its supplier evaluation tool. Once a high risk is detected the degree of implementation of the risk response milestones are monitored and reported within the IT-tool. In addition to this project-based monitoring a recurrent trending of the supply risks over time is in place. It compares the risk assessments at individual supplier level over time which enables a longitudinal risk performance picture of each supplier.

5.3 Enabling Processes

5.3.1 Risk Management Guidelines and Procedures

Here we observed two firms at ML2, five firms at ML3 and one firm at ML4. The firms with mature processes show that it is also decisive for SRM to assign clear responsibilities of involvement. This is necessary for all sourcing processes as risk management is not a separate process, but has to be integrated throughout. At HealthCareCo a strong top-down alignment is one a major success factors to achieve compatibility with procedures and tools with the of ERM standard. At AutomotiveCo, several guidelines regarding SRM on different hierarchy levels exist (board guidelines as well as supply chain manual). Moreover, for effective alignment and applicability of guidelines a member of the corporate purchasing function has been appointed to join the most senior corporate risk management board. Also BankingCo relies on comprehensive guidelines that are derived from corporate risk management.

Guidelines define – e.g. at HealthCareCo – criticality thresholds which trigger the hierarchical reporting of risks. This limits responsibilities not only to procurement, but extents it to the whole firm. In addition we found the guidelines to specify the re-assessment an reporting intervals which shorten as the damage potential rises. The same logic applies for the reporting frequency.

5.3.2 IT Integration of Supply Risk Management

Concerning the IT integration of SRM processes we observed five firms at ML3 and three firms at ML4. It seems that IT integration is the facilitator for efficient SRM especially in the assessment and the monitoring processes, while it also facilitates the other core steps of SRM. At ML3 the IT integration is enabled by an Excel tool since integrated software solutions for SRM are lacking. These risk assessment tools often enable the involvement of different functions and sometimes provide automatic import and export of supplier specific data from and to the supplier evaluation tool. This is the case at BankingCo, FashionCo, LogisticsCo, and EnergyCo.

At firms of greater maturity such as ElectronicsCo and FashionCo, employees can enter their risk identification and assessment in a tool which centrally stores all information. This assessment is linked to supplier level evaluation scorecards which shows that IT has not only a supportive, but also an integrative function. Thus, a mature IT integration leads to a better interface between supply risk assessment and the subsequent risk treatment strategies. At HealthCareCo, the supplier management tool enables the lead-buyer to set-up specific risk treatment projects which enable the tracking of risk management KPIs in the regular supplier management software that purchasing professionals use in their daily routines. The risk owner is enabled to implement a reporting structure to internal clients, corporate risk management and direct supervisors. Thus, IT integration is a mean to disseminate and control risk management information flows, while integrating SRM in purchasing professionals' daily job-routines.

5.3.3 Training for Supply Risk Management

Here, we observed two firms at ML2, five firms at ML3 and one firm at ML4. As SRM cannot be successful only by using tools, it is necessary to integrate risk in the understanding of procurement staff. Training guarantees a sustainable SRM approach as our best practice firms' show. Such training events also create risk awareness and sensitize employees to the issue. Different SRM training and qualification concepts exist at our case companies. At LogisticsCo the tailored SRM workshops fostered the gradual development of a risk culture within corporate supply management. Whereas LogisticsCo invited external providers to train their purchasing staff for the SRM tool, others use internal risk management specialists to train purchasing personnel. For instance at AutomotiveCo the SRM training is part of the mandatory trainings for PSM employees. This training is given by internal specialists within the range of courses taught at their corporate supply chain academy.

While it is important to look at the most suitable qualification concept (internal vs. external trainers), it is crucial to include relevant content in the SRM trainings. From the interviews it became clear that it is wise to combine a hands-on SRM IT-tool oriented training with a broad and conceptual training to sensitize participants why SRM is necessary. This is approach was pursued by AutomotiveCo, HealthCareCo, and LogisticsCo.

The other firms tended to focus on the tool-based training, e.g. InsuranceCo and BankingCo. Throughout the interviews it also became clear that SRM is still in development stage at our case companies since often only 50–70% of the SRM tool users had been trained for application. In other cases the conceptual training had been exclusive to lead-buyers or category managers.

6 Conclusion and Implications for Management Practice

From the investigation it has become clear that SRM decides especially in turbulent times about the strategic contribution of supply management to firm performance. We have seen in eight cases from different industries where processes and capabilities differ in terms of proficiency. We also found common ground and standards in SRM processes across industries.

In order to provide the opportunity for practitioners to compare their SRM proficiency to the best-in class we listed best-practices for strategic, core and enabling SRM processes throughout. Since SRM is not a simple tool, but rather a complex capability that is broken down into more finite sub-processes, firms must install stable processes in order to react to changing environments as the financial crisis as shown. As change is persistent, so is risk. Thus, the way to proactively manage supply risks is to establish a solid understanding about the own firms proficiency in SRM. We believe that this benchmarking enables firms to position their processes relative to their industry peers and to firms from other industries. From this starting point managers can now set targets for improvement of their firm's SRM process proficiency. Moreover, we believe that this cross-industry picture of SRM processes supports beginners in the field in setting-up stable SRM processes, which are receptive to external stimuli and are able to effectively detect and manage risk before the next shock strikes their company.

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Enterprise Risk Management from Theory to Practice: The Role of Dynamic Capabilities Approach – the "Spring" Model

Amerigo Silvestri, Marika Arena, Enrico Cagno, Paolo Trucco, and Giovanni Azzone

Abstract Enterprise Risk Management has come to the forefront as an essential device for assessing business threats, opportunities, and their impact on the creation of value. In this context, this chapter attempted to propose an operational ERM frame-work, the "Spring" model, which is specifically aimed to support the transition of ERM from the governance sphere to the operational units.

Keywords Enterprise Risk Management · Governance

1 Introduction

Over the last 10 years, Enterprise Risk Management (ERM) emerged as a new paradigm for identifying and managing risks (e.g. COSO 2004; Beasley et al. 2006; Olson and Wu 2007; Kajüter et al. 2007; Power 2007). It is centred on the idea of risk management as a process that crosses the entire organization, designed to identify potential events that may affect the achievement of entity objectives (COSO 2004).

Initially developed under the influence of major regulatory programmes (Spira and Page 2003), ERM gained rapidly the attention of both researchers and practitioners, as confirmed by the growing number of publications dealing with this issue. Professional associations and public bodies have proposed approaches and guidelines for implementing ERM systems (e.g. AIRMIC, IIA, PRIMO), and the websites of consulting firms have devoted increasing space to services related to ERM (http://www.pwc.com; http://www.kpmg.com; http://www.deloitte.com; http://www.protiviti.com).

Today, after a few years from the official formalization of the ERM concept in the COSO Framework (COSO 2004), we can say that the idea on which it founds is well known among different economic subjects and it is widely accepted by both

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companies and regulators (e.g. Sobel and Reding 2004; De Loach 2004; Nocco and Schultz 2006; Woods 2007). The conception of integrated risk management, which is at the basis of ERM, is looked at as a possible answer to avoid that the crises occurred in the past decade could happen again. The adoption of ERM systems has become a blueprint of good governance and ratings agencies have introduced ERM analysis into the corporate credit rating process (Standard and Poor's 2008). Henceforth, in several companies, ERM has entered the agenda of audit committees' meetings (KPMG 2009; PWC 2008) and corporate websites and official reports often devote specific "ERM sections" to how organizations manage risks.

However, if we look at the cases of ERM implementation, we find that the label ERM can be seen as "an umbrella" (Mikes 2009) under which there are several diverse risk management techniques and arrangements (Lam 2003; Power 2007; Mikes 2009). Power (2007) looks at ERM as an evolving assembly of practices and Mikes (2009) highlights the existence of systematic variations in ERM, by which ERM systems appear mainly as an adaptable mix of different types of risk management tools.

Furthermore, the extent to which ERM succeeds in leaving the high level governance sphere and really penetrate the firms' operational levels is still questionable. Additionally, analysing the ERM literature, we can find only few contributions exploring how ERM works in practice, while most of the extant research deals with the role of ERM in the corporate governance debate (e.g. Scapens and Bromwich 2009). This circumstance can be explained in the light of the recent governance reforms, which reflect a view of corporate governance, internal control and risk management as three inter-dependent elements (Woods 2009). The COSO Framework actually finds its conceptual foundation in the COSO guidance on internal control, published in 1992 after the scandals related to fraudulent financial reporting occurred in the mid-1980s (COSO 1992). The boundaries between the concepts of internal control and risk management are not neat, and it is not always clear whether risk management is a component of the internal control system or vice versa, but risk management is generally considered an integral part of the corporate governance process (McRae and Balthazor 2000; Woods 2009). Maybe informed by this view, several managers continue to look at risk and compliance as two sides of the same coin, reflecting a "common, organizational focus on managing risk to prevent known, historical business failures rather than to anticipate likely (or seemingly unlikely) game-changing events" (PWC 2009). In many cases, risk management is treated as an afterthought, to be considered in conjunction with the relevant appointments of corporate governance such as the publication of the annual report or the issue of quarterly reports (e.g. Bowling and Rieger 2005).

According to Power (2009), the circumstances by which ERM implementations failed or fallen short of their promise, can be attributed to three main features of the "design philosophy" of ERM.

First, Power (2009) considers the notion of risk appetite, as introduced by the COSO, to be highly problematic. According to the COSO Framework, organizations should seek to identify all risks that could prevent the achievement of their objectives and implementing controls and mitigation actions to obtain a residual risk that is consistent with a target risk appetite. In this respect, the functioning of the ERM model has been compared to that of a "thermostat which adjusts to changes in environment subject to pre-given target temperature" (Power 2009). However, this kind of approach presumes that risk appetite can be unequivocally known and understood by organizations and individuals. Basically it requires the board of directors and senior managers to define a certain threshold of risk appetite that is the same across all the organization and among all the managers. This assumption is clearly in contrast with the evidence produced by behavioural studies which suggest that decisions dealing with risk are subject to framing and biases (e.g. March and Shapira 1987; Hood 1996), making the real functioning of the systems more complex.

The second issue that is identified as problematic by Power relates to how ERM contributes to the "logic of auditability". As previously highlighted accounting principles of internal control provide the foundation of the ERM Framework design. This situation signs a close coupling between risk management and internal controls (Spira and Page 2003) and frames the risk management activities as control activities. This results in the tendency to manage risks by elaborating detailed controls with corresponding documents trails to prove the quality of process following the approach that is typical of auditing processes (Power 2004; Kilner 2004; Bowling and Rieger 2005; Martin and Power 2007; Power 2009).

The third problem raised by Power, is that this kind of risk accountability has proven to be incapable of articulating and comprehending critical risks, particularly those induced by other risk combinations. Over the last 15 years, corporate collapses and financial scandals have clearly shown that internal control mechanisms can fail and the financial crunch has made evident how these failures can affect rapidly different economic subjects. In response to this situation, we have assisted to frequent calls for making the internal control-risk management systems more embedded at different organizational levels (McGinn 2009; O'Donnell 2009; Price 2008; Power 2009). Despite this fact, ERM concept of "*embeddedness*" appears to remain limited at entity level (Power 2009), in line with the requirement of corporate governance codes (such as the Turnbull), but overlooking the company's relationships with the broader social environment.

Moving from these considerations, this paper attempts to propose an operational ERM framework, which takes into account the specific problems highlighted above. The proposed operational model – called "Spring" model – has its foundation in the basic ideas of ERM, but it is specifically aimed to support the transition of ERM from the governance sphere to the operational units. In order to achieve this objective, the "Spring" model explains how risk can impact different parts of the organization (e.g. corporate, functions, business units, processes, projects) and how it can be effectively managed at different levels through company's dynamic capabilities (Eisenhardt and Martin 2000).

The proposed model was validated through a case study method (Yin 1994). A test was performed on a large multinational contractor competing in the Oil & Gas service industry. Based on this case, we first classified the company's capabilities into four broad categories (Integration/Coordination, Learning, Reconfiguration, Delivery); second, we analysed how dynamic capabilities could be exploited to manage risks; third, we studied the effect of various events on different organizational levels and we examined the risk propagation and control mechanisms. The test case returned the evidence that the "Spring" model is able either to better explain risks interactions and dynamics at different organisational levels, and to highlight a larger set of available risk control options, if compared with the decision support offered by the Risk Management System currently in use in the Company.

The chapter is articulated as follows. The next section is devoted to analyse how different organizational dimensions interact with the dynamics of risk identification and management. Section 3 develops the "Spring" model. In Sect. 4, the proposed model is tested in a leading company of the Oil and Gas industry. In Sect. 5, we discuss the implications of this work and we conclude in Sect. 6.

2 Organizational Complexity and Risk Evolution

The objective of this paper is to propose an operational ERM model, aimed to support the transition of ERM from the governance sphere to different organizational levels. In order to achieve this objective, we need to take into account how different organizational dimensions interact with the dynamics of risk identification and management. In this respect, two issues appear particularly critical: (1) the growing organizational complexity which companies have to deal with; (2) the increases risk exposure due to the diffusion of advanced technologies and the proliferation of interdependencies within the organization and among different organizations.

2.1 Organizational Complexity

In the current competitive context, the idea that society is increasingly complex is widespread and almost axiomatically accepted. To deal with the surrounding context, organizations tend to adopt more elaborate organizational structures (e.g. Rummler and Brache 1995; Hammer and Stanton 1999; Van Der Merwe 2000).

On the one hand, to manage business and technological complexity, an increased specialization is required, with respect to roles, expertise and skills. On the other hand, this increased specialization makes effective communication between functions, sharing of knowledge, and intra-organizational understanding more difficult, limiting the ability to respond to the dynamism of the external context. In response to these pressures, several organizations have configured their operations through some sort of matrix structures, mixed organizational forms in which the vertical hierarchy is overlayed by some forms of lateral authority which cross departmental boundaries (e.g. Silvestro and Westley 2002).

On the one side, we find resources and/or functions, which can be employed for the production of goods and services. On the other side, we find cross-functional elements, such as process, products and projects. Clearly this sort of matrix can be diversely balanced – i.e. one of the two dimensions of the structure can be more or less relevant than the other. For instance, Larson and Gobeli (1987) identify three distinct types of matrix: functional, balanced, and project. In a functional matrix, while staff involved in the delivery process remains under control of the functional manager, project managers are formally designated to oversee the project across different functional areas. In a balanced matrix, the functional manager and the project manager share responsibility for the project resources. In this case, the two dimensions of the matrix have the same weight and project managers interact on an equal basis with functional managers. In a project matrix, the functional managers' authority is the smallest, since functional managers only assign resources for the project and provide technical advice on an as-needed basis.

These two interacting dimensions (resources and function/process, product and projects) are not the only source of organizational complexity. A second feature that characterizes several companies is represented by their multi-level nature. For instance considering project based organizations we can distinguish at least three organizational levels (Fig. 1):

- The corporate level, this is the more aggregate unit of analysis.
- The project portfolio level, that includes groups of projects that share and compete for the same resource and are carried out under the same sponsorship and management.
- The single project level, which is the more disaggregated unit of analysis.

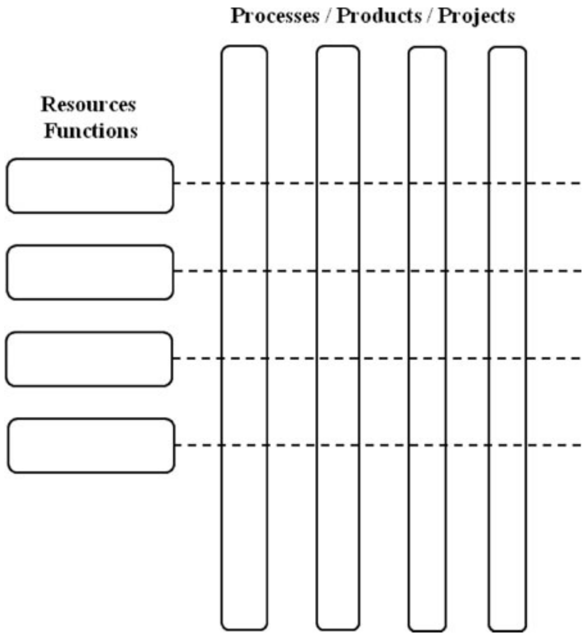

Fig. 1 Complex organizational structure

These kinds of structures have relevant implications in term of how risk can be identified and managed, because different elements that constitute the organizational structure are intertwined. This leads to two main challenges:

- First, there are several interdependent elements, which must be understood holistically, rather than in isolation. Each organizational unit can influence the overall system at different levels. On the one hand, risks can arise bottom-up at different levels, both as singular cause, and as the result of interdependences among different organizational units (e.g. different products/functions). On the other hand, risk originated from the corporate level can downwardly affect different organizational levels (top-down propagation).
- Second, the system is highly dynamic. Each element can rapidly change affecting the other system components, with a short timeframe for interventions (e.g. Dörner 1996).

2.2 Risk Evolution

The second aspect that contributes to make the process of risk identification and management more complex in the organizational context refers to the proliferation of risks that characterizes the so called "risk society" (Beck 1992).

The risk society perspective emphasizes the failure of industrial society in controlling the growing environmental and technological threats (Lupton 1999; Miller 2009). Although risk has always been part of business activities, in this century companies had to face several large-scale events that were once thought unlikely, such as the credit crunch, the energy supply volatility, the climate change, the overhaul of technology. All these risks emanate from corporate industrial activities and the same technologies that should lead to growth and prosperity may also negatively impact the organization, causing disruptions and undesirable long-term effects – i.e. the so-called "manufactured risks" (Giddens 1999). The society, in turn, is increasingly aware that it produces dangers to itself and its perception of risk is increased. In Beck's words, the optimism of progress, that has characterized the industrial society, has been replaced by a "widespread public anxiety about risks", and these anxieties have been fed by crises, environmental catastrophes and accidents.

This circumstance contributes to create further complexity when dealing with risk identification and management. Organizations cannot be studied in isolation, since they are increasingly interconnected and are part of an interdependent system, which includes other organizations, the broader society, and the natural environment. As the complexity of this system increases, so do the resulting challenges associated with risk assessment and management (Miller 2009).

Based on the above considerations, we frame our work considering the organizations as:

- Multi-level entities.
- Configured as a sort of matrix.

- Whose components influence each other.
- And interconnected with the external environment and with other organizations.

This conceptualization of the organization allows us to deal with the dynamic effects of risk across different organizational units – functions, resources, products, projects, processes – and across different organizational levels.

3 Development of the "Spring" Model

In its day to day operations, every company should identify and manage risks through formal or informal routines. Traditional risk management approaches, however, focus on what may be called "hierarchical structures" for the identification and reporting phases, and neglect "assets" for the risk management phase.

The resources available in the organization for the risk mitigation or enhancement, are essential for a fully effective decision making process and for improving the overall organization performance as well.

The core principle of "Spring" model is to integrate the initial situation of the organization in the business environment with the target situation through a full understanding of the overall strategy and the set of dynamic capabilities. This means that that the model supports the refinement and improvement of risk definition in order to enhance the integration of risk management into operational practices. In our view, a risk can be defined as "the interaction of internal or external events and the dynamic capabilities of the organization that may influence the degree of achievement of company's objectives". Accordingly, risk is characterised by three different entities (i.e. events, capabilities and objectives) that are mutually combined through three different actions (i.e. interaction, influence, achievement) and with different attributes that can be utilized in accordance with the business environment and the scope of the risk management process (see Fig. 2).

Considering the risk characteristics the "Spring" model provides an easily representation of risk propagation mechanisms in accordance with the business environment, business objectives and organizations' capabilities (Fig. 3). Starting from the **initial situation**, which is determined by the results achieved by the company so far as well as all the experiences cumulated in the business environment, the executive management identifies either the business **objectives** that represent all the targets to be accomplished by the company in a given time horizon, and the decisions that must be taken to achieve different types of objectives (i.e. **Strategy**). A single event or a group of **events** arising from a series of causes may impact on the organization strategy or **capabilities** resulting in threats or opportunities. The model is represented as a flexible path the company must follow (*e.g. business strategy*) to achieve its goals (*targets*) within a specified time frame, starting from the earlier state (*initial situation*). In business activities, changes may occur due to external or internal factors (*events*) that may impact the system differently and determine a reaction of the organization which can use the mix of "Spring"

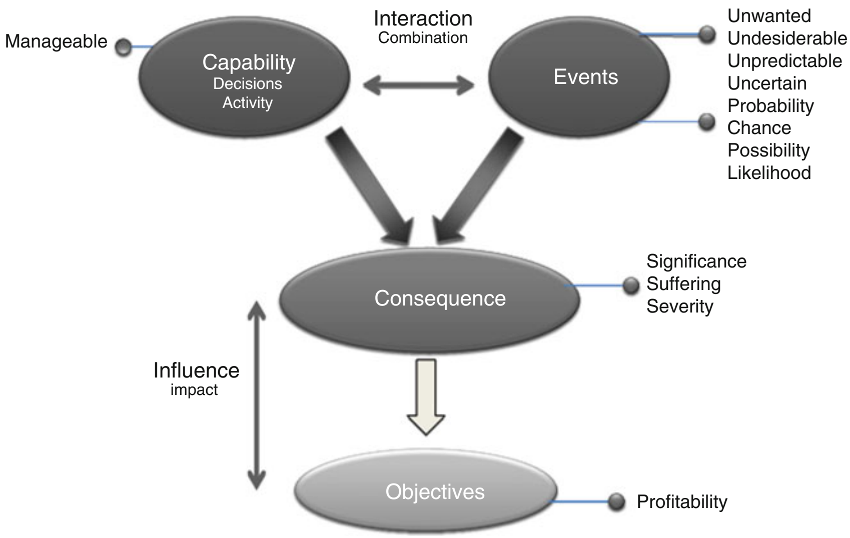

Fig. 2 Risk entities, inter-relations and attributes

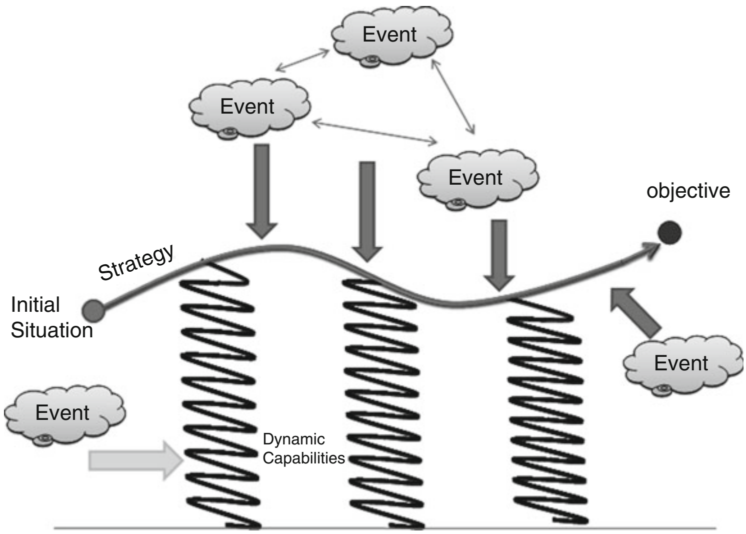

Fig. 3 The "Spring" model

(*capabilities*). Consequently, coordinated actions deploying dynamic capabilities across the organization should be undertaken in order to accomplish the mission.

The risk effects are represented in the model through the variation of its components, for example, events impacting on the strategy could result, for example, in a strategy modification, capabilities "contraction" or in objectives' modification. The flexibility of the "Spring" model consists of two key features: events or group of events can impact on the other components without exceptions, variation in one or more components can involve other model elements. One of the issues addressed by the model is identifying the dynamic capabilities as a way to manage risks.

In practice capabilities are represented as "Springs" that make the idea of a ***contraction*** and a ***controlled release in continuity*** as if the object was under the influence of forces (events) to be absorbed (threats) or exploited (opportunities). Our conceptualization of capabilities has been informed by the definition of dynamic capabilities by Eisenhardt and Martin (2000), according which dynamic capabilities *"are the firm's processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match and even create market change. Dynamic capabilities thus are the organizational and strategic routines by which firms achieve new resources configuration as market emerge, collide, split, evolve and die."* (Eisenhardt and Martin 2000).

In accordance with Eisenhardt and Martin (2000) the difference between dynamic capabilities and resources is that the focus of the resource based view is toward specific physical assets, organizational and human resources that can be utilised to implement strategies to create value. The resource-based view includes skills that are essential to creating competitive advantage (e.g. skills in molecular biology in biotechnology companies). On the contrary, the dynamic capabilities are the organizational and strategic routines by which management can change their resource set to generate new strategies for creating value. Specifically, dynamic capabilities represent the processes to integrate, reconfigure, gain and disposal resources to match or create market change. The evolution and the creation of dynamic capabilities are via a single path that combines the influences acquired during the company's history and transforms them into routines. Therefore, the dynamic capabilities are path dependent, or derived from the mechanisms of learning that can come from repeated processes and learning from mistakes. Dynamic capabilities can be classified according to the kind of role they have in the organizational or management process. In particular, dynamic capabilities can be grouped in four broad categories roles of the various processes:

- **Integration/Coordination** able to coordinate and integrate activities across the enterprise, pursuing efficiency improvement. For the integration processes capabilities are aimed at obtaining strategic benefits from integration with the company's external activities and technologies. Regarding coordination capabilities are seeking to improve the internal organization of the company not only physically but also from the informative point of view.
- **Learning** capabilities allow, through repetition and testing, the execution of the same tasks faster and better. In addition, through learning from the external environment, management can also identify and exploit new opportunities. Generally, these types of capabilities have a strategic role, as are processes that are activated by management to find something that is not present within the company.
- **Reconfiguration** capabilities allow management to reconfigure the structure of the assets by making a transformation inside and outside the organizations'

boundaries. Changes are more expensive and the availability of capabilities that allow a change with low costs enables companies to be more responsive in very dynamic markets.

- **Delivery** capabilities enable a company to run continuously and to complete activities that create the product or service to be sold. In this set there are management processes and controls that allow the proper alignment between company and customer expectations. The purpose of all these capabilities then is the proper implementation of business activities.

The dynamic capabilities representation leads to the concept of **resilience**, which includes the following characteristics:

- Absorption of external “energy”.
- Guarantee of operational performance standard when an external energy is applied.
- Ability to recover or to overtake the initial situation.
- In particular, organizational resilience needs of skills, adaptability and flexibility required to adopt new behaviors, once disturbances and disruptions have occurred or new opportunities have emerged (Fig. 4). Resilience can be seen as the capability of each management level, each organizational unit or the company as a whole to withstand external and internal pressures while continuing to guarantee the achievement of business objectives, thanks to the dynamic exploitation of capabilities at different levels, reconfigurations of mutual influences and improved multi-level decision making (e.g. Frost et al. 2000; Walker et al. 2004; Hollnagel et al. 2006). A more detailed description of organizational resilience is

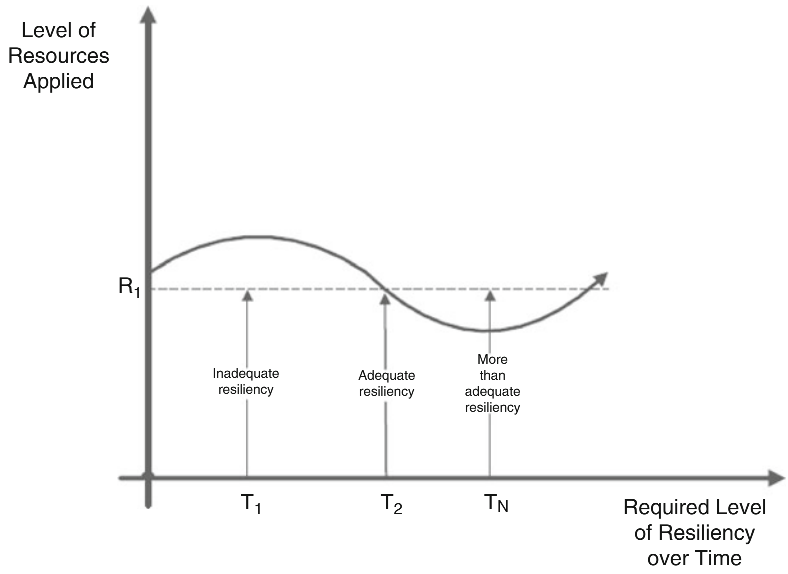

Fig. 4 Organizational resilience behaviour over time

provided by Silvestri et al. (2010) where this concept is specifically developed with respect to the Engineering and Contracting industry.

Finally, the model encompasses three possible risk propagation and control mechanisms (Fig. 5):

- Firstly, a variation of a given target at a certain level can result in an event affecting another organizational level. In the event of a target variation, it may happen that related events are generated to the higher and lower levels, or the variation remains confined to the original level where the organizational resilience must be exploited;
- Secondly, the unavailability of a capability in a level could generate an event in another level. Indeed, when a capability is not available and the management does not have the option to utilise the relative structural resilience, requests for other capabilities (organizational resilience) are needed, and the best alternative in terms of trade-off between target change and effect (i.e., management decides to vary the target of that level that results in minor losses) represents the real option for the management;
- Thirdly, an event can impact simultaneously on different levels because of the occurrence of a "global risk". The overall risk impacts at various levels as a change in objectives or depletion of several capabilities. To understand the ways in which they propagate within the company, these consequences can be linked to the two interaction mechanisms described above. The risk control options are activated between the organisational levels on the basis of available capabilities according to a compensation mechanism.

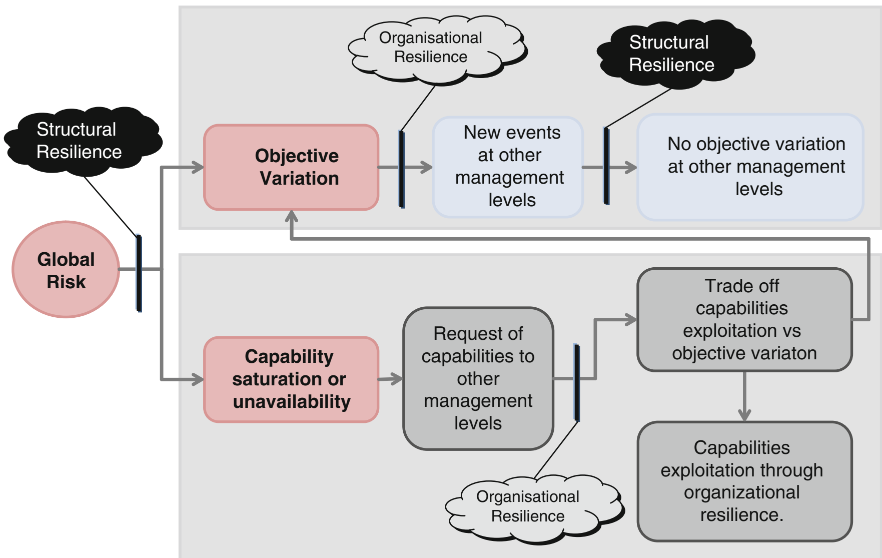

Fig. 5 Risk Propagation and control mechanisms

The “Spring” model can be tailored in accordance with organizations’ needs answering to the following questions:

- Which and how many management levels have been established in the organization?
- Which are the business objectives at each management level?
- Which are the indicators established to measure the initial and the target situation?
- Which are the dynamic capabilities available for each management level?
- Which are the risk propagation and control mechanism across the organization?

According to these questions, a case study in the next section will be illustrated.

4 Implementation of the “Spring” Model in an Engineering & Contracting Company

The “Spring” model has been implemented in a large Engineering & Contracting (E&C) company competing in the Oil and Gas services industry. This method was considered the most suitable to validate the proposed model at this early stage of knowledge. Data were collected from multiple sources to capture key dimensions of the problems analyzed (Yin 1994): semi-structured interviews; official documents and presentations; archives; direct observation and internal document usually not available to the public.

Following, we first introduce the company where the “Spring” model was tested, then we present the implementation of the proposed model in the case at hand.

4.1 The Company

The chosen company provides many different services, including specialized services and maintenance, modification and operations, with a particular focus on technologically challenging projects, such as activities in remote areas, deepwater, gas, difficult oil. The group has a strong local presence in strategic and emerging areas such as West Africa and FSU, Central Asia, Middle East, North Africa and South East Asia and solid relationships with National Oil Companies, who are playing a rising role in the Oil and Gas business. It employs over 30,000 people, organized into three global business units: Onshore, Offshore and Drilling. In 2009, revenues amounted to 11 billion €, with operating profit of 1 billion € and the level of new contracts awarded to the group was 13 billion €.

The main risks faced by the group include market, credit, liquidity, operational, country. The key risks driver is the typology of contract regulating the relationship between the client and the contractor (i.e. project-based company). In fact, a lump sum contract (under which the client agrees to pay the contractor a specified amount, for completing a scope of work in a defined time horizon) entailing engineering, procurement and construction activities of a complex industrial plant will lead to a risk management focused on time and costs. On the contrary a cost-plus contract (under which the contractor is reimbursed for the costs incurred, and is paid an agreed upon percentage of such costs as contractor's profit) will make the organization more sensitive on quality issues.

At present, the company has in place two separate Risk Management Systems: the first one is mainly used at corporate level and it is focused on financial risks; the second one is applied at the operational level and it is mainly focused on project risks. The corporate risk management system is articulated into two components: risk assessment and control identification. The risk assessment process follows a top-down approach: first, the group's companies that could have a significant impact on the financial statement are identified on the base of financial parameters (e.g. turnover, net revenues, profits before taxation) and their relevance in terms of processes and specific risks; second, significant processes, within each company, are identified based on quantitative and qualitative factors (e.g. significant changes in business conditions, complexity of the accounting treatment used for an item of the financial report). Then, risks are prioritised in terms of their potential impact and probability of occurrence. The control system comprises:

- Entity level controls, which operate across the relevant entity (Group/individual Company). A checklist based on the model adopted in the COSO Report divides entity level controls into five components (control environment, risk assessment, control activities, IT systems and information flows, monitoring activities).
- Process level controls divided into specific controls, (i.e. all activities aimed at preventing, identifying and correcting errors and irregularities occurring during operating activities), and pervasive controls, (i.e. structural elements of the internal control system aimed at establishing a general environment which promotes the correct execution and control of operational activities such as segregation of incompatible duties and general IT controls).

The second risk management system (henceforth ROM) is used at operational level. It was established in 2006 to support business units in the execution of a project (by providing assistance, advice . . .). Its scope clearly emerges considering the definition of risk on which it founds: "Risks and Opportunities are uncertain events or conditions that, if they occur, have an effect on a project or a function objective" (Company's internal presentation). Thus, ROM can be looked at as a structured approach to risk management and knowledge sharing at operational level. For each project, relevant risks are identified through common techniques such as brainstorming, Delphi method, expert interviews and checklists. Then, risks are assessed and prioritized for subsequent analysis by combining their probability of occurrence and impact (through a 5×5 matrix). Finally, the central element of ROM is the reporting process, which communicates risk status and other information throughout and outside the project. ROM reporting is mainly referred to three issues:

- Risk and opportunity register, that is the list of all the identified events.
- Risk and opportunity, that is a detailed report of each risk or opportunity.
- Action log, a list of all the actions planned for managing risks.

4.2 The "Spring" Model in Action

The preliminary step for the implementation of the "Spring" model is the mapping of relevant internal processes.

To this end, the processes established in a generic project can be distinguished between **primary** processes, which impact directly on the performance required by the project stakeholders (i.e., Proposal/Project Management, Engineering, Procurement, Material Management, Construction and Commissioning. . .); **ancillary** processes which support primary processes in the accomplishment of project objectives (i.e., Project Control, Contract Management, Finance, Human Resources and IT management, Quality Health Safety and Environment, Finance. . .). In addition, all the projects are managed and coordinated through **Management supporting processes**, which support the whole organization in the accomplishment of business and compliance objectives (Planning and M&A, Investor Relations, strategy and Development, Organization, General counsel, Internal Audit; Assets Technologies, Company Secretary. . .) (Fig. 6).

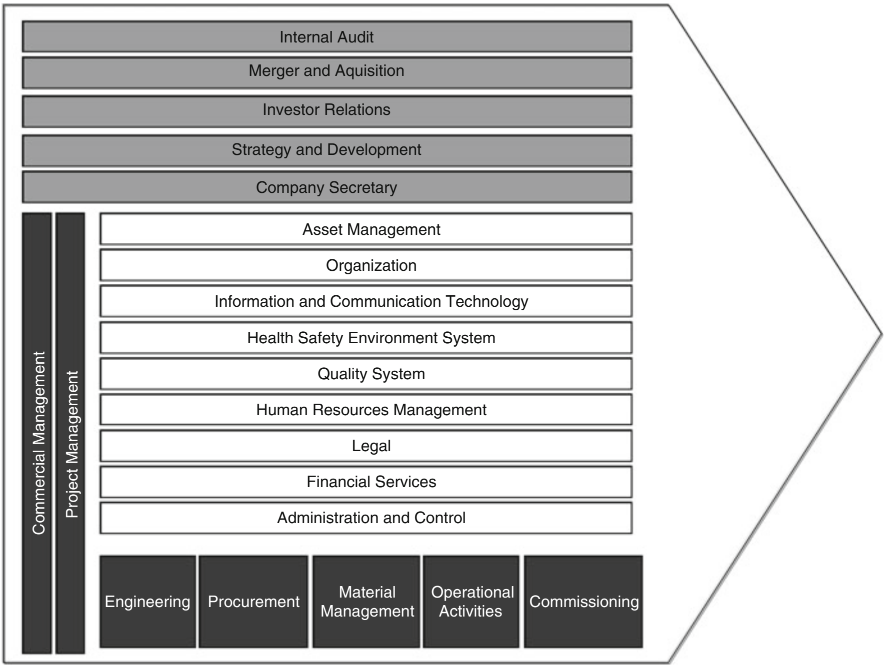

Fig. 6 E&C Company Value Chain

The process analysis was completed by an organizational analysis leading to the identification of key organization levels and the related management roles. In the case setting, the project organization is composed by:

- The **corporate** level, considering the whole organization (this is the more aggregate unit of analysis). It is leaded by executive management, aimed at the Enterprise value creation or enhancement, measured through the EVA indicator (e.g. Rappaport 1986; Wenner and LeBer 1989; Stewart 1991).
- The **project portfolio**, considering groups of projects that share and compete for the same resource. It is leaded by operations management, aimed at the Portfolio execution and enhancement, measured through Portfolio backlog, profitability and progress indicators.
- The **functions** level, considering coordinated group of activities devoted to the achievement of a product component or ancillary services. It is leaded by Functional management, aimed at the development and execution of activities, measured through resource saturation indexes and cost performance indexes.
- The **project life cycle** level, considering the core processes for delivering value to the Client, it is the more detailed unit of analysis. It is leaded by Project management, aimed at the project planning and execution according to scope, time, costs and quality required by the Client, measured through profitability indexes.

The four levels are diversified in relation to the risk control options they can exploit to deal with uncertainty. In fact, while at corporate level, pervasive risk control options are available (i.e. managers at corporate level can easily define actions to reach different organizational levels), at portfolio level, managers can employ less pervasive but more specific (i.e. localized in a certain area of the organization) risk control options. In the same way, while at project level, coherently with the more limited influential areas, specific risk control options are available, at the function level specific as well as specialized (i.e. depending on a precise and definite knowledge) risk control options are ready made.

With reference to the proper management level, a typical set of dynamic capabilities and the related classification for E&C companies in the Oil and Gas market is reported in Table 1. In this respect it is worthy to note that capabilities were classified referring to the organization as a whole and not considering the specific role of each capability at specific each management levels; for instance, the capital expenditure management can be considered as a delivery capability at the corporate management level, whereas it is a reconfiguration capability from the enterprise point of view.

The comparison between the typical dynamic capabilities for an E&C organization and the Company analysed led to the identification of a complete capability map, including 465 different capabilities, and reported in Fig. 7.

As far the three risk propagation and management mechanisms are concerned, they were identified in the case study as strong links between the project level and the portfolio or function levels, as well as weak links between the project and enterprise levels. In accordance with the organizational approach adopted by the company, the links between different management levels are not mutual (bidirectional), resulting in a reduced organizational resilience. In Fig. 8 weak

Table 1 Typical dynamic capabilities in E&C organization

Risk management level	Typical dynamic capability	Capability classification
Enterprise	Financial control	Delivery
	Multibusiness coordination	Integration/coordination
	Merger and acquisition	Reconfiguration
	Capital expenditure	Reconfiguration
	International management	Reconfiguration
	...	...
Portfolio	Asset management	Integration/coordination
	Client management	Learning
	Business line selection	Integration/coordination
	Contract design	Delivery
	...	...
Projects	Project architecture	Integration/coordination
	Resource utilization	Delivery
	...	...
Functions	Systems and technology	Integration/coordination
	Knowledge	Learning
	Process design	Reconfiguration
	Workload management	Integration/coordination
	...	...

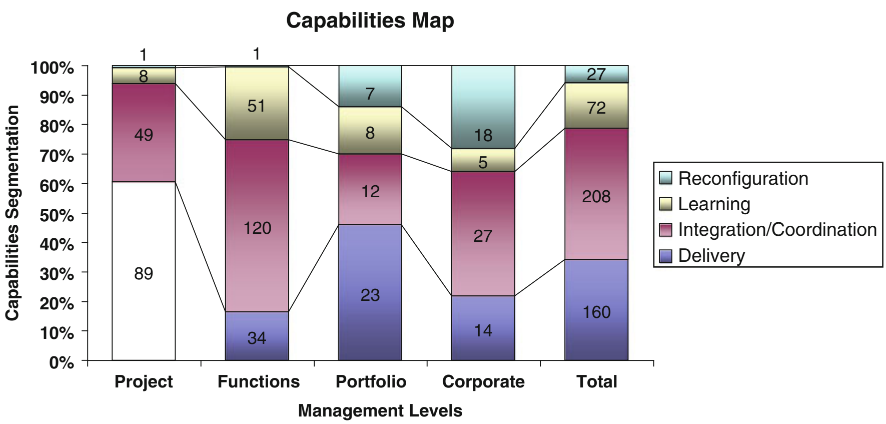

Fig. 7 Capability map

links were represented through dashed arrows, and strong links through solid line arrows.

The primary objective of the case study is to demonstrate the potential of the "Spring" model of better classify the "resources" and fully highlight the available options to keep risks under control. To this end in the following some specific risks will be analysed in order to highlight potential impacts and countermeasures at different levels in the organisation. More specifically, the available risk control options will be identified by selecting the most effective capabilities, at different

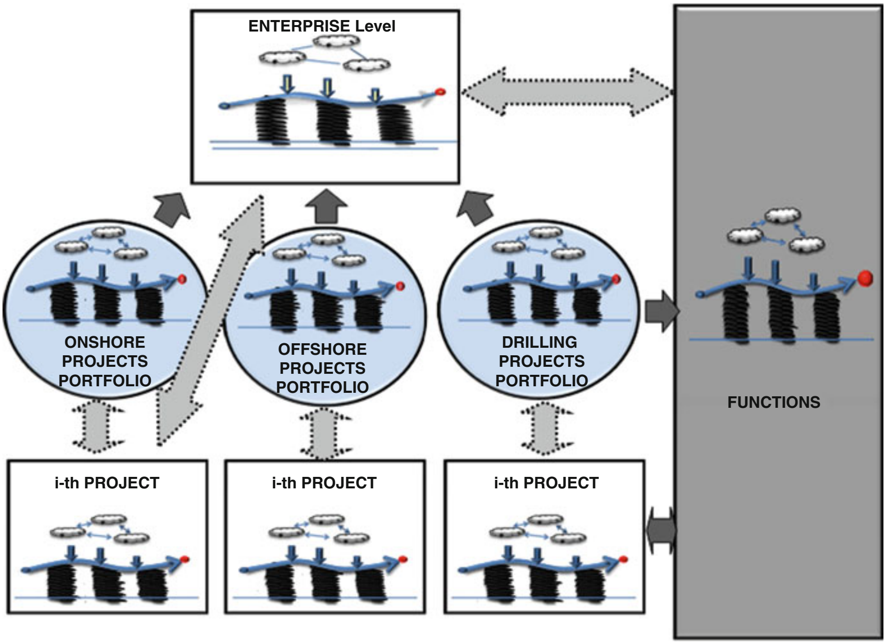

Fig. 8 The "Spring" model in the Oil and Gas Contractor

organisational levels, to absorb (or exploit) the expected impact of the risk under analysis.

1. *Objective variation at project level*
   The first risk analysed consists into "project delay due to engineering documents approval from the client due to different geographical locations and engineering & procurement reworks".

   Through the current Project Risk Management system adopted by the Company, the impacts were evaluated on the basis of the economic effects on the project and the prospective client's dissatisfaction. Mitigation actions were addressed within the project organization leveraging on procurement and contract administration capabilities. In addition, an informal warning related to the delay in the vessel mobilization was issued to business unit management. Thanks to the "Spring" model it was possible to systematically identify other potential impacts as:

   - Proposal ongoing with the same client are blocked due to client's dissatisfaction at project portfolio level;
   - Assets unavailability for other projects at project portfolio level;
   - Resources unavailability for other projects at functions level;
   - Engineering centre selection ineffective for future projects at corporate level. In addition to the capabilities utilized by the project team at project level, further risk control options were identified in order to manage impacts at

all levels. For example, at the corporate level the exploitation of "engineering centre selection and monitoring" was identified as an available capability to localize engineering centres closer to the client; at portfolio level the "client relationship management" was identified as a key capability to evaluate possible compensations to the client through other projects; finally at functional level "engineering workload management" and "ICT infrastructure and applications planning" were selected as additional capabilities to mitigate the risk of project delay and the related induced risks.

2. *Capability unavailability or saturation at portfolio level*
The second risk analysed refers to the eventuality that "awarding of contracts including specific welding activities could not be possible due to unavailability of skilled subcontractors in a specific area".

Again, risk impacts were evaluated considering the influence on proposals and the potential effect on the commercial plan through the Proposal/Project Risk Management system. Mitigation actions were addressed within the proposal organization through the client relationship management and negotiation capabilities in order to exclude the welding activities from the scope of work and improve the competitive advantage of the company. According with the "Spring" model it was possible to identify additional opportunities as developing:

- New professional skills exploiting construction competencies available in other areas, at portfolio level;
- Strategic alliances in the area, at portfolio level;
- Different welding supervision activities in order to manage not accustomed subcontractors, at functional level;
- Local permanent organization in order to directly manage all construction activities, at corporate level.

Furthermore, different risk control options were identified in order to manage impacts at all levels. For example, additional capabilities that could allow to enter the geographical market are: "Execution centres selection and monitoring" at enterprise level, "Business planning for new ventures and partnership" at portfolio level and "Operations best practice identification and management" at functional level.

3. *Global risk impacting on all management levels*
In the event of a risk impacting on all the management levels the risk control options can be derived as in the case of target variation and capability saturation. Nevertheless, the testing of the third risk propagation/control mechanism could be relevant when a simulation approach is implemented in order to evaluate trade-off between different risk-control options among management levels. In addition, a quantitative simulation of the third mechanism could provide evidences on the degree of effectiveness and efficiency of the organizational resilience of the Company.

5 Discussion

In the introduction the limitations of theoretical ERM models such as the COSO framework have been already discussed, pointing out the need of developing a tool to support the transition of ERM from the high-level governance sphere to operational processes. Here, we first compare the “Spring” model against the Risk Management System currently in use in the Company analysed in the case study in order to highlight its practical advantages. Second, we compare the proposed approach against other operational risk management frameworks reported in literature, to explain how it can support the application of ERM principles at the operational level.

Comparing the features of the proposed “Spring” model against the two existing risk management systems in the Engineering & Contracting Company considered in the case study few advantages can be highlighted (Table 2). First, none of the tools currently adopted in the company relates corporate and operational levels, which remain two separate worlds. On the contrary, the “Spring” model founds on the interaction of different levels. It allows analyzing how risk can impact corporate units, project portfolio, functions and projects, and how risk can be effectively managed, at different organizational levels, through the organization’s capabilities and resilience.

Table 2 Comparison between the Risk Management System currently in palace in the company and the “Spring” model

Risk management phase	*Current risk management system*	*“Spring” model*
Risk management planning	– Different organizational levels are seen as independent units – Different risk categories are treated independently	– Enables the integrate planning of risk across different organizational levels and different risk categories
Risk identification	– Limited either to the project organizational level (ROM) or to financial risks (financial risk management)	– Enables risk identification across the whole organization – Fosters a common risk view through different organizational levels
Risk assessment	– Limited either to the project organizational level (ROM) or to financial risks (financial risk management)	– Tracking the interdependencies among risk s and impacts at different organizational levels
Risk control	– Risk and control options limited at the project organizational level – Ad hoc definitions and descriptions of the risk control options	– Exploitation of full spectrum of risk and control options – Definition of specific responses according to the risk category – Exploitation of scenario analysis and trade-off evaluation between different management levels
Risk monitoring and review	– Limited to the project organizational level	– Risk monitoring and control is carried out in an integrated fashion in accordance with organizational resilience (capability allocation)

Furthermore, the current approach looks at different types of risks independently: financial risks are addressed at corporate level, project risks are tackled at operational level without considering the interaction between them and without a stage of risk consolidation at project portfolio level. Therefore the corrective actions are taken locally, for each single project. The idea at the basis of the "Spring" model is to capture the synergies between events occurring in different projects, defining a sort of algorithm that rules the propagation mechanisms of risks and corrective actions.

A second level of discussion can be set at a more theoretical level. Indeed, the operational management literature provides very few contributions on operational risk management frameworks or models. Thus to benchmark the features of the "Spring" model we refer to two well regarded models that can be considered paradigmatic of holistic and integrated risk management approaches at operational level (Table 3):

- The PricewaterhouseCoopers Operational Resilience Model (PWC 2001), that provides an example of holistic approach to operational risk management.
- The Operational Risk Management Model developed by Lewis (2003), that identifies and analyses operational risks as a cause-effect chain of misalignments

Table. 3 Benchmark of the features of the "Spring" model

Risk management & organizational dynamics	**COSO framework**	**Operational risk management models (e.g. PWC 2001; Lewis 2003)**	**"Spring" model**
Linkage between strategic and operational level	– Based on the idea of integration through the organization, though in many cases, pre-existing practices continue to exists – Based on the idea of comprehensiveness, though at present most application of ERM are often focus on high level risks (e.g. governance and finance)	– Focused on the operational level only	– The linkage between strategic and operational levels is ensured through the organization thanks to the concept of capabilities
Risk response	– Risk response is ensured through control activities, often associated to the creation of documental evidence (as in the auditing process)	– Different risk control strategies are identified, though they can be applied within certain internal and external boundaries	– Allows the identification of a set of resources for implementing a resilient response to a specified combination of potential or actual events (internal or external)

between external market requirements and the internal operational capabilities of the company.

Given the objectives of the paper, i.e. to develop an operational ERM model, features of other operational risk management models strictly applied to specific types of risks (e.g. ISO 14000, OHSAS 18000) were not taken into consideration for benchmarking.

The PWC Operational Resilience model represents an organization's business processes through an "operational resilience envelope". It is based on five pillars, aimed to ensure operational resilience. These are:

- Performance Definition, translating business strategy into operational requirements and performance measures.
- Service Management, establishing an independent service management function and defining the scope of responsibility for delivering end-to-end operational resilience.
- Operational Scalability, establishing and maintaining operational performance levels based upon expected stress levels and taking into account existing operational tolerances.
- Operational Continuity, defining procedures to accommodate operational failures, to ensure continued service delivery without the need to invoke full business recovery measures.
- Business Recovery, defining procedures to manage the displacement of critical resources to an alternative processing location in response to a major incident.

This model states the linkage between strategic and operational objectives, through "performance definition". Then it defines four sets of integrated actions (service management, operational scalability, operational continuity, business recovery) that can ensure operational resilience. Though holistic in its aims, this model focuses on the operational level as unit of analysis, therefore failing to truly consider the impact of operational risk on the other organizational levels. Roughly speaking, we can say that this model is "selectively integrated" since it tackles a selected part of the organization (i.e. the operational level). On the contrary, the proposed "Spring" model, relies on the concept of capabilities to ensure the linkage between corporate and operational levels, using capabilities as a mean to respond to unforeseen events (in the end ensuring the achievement of corporate objectives). In this way, our unit of analysis becomes the entire organization and different risk categories are actually managed in an integrated way across the organisation.

The second model used as a benchmark is the operational risk model, developed by Lewis (2003). This model moves from the combination of conceptual insights from Operational Management and Risk Management. Therefore, it specifically focuses on structural and temporal pathology of operational failure and the subjective layers (e.g. stakeholders, clients, etc) of internal and external loss that appear to influence overall negative consequences. The operational risk approach proposed by Lewis aims to foster the integration between causes and consequences through the information infrastructure. It consists of three elements:

- Causes, the input element of the model that need to be refined to address both the structural (i.e. repetitive, continuous in time) failures and time-limited causal event.
- Consequences, the outcome element of the model that are determined by internal (i.e. operational) and external losses (i.e. customer and stakeholders).
- Controls, the actions required to influence on negative consequences.

The complexity of the interrelation between the first two elements (i.e. cause-effect mechanism) and the variability of the possible outcomes may suggest that the ex-ante control strategy will never succeed. In such context even the most controlled systems will experience failures and, therefore, need to adopt mitigation or recovery control strategies. In this way, the cause-effect analysis could be useful in providing a common reference point for debating the specific pathology of any operational risk. Moreover, the additional "loss layer" highlights a number of additional conceptual challenges enlarging the consequences and controls options. The model does not describe how even discrete events can be interrelated and propagate over time. The model highlights the wide range of risk control options but it does not provide any particular solution to support decision-making. Finally, this model does not make the linkage between operations activities and corporate objectives explicitly, therefore focusing again on the sole operational level.

In summary, it can be stated that when compared to other theoretical ERM frameworks, the "Spring" model has two distinctive features:

- First, it tailors the ERM concept to the organisational structure of the company, thus taking into consideration the implications for the risk management process of the multiple interactions between entities in more complex organisational structures. To this extent, the implementation of the proposed model in a project based environment defines the relationships among different organizational levels and specifies the project portfolio level into the ERM framework. Within the portfolio, rules of operation/interaction, compensation mechanisms and decision-making processes may be identified so that the interaction does not happen only between projects and functions but also through a higher level of compensation and exploitation.
- Second, independently on the level or scope of its application, the proposed model allows the identification of a set of resources for implementing a resilient response to a specified combination of potential or actual events (internal or external). As discussed in the case study, the set of resources to be mobilized includes financial, physical, individual and organizational undertaking and is allocated in combination with organizational processes. Through this approach, the "Spring" model exits the finance and governance sphere and provides managers with a more operational guidance than the COSO framework.

In order to exploit any knowledge cumulated by the organisation, the "Spring" model can entails the link between already existing risk management systems and does not require any specific organizational structure for its effective implementation.

6 Conclusions

In recent years, Enterprise Risk Management has come to the forefront as an essential device for assessing business threats, opportunities, and their impact on the creation of value. ERM is now considered an important process for companies regardless of their sector, activities and origin (Price 2008; McGinn 2009; O'Donnell 2009). On the one hand, ERM is seen by regulators and markets' actors as a way to pressure companies to carefully evaluate their risks and the possible consequences of their risky behaviour. On the other hand, ERM embodies a concept of risk management which is positive and entrepreneurial: risk is seen not only as a threat to companies operations but also as an opportunity of wealth creation. This trend led a number of companies to adopt risk management practices, entailing new processes in the company and devoting, sometimes, a significant amount of resources to these exercises.

Notwithstanding a unanimous agreement on the potential benefits of ERM, there is limited availability of empirical evidence of concrete ERM application, and the existing literature often focuses on financial entities. Furthermore, despite the fact that the idea of integration at the basis of ERM is widely recognised, some authors started to challenge ERM concept at its design level (Power 2009). The same principle at the basis of ERM, the identification of all risks facing an organization, can induce managers just to create bureaucratic trails to prove the quality of process, making the production of evidence "more important than managing real risks" (Kilner 2004; Fraser and Henry 2007; Martin and Power 2007). Under these perspectives, companies tend to adopt ERM mainly as a compliance exercise (Bruce 2005; Collier et al. 2007) or "after-the-fact inspection" (Bowling and Rieger 2005).

In this context, this chapter attempted to propose an operational ERM framework, the "Spring" model, which is specifically aimed to support the transition of ERM from the governance sphere to the operational units. The proposed model tries to take into account how different organizational dimensions interact with the dynamics of risk identification and management. To this extent the model is tailored on an ideal type of organization that is configured as a multi-level entity, structured as a sort of matrix, where its components influence each other, and are interconnected with the external environment and with other organizations. Based on this idea, the "Spring" model explains:

- How risk can impact different organizational entities
- How risk can propagate across the organization
- How risk can be effectively managed, at the proper organizational level, through the organization's dynamic capabilities

The "Spring" model aims to manage risks at all levels of business and can be interpreted from a double perspective:

- Prospective analysis. In particular, it is necessary to consider the risks arising from the higher levels and the risks that could propagate to the underlying layers.

In risk estimation phase, the management will be able to estimate the impacts and determine possible corrective measures that can mitigate the risk. In particular, the management will need to develop an alternative plan of resources reallocation, in order to compensate for the lack of resources. Accordingly, a reallocation of risks is required in order to identify the best feasible scenario.

- Retrospective analysis. In particular, it refers to a scenario in which the event has already occurred, and the model could be no longer used to manage risk, since you are no longer in conditions of uncertainty. Consequently, the model can be used to generate new functional knowledge to the future of a company, because only with deep insight into the source of an impact can be associated risks.

This work can extend the current ERM literature from different points of view. First, moving from the basic concept of integrated risk management that is typical of ERM, this work proposes an operational ERM model, therefore attempting to further develop the ERM philosophy from a conceptual perspective. This is rather new in the existing literature, where analytical and interpretative studies tend to prevail. Second, the "Spring" model actually proposes an alternative approach to manage risks at different organizational levels, referring to the concept of dynamic capabilities. This approach may provide a potential alternative to solve the problems related to the "internal control view" of risk management. Firstly, the "Spring" model does not fund on the concept of risk appetite to "initiate" the risk management cycle. Instead, it relies on the concept of resilience, which is linked to operational performances. Secondly, the two concepts of resilience and dynamic capabilities enlarge the idea of "traced" control activities to manage risk, supporting the shift from the governance sphere to the operational domain. Thirdly, the concept of risk adopted in this work, as well as the idea of resilience utilised, help the identification and the proactive management of risks resulting from the interrelations among different organizational entities and external business environment. Fourthly, the dynamic capability approach could better respond to the recent calls for establishing "a culture of risk management throughout the organization" in order to make ERM really effective (Bruno-Britz 2009, p. 20).

Finally, a further contribution of this work relates to the test performed in a large contractor competing in the Oil and Gas industry, that required actually identifying and classifying the dynamic capabilities of the company analysed. This classification can provide a general model that is applicable to similar companies.

In the end, we discuss the main limitations of the present work and the areas for future development.

So far, the "Spring" model has been tested on a single real case; besides, the empirical validation was based on qualitative data, through the analysis of the events that can impact different organizational levels and the capabilities through which the organization can manage these risks. Future research should test the predictive potential of the proposed model through simulation tools, adopting a quantitative approach. This could also allow the comparison of different managerial paths (i.e., action plans that adopt different sets of capabilities) to respond to a specific event (i.e., identify the more effective/efficient solution).

A second area of improvement deals with the application of the model to organizations from different business sectors. In our view, the general principles at the basis of the "Spring" model could be tailored to the specificities of different industries. Furthermore, the use of dynamic capabilities as an instrument to manage risk could be applied at network of companies, therefore responding to the claim for higher interconnectedness.

A further potentially interesting issue is the integration of the proposed model with the planning and control system. First, company's targets, at present, are considered input factors of the "Spring" model (i.e., planning and risk management are sequential processes, though the output of ERM can influence targets defined in the first stage). Future research could attempt to integrate planning and ERM, to consider targets and risks simultaneously. It is clear that this approach could allow identifying a theoretically optimal solution for business resilience, though increasing the complexity of whole process (Azzone 2008). Second, the model could also be extended through the identification of a set of Key Risk Indicators, for each organizational level, to contemporary monitor risk exposure and organization's performances.

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Part IV
Risk Management in Macro-economy

Risk Index of China's Macroeconomic Operation: Method and Application

Wang Shuzhen and Jia Dekui

Abstract The overall risk of economic performance of China was evaluated through the establishment of risk index of economic operations in this paper. The results show that China's overall risk status is running a "risk concern" level in 2010 and 2011. Excessive bank credit and the value shrink of huge foreign exchange reserves will be the main risk factor in 2010, however, in addition to these factors, asset bubbles and rising inflation pressures will be the other factors in 2011. To promote the economic development in the next two years, China should gradually withdraw from loose monetary policy and take appropriate fiscal policy to eliminate the side effects of policies response to the crisis. And other measures such as interest rate adjustment and inflation expectations leading should be taken to prevent the breeding of asset price bubbles and increasing of inflation risk.

Keywords Economic operation · Monetary policy · Risk index · Risk management

1 Introduction

The risk of economic operation often reflects the possibility of a significant deviation from the real economy compared to its normal (or balanced) state. In practice, the various objectives of macroeconomic level is often used to measure the actual situation of economic operation, therefore, the risk level of economic operation mainly to reflect the extent of deviation of key economic variables from its normal level.

Since 2010, the trend of China's macroeconomic performance is better. However, the current environment of economic development is still extremely complex, and some uncertain factors still exist. Moreover, European sovereign debt problem is getting worse, and economic recovery of developed countries is very slow. In China, there are also potential risks existing in fiscal and financial areas, furthermore,

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the government is facing significant inflationary pressures and heavy task of changing the economic structure. Therefore, the outlook of economic is not optimistic.

The paper tries to assess the risks of China's economy by establish risk index of economic operations. The remainder of the paper is organized as follows. The related literature is reviewed in the next section, and in Sect. 3 we present our model of the risk index. In Sect. 4 we forecast the size of the risk level of China's economic in 2010 and 2011. The final section summarizes and presents the policy implications.

2 Literature Review

The related research abroad is mainly for macroeconomic forecasting, and there are also many studies on the design of appropriate criteria for evaluating macroeconomic forecasts.

Robert and Herman (2000) discussed include the comparative accuracy of macro econometric models compared to their time series alternatives, whether the forecasting record has improved over time, the rationality of macroeconomic forecasts and how a forecasting service should be chosen. The role of judgment in producing the forecasts is also considered where the evidence unequivocally favors such interventions, and the use of macroeconomic forecasts and their effectiveness is discussed.

Dandan and Jansen (2007) propose several variants of a general structural factor forecasting model, and use these to forecast certain key macroeconomic variables. They make the choice of factors more structurally meaningful by estimating factors from subsets of information variables, where these variables can be assigned to subsets on the basis of economic theory. They compare the forecasting performance of the structural factor forecasting model with that of a univariate AR model, a standard VAR model, and some non-structural factor forecasting models. The results suggest that structural factor forecasting model performs significantly better in forecasting real activity variables, especially at short horizons.

Scott (2001) evaluates recent forecast errors made by private forecasters in an attempt to understand why forecasts have gone so far away. The results show that GDP and unemployment rate forecasts and, to a lesser extent, inflation forecasts veered off track in the second half of the 1990s. Although the errors are not unusually large in historical perspective, they are economically significant and troubling—particularly from the perspective of monetary policymakers who require accurate forecasts to set interest rates appropriately. On average, macroeconomic forecasts are approximately unbiased, but they are inefficient and the forecast errors are characterized by improper correlation. These factors indicate that macroeconomic forecasts leave considerable room for improvement.

For the method of economic operation evaluation, the original approach calculated a variety of statistics that measured the errors of the forecasts and then compared these errors with those generated by alternative methods or individuals.

The newer approach for forecast evaluation is to base it on the loss functions of the users (Pesaran and Skouras, 2002). Elliott and Timmermann (2008) in summarizing the theoretical literature on how to evaluate forecasts take the same approach. These studies definitely suggest that the preferred evaluation methodology be based on decision-based methods, Pesaran and Skouras, however, noted that it has had limited use, and that most studies focused on statistical measures to evaluate the skills of the forecaster or accuracy of the model.

Stekler (2010) provide some perspectives on the issues involved in judging the quality of these forecasts. His study finds that there are not many positive results to report about the quality of our forecasting techniques, despite all these efforts. He still fails to predict turning points and the short run forecasts still display biases and inefficiencies. It is provided that the limited amount of evidence about long-run labor market and population projections suggests that, in some dimensions, they are no better than naïve models.

The other related research is mainly on the quality assessment on the macroeconomic or on establishing evaluation index system for measuring economic operation. Yingmei and Junjun (2007) collected 37 indicators to reflect the quality of macroeconomic performance. Based on above indicators, there are 14 representative indicators was selected through impulse response functions and variance decomposition analysis. They are growth rate of GDP, growth rate of household consumption, growth rate of import and export, growth rate of cash flow, growth rate of foreign exchange reserve, revenue growth, growth rate of per capita net income of rural residents, the proportion of tertiary industry to GDP, the proportion of deposits and loans, revenue share of GDP, the value of the deficit ratio, debt ratio, elasticity coefficient of energy consumption and electricity consumption.

China Economic Monitoring Center selected representative indicators and established the economic monitoring system on the basis of statistical indicators. The monitoring indicators include the leading index, consistency index, lagging index and early warning index. The selected indicators for construction of early warning index include fixed asset investment, retail sales, per capita disposable income of urban residents, bank loans, M2, PPI, import and export volume, revenue, profits of industrial enterprises and CPI.

Zhengming et al. (2005) used Granger's Causality Test and VEC models; they explore the dynamic, complex relationships in China's macroeconomic operations by empirically analyzing the interactions among different aggregate indices. The results indicate that price level, economic growth and fixed capital investment significantly interact on each other. In the short run, both fixed capital investment and economic growth have lagged positive effects on price level. In the long run, fixed capital investment and price level move in a reverse direction, as the current investment is transformed into supply in the future and therefore makes price fall. Moreover, the general monetary supply (M2) also influences price level via fixed capital investment and gross economic output.

Chaoyang (2006) found that the amount and use of bank loans can be used as leading indicators of economic operation in China. Shi Liangping (2007) evaluated and amended the China's macro-economic early warning system. He pointed out that the capital investment; the level of labor education and the level of exports play an important role in promoting economic growth. There is other several documents have also been similarly studied, and it will be not repeated more.

On the basis of existing literature, the following research will be focused on the assessment of macroeconomic risk by constructing the evaluation index of macroeconomic risk.

3 Establish of Risk Index

The preparation steps of risk indices are as follows. Firstly, a set of representative indicators should be selected for constructing risk measurement models. Secondly, changes in macroeconomic trend would be investigated at a certain time range by using the model, and the measurement results will be obtained. Next, measure results and the size of the risk range are standardized treatment, and the value of risk index will be calculated finally.

3.1 Index Selection

The indicators chosen to follow the principles of relevance, comprehensiveness, testability, stability, and independence, moreover, the scientific and indictor function of risk index is very important for macroeconomic forecasting.

Taking into account the economic objectives mainly include economic growth, price stability, full employment and balance of payments, besides, the authorities attach great importance to fiscal balance and the stability of the financial system in practice. For this reason, indicators selection should reflect the above aspects. The following provides the results of initial choice of indicators (Table 1).

The next step is further selecting of index by correlation analyzing from January 2000 to March 2010, and related indicators have a high degree of similarity changes

Table 1 Preliminary index selection results

Economic growth	Price stability	Full employment
Fixed asset investment growth (X1) Retail sales growth (X2) Export growth (X3)	CPI (X4) PPI (X5) RPI (X6)	Registered urban unemployment rate (X7) Employment growth rate in urban (X8)
Balance of payments	Revenue and expenditure	Financial stability
The difference between import and export (X9) Reserves/GDP (X10) Growth rate of foreign exchange reserves (X11)	Completion rate of tax (X12) Deficit/GDP (X13) Revenue growth rate (X14) Expenditure growth rate (X15)	Loan growth (X16) M2 growth (X17) Value of stock market/GDP (X18) Growth rate of cash in circulation (X19)

should be streamlined after R-cluster analysis. After correlation analysis, the significant cause of Granger causality index is selected by Granger causality testing, and the final eight indicators are selected. The results are given in Table 2.

3.2 Index Weights

For different importance and representative impacting on the economy, it is necessary to calculate the weight of each factor. We will use analytic hierarchy Process (AHP) to calculate the weight. The public official announcements and the inclination of different policy objectives were referred to determine the relative importance of different indicators. For example, People's Bank of China expressed the ultimate objective of monetary policy to "maintain price stability and promote economic growth"; moreover, China's monetary policy direction and control purposes are consolidating the economic recovery and preventing higher inflation in 2010. As a result of comparison of index weight, we consider that an indicator of economic growth is defined as "slightly important" compared with the inflation index.

If the weight of these indexes cannot be determined according to the principles, then Delphi Method will be used to determine the weight (the definition of the relative importance of indicators is shown in Appendix). The results of weight calculation are shown in Table 3.

Table 2 Final results of index selection

Economic targets	Index
Economic growth	Retail sales growth (S1)
	Export growth (S2)
Price stability	CPI (S3)
	PPI (S4)
Full employment	Employment growth rate in urban (S5)
	Registered urban unemployment rate (S6)
Balance of payments	Reserves/GDP (S7)
Revenue and expenditure	Deficit/GDP (S8)
Financial stability	Loan growth (S9)
	Value of stock market/GDP (S10)

Table 3 Value of Index Weights

Index	Weights
Retail sales growth (S1)	0.1821
Export growth (S2)	0.1738
CPI (S3)	0.1543
PPI (S4)	0.1021
Employment growth rate in urban (S5)	0.0974
Registered urban unemployment rate (S6)	0.0634
Reserves/GDP (S7)	0.0575
Deficit/GDP (S8)	0.0520
Loan growth (S9)	0.0812
Value of stock market/GDP (S10)	0.0362

3.3 Model and Risk Interval

After multiply indicator variables by weight and add the above results, we will get the weighted evaluation model of economic operational risk according to previous results of indicators and weights. The risk index model is as follows.

$$\begin{aligned} RIEO = {} & 0.1821S_1 + 0.1738S_2 + 0.1543S_3 + 0.1021S_4 + 0.0974S_5 \\ & + 0.0634S_6 + 0.0575S_7 + 0.0520S_8 + 0.0812S_9 + 0.0362S_{10} \end{aligned} \quad (1)$$

For the standardization of risk status and comprehensive evaluation, each indicator should be scored, and the risk status should be classified into five levels according to the forecasts.

We will use the percentage system to rate the indicators, and the five categories include “no risk” (0–20), “risk concern” (20–50), “risk” (50–70), “high risk” (70–90) and “top risk” (90–100).

The threshold at different levels is to be referred to general international standards or existing research results, and we will get the other threshold of indicators that have not reference standard by using recent economic forecast with average adjust.

The results are given in Table 4.

If an indicator variable is to be high enough, which may lead to systemic risk, therefore, this study intends to establish function expression as follows by setting the middle value of “high risk” status as the critical value.

$$\begin{aligned} RIEO &= \sum S_i W_i, \quad \text{when } S_i < 90 \\ RIEO &= S_i, \quad \text{when } S_i \geq 90 \end{aligned} \quad (2)$$

Table 4 Definition of risk status

Index	No risk	Risk concern	Risk	High risk	Top risk
S1	13–18%	10–13%	5–10%	0–5%	<0%
		18–22%	22–25%	25–30%	>30%
S2	10–25%	0–10%	−10 to 0%	−10 to −20%	<−20%
		25–30%	30–35%	35–40%	>40%
S3	1–3%	3–5%	5–7%	7–10%	>10%
		0–1%	−1 to −3%	−3 to −5%	<−5%
S4	1–3%	3–5%	5–7%	7–10%	>10%
		0−1%	−1 to −3%	−3 to −5%	<−5%
S5	>2.5%	1.5–2.5%	0.5–1.5%	−0.5 to 0.5%	<−0.5%
S6	1–3%	3–5%	5–7%	7–10%	>10%
S7	10–30%	30–40%	40–50%	50–60%	>60%
		8–10%	5–8%	3–5%	<3%
S8	<2%	2–4%	4–7%	7–10%	>10%
S9	13–15%	10–13%	8–10%	5–8%	<5%
		15–18%	18–23%	23–28%	>28%
S10	20–30%	15–20%	10–15%	5–10%	<5%
		30–50%	50–70%	70–100%	>100%
Score	**0–20**	**20–50**	**50–70**	**70–90**	**90–100**

After predicted value of the variable and scored risk status, we can calculate the value of RIEO by using the above function.

4 Risk Forecast

We forecast the possible changes of risk of China's economic operation in 2010 and 2011, and the related predicted value of the variable was calculated by using method autoregressive moving average model (ARMA). Data used here from the CCER Economic Research Service Network database and Wind financial information database.

The final forecast results are shown in Table 5.

In all risk factors of China's economy operation, the forecasts showed that reserves/GDP and bank loans will be in the "at risk" status in 2010, and they may affect China's economy operation seriously in next one or two years. Furthermore, under the recent reform of exchange rate formation mechanism, appreciation of the Renminbi will continue and the value of huge foreign exchange reserves will shrink continuously.

Since 2009, bank loan grow rapidly and a considerable number of money does not flow into the real economy. This will lead to asset bubbles and financial risk in future, and which caused a hidden danger to the economic operation.

In 2010, China's capital market has experienced significant volatility of the stock market, and risk in stock market is gradually accumulated, therefore, the target risk rating for the "risk focus" state, and it is close to the "risky" level. Under the influence of several major factors in the above, the value of RIEO is equal to 32.5 in 2010, so the risk state is at the "risk concern" level.

According to the results in Table 5, the main risk factors such as credit expansion and capital market volatility, will affect China's economy operation continuously in 2011, and the value of RIEO is equal to 35 in 2011, so the state of risk rating is "risk concern" status. Compared with 2010, inflation is likely to continue to rise in 2011; moreover, employment and revenue are likely to be adversely affected by slow economic recovery.

Table 5 RIEO Value of 2010 & 2011

Index	2010		2011	
	Forecast (%)	Risk	Forecast (%)	Risk
S1	18.5	22.5	19	25
S2	20	20	15	22.5
S3	3.3	24.5	3.8	32
S4	4.5	42.5	5	50
S5	2.2	29	2.0	35
S6	4.5	42.5	4.5	42.5
S7	40	50	38	44
S8	3%	35	3.2	38
S9	21	62	18	50
S10	45	42.5	50	50
RIEO	**32.5**		**35**	

Under the influence of several major factors in the above, it can be inferred that if the government take appropriate policy measures, then the risk of the Chinese economy will be in full control, and the state of steady and rapid economic growth is expected to continue.

5 Conclusion

We have identified the main risk factors that impact China’s economy operation, and on this basis, a risk index model was established to evaluate China’s economic risks situation in future. The main conclusions include that China’s economy is in a “risk concern” level in 2010 & 2011, i.e. reserves/GDP and bank loans will affect China’s economy operation seriously in next one or two years. Furthermore, appreciation of the Renminbi will continue and the value of huge foreign exchange reserves will shrink continuously in 2010. Furthermore, this study shows that inflation is likely to continue to rise and both employment and revenue are likely to be adversely affected by slow economic recovery in 2011.

Taking into account the above factors, to promote the economic development in the next two years, China should gradually withdraw from loose monetary policy and take appropriate fiscal policy to eliminate the side effects of policies response to the crisis. And other measures such as interest rate adjustment and inflation expectations leading should be taken to prevent the breeding of asset price bubbles and increasing of inflation risk.

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Appendix

Matrix of the Importance of Indicators

Assignment	Definition
1	Equally
3	Somewhat
5	More
7	Obviously
9	Very
2, 4, 6, 8	Median

Systemic Risk

Johannes Hauptmann and Rudi Zagst

Abstract One of the aftermaths of the financial crisis is the search for a good measure to quantify systemic risk, i.e. the negative spillover effects that an individual institution or an industry sector might have on others or even the financial system as a whole. In a general setting, we introduce a measure for the systemic risk contribution of individual institutions which embeds different approaches made so far in the literature. Our approach ensures that the contributions to systemic risk of the individual institutions add up to the aggregate systemic risk and thus allows for supervisors to identify systemically important financial institutions and to set adequate capital requirements. To apply the proposed method, we give examples of how a market distress can be identified and show how the contribution to systemic risk changed along the financial crisis.

Keywords Financial crisis · Risk contribution · Risk measure · Systemic risk

1 Introduction

Since the beginning of the financial crisis in 2007 practitioners as well as academics have been discussing the problem of a comovement of financial assets in turbulent market periods. Especially during times of crises, tail comovement increases. (Acharya et al. 2010a) address this fact on the background of the financial crisis 2007–2009. A detailed view on the financial crisis is also given in (Brunnermeier 2009). The so-called correlation breakdown, a phenomenon describing the fact that correlations between financial assets tend to increase sharply in turbulent markets, has been proclaimed by many authors (see, e.g. (Bernhart et al. 2009), (Bertero and Mayer 1989), (King and Wadhwani 1990), or (Kim and Lee 1993)). This naturally contradicts the concept of diversification exactly when it is needed

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most. Peculiarly during times of crisis high correlations and (tail) comovement of congenerous institutions appears to amplify the market downturn leading to an increase of systemic risk. This is an important phenomenon to be understood by the supervisors of financial institutions. Therefore, the discussion on systemic risk and necessary adjustments in the regulation of financial institutions has become an important topic between international policy makers, regulators, practitioners, and academic researchers.

(Das and Uppal 2004) defined systemic risk as the risk of rare events affecting the value of various assets. (Duan and Wei 2007) studied the influence of this risk on the prices of equity options. After the financial crisis, scientists and regulators paid more attention to this topic. Primarily there is a burgeoning literature on measures for systemic risk: (Acharya 2009) defined systemic risk by measuring correlation of assets, (Huang et al. 2009) quantified it through the probability of a combined failure of congenerous institutions. The measurement itself is often linked to suggestions of regulation methods like in (Brunnermeier et al. 2009) aspiring countercyclical regulation in the influential Geneva report. Current regulation methods are mostly severe during times of crisis and gentle during booms resulting in intensifying the respective phase. This problem of procyclity and the resulting margin spirals are also addressed by (Borio 2004) and (Adrian and Shin 2009) who find empirical evidences for the margin spiral in the investment banking sector. (Brunnermeier and Pedersen 2009) engage in loss and margin spirals and show that market liquidity is correlated with fragility across assets and comoves with volatility. (Acharya et al. 2009) estimate systemic risk by the marginal expected shortfall for an aggregate shock and recommend taxing institutions by their contribution to systemic risk. (Acharya et al. 2010b) present a regulation model in the insurance sector.

(Adrian and Brunnermeier 2009) estimate the behavior of the financial system under the condition of a single institution being in distress and introduce a measure called the *CoVaR*, i.e. the Value at Risk (*VaR*) of a financial system conditional on a single institution being under distress. The institution's (marginal) contribution to systemic risk is defined to be the difference between the *CoVaR* and the unconditional *VaR* of the financial system.

(Huang et al. 2009) construct a systemic risk indicator based on CDS spreads of individual banks and the comovements in banks' equity returns. The risk indicator is interpreted as the insurance premium to cover distressed losses in the banking system. The aim is to estimate the behavior of a single institution under the condition of the financial system being in distress. Based on that paper, (Huang et al. 2010) apply this method to a portfolio of 22 major banks in Asia and the Pacific. In their paper not only the aggregated level of systemic risk is considered but also the components of the systemic risk. The systemic risk contribution of each bank to the banking system is defined as its marginal contribution to the systemic risk of the whole banking system.

The aim of both of the last two approaches is to identify and measure the risk on the financial system by institutions which are interconnected in a way that they can cause negative spillover effects on others or even the financial system itself. As opposed to the first approach, the second approach has the advantage that the marginal contributions add up to the aggregate systemic risk. This is important as supervisors are thus able to identify systemically important financial institutions and to set adequate capital requirements according to the systemic risk of the individual bank. We thus follow the second approach here but put the definitions into a more general setting.

In Sect. 2 we show different possibilities of how to describe distressed markets. How the contribution to systemic risk can be quantified and allocated between the different single institutions, industry sectors or asset classes is discussed in Sect. 3. Sect. 4 is dedicated to the results of our market analysis and in Sect. 5 we conclude.

2 Distressed Markets

In this section, we show different methods to describe distressed markets. The detection and adequate modeling of market turbulences is an important component for a sound risk management. We assume that we are dealing with a portfolio of assets where assets can also stand for a complete asset class or an industry sector. Therefore, now and in the sequel, let $x = (x_1, \ldots, x_n)'$ denote a specific portfolio of individual assets with random return processes R_i over a given time horizon, $R(x)$ be the portfolio return and the weights x_i summing up to 1.

Let $\Re isk$ be a risk measure which assigns the risk $\Re isk\,(x)$ to the portfolio return $R(x)$. Typical examples are the Value at Risk (VaR) or the Conditional Value at Risk ($CVaR$). We hereby assume for the ease of exposition that all appearing functions and measures exist and are finite. Furthermore, let $\mathcal{I} \in \{0, 1\}$ be an indicator process indicating that the financial market is in distress at time t iff $\mathcal{I}_t = 0$.

2.1 Value at Risk

The Value at Risk is the probably most common risk measure used in financial institutions, see e.g. (Jorion 2007) or (Jorion 2006). Given a fixed time horizon, e.g. one week, and a significance level $1 - \alpha \in (0, 1)$, the Value at Risk of portfolio x, $VaR_\alpha(x)$, is given by

$$VaR_\alpha(x) = \sup_b \{\mathbb{P}[R(x) \leq b] < q\} = \inf_b \{\mathbb{P}[R(x) \leq b] \geq q\}.$$

We set the financial market indicator $\mathcal{I}_t = 0$ if $R_t(x) \in (-\infty, VaR_\alpha(x)]$ and $\mathcal{I}_t = 1$ else. Consequently, the financial market is considered to be in distress at time t, iff the return at that time is below the VaR.

Fig. 1 Turbulent (*shaded*) and normal market periods as estimated via the ***VaR*** or quantile approach

The result for the distressed market sequence is shown in Fig. 1 (Here the reported results are based on the S&P500 Index using data from 01.04.1987 to 29.12.2009). The time horizon for which the *VaR* is derived is 1 week, $\alpha = 5\%$.

Remark (Normal Distribution). *Let R(x) be normally distributed with expectation $\mu(x)$ and standard deviation $\sigma(x)$. Then, the Value at Risk can be easily calculated as:*

$$VaR_\alpha(x) = -(\mu(x) - \Phi^{-1}(1-\alpha) \cdot \sigma(x))$$

where $\Phi^{-1}(1-\alpha)$ denotes the inverse of the standard normal distribution at the point of the confidence level $1-\alpha$.

For short-term horizons, the expected return is usually neglected and we get

$$VaR_\alpha(x) = \Phi^{-1}(1-\alpha) \cdot \sigma(x).$$

For the ease of exposition, we will use the latter definition assuming that the one-week horizon for calculating the VaR is short enough to assume that $\mu(x) = 0$. A generalization to the first definition is however straightforward.

2.2 Turbulent Markets

The recent market turmoil has once again emphasized the need for models of asset returns that exhibit real-world characteristics of return distributions. In contrast to the classical Black-Scholes model with constant parameters [see (Black and Scholes 1973)], regime-switching models allow for periods in which different market environments prevail by means of time-varying (stochastic) model parameters. The class of Markov-switching models introduced by (Hamilton 1989) has the feature that the state process indicating the current market regime is described by a Markov chain. This model class has grown in popularity as it can capture fat tails, asymmetries, autocorrelation, and volatility clustering [see e.g. (Timmermann 2000)], and has been applied, e.g. in (Alexander and Dimitriu 2005), (Chan et al. 2005), (Bernhart et al. 2009), and (Ernst et al. 2009).

The return dynamics of a global stock portfolio or market index is modeled with a discrete-time Markov-switching process. Depending on the unobservable state process $\mathcal{I}$, with states in $\{0,1\}$, the return process R of the global market index is characterized by a state depending drift and volatility parameter and described by

$$R_t = \mu_{\mathcal{I}_t} + \sigma_{\mathcal{I}_t}\varepsilon_t,$$

where ε_t is standard normally distributed. The indicator process $\mathcal{I}$ is modeled as a time-homogenous Markov chain with transition matrix

$$\begin{pmatrix} 1-p & p \\ q & 1-q \end{pmatrix}$$

Where $p = \mathbb{P}(\mathcal{I}_t = 1|\mathcal{I}_{t-1} = 0)$ and $q = \mathbb{P}(\mathcal{I}_t = 0|\mathcal{I}_{t-1} = 1)$. The initial distribution of $\mathcal{I}$ is $(\eta,1-\eta)$ with $\eta := \mathbb{P}(\mathcal{I}_1 = 0)$, and the stationary distribution is $(\pi_0,\pi_1) = (q/(p+q),p/(p+q))$. The model is completely parameterized by the vector

$$\theta = (p, q, \mu_0, \mu_1, \sigma_0, \sigma_1, \eta),$$

with $p,q,\eta \in [0, 1]$, $\mu \in \mathbb{R}$, and $\sigma > 0$.

As the indicator process $\mathcal{I}$ is not directly observable from market data, it will be estimated indirectly using the global stock market index. Utilizing the market index to estimate the state-indicator process allows for a convenient two-stage estimation procedure. The estimation is accomplished by the R-routine `BaumWelch` of the *RHmm*-package. This routine employs the Maximum Likelihood approach described in (Baum et al. 1970). After estimating the model, the most likely state sequence of $\mathcal{I}_t$ at any time t can be inferred by applying Viterbi's Algorithm [see (Viterbi 1967)]. If the model is applied like this, it nicely separates the empirical time series (as above we use S&P500 Index data from 01.04.1987 to 29.12.2009) into a turbulent market ($\mathcal{I}_t = 0$) with high (weekly) standard deviation (3.6085%) and negative (weekly) average return (−0.1927%) and a normal market ($\mathcal{I}_t = 1$) with positive average return (0.2816%) and moderate standard deviation (1.5525%). The estimated probabilities of $p = 5.1156\%$ and $q = 2.1965\%$ show a high persistence of staying in an actual regime and give a stationary distribution of (30.0393%, 69.9607%)

According to the general definition, the financial market is considered to be in distress iff $\mathcal{I}_t = 0$, i.e. if the market state is turbulent. The result for the most likely state sequence is shown in Fig. 2.

Fig. 2 Turbulent (*shaded*) and normal market periods as estimated via a Markov-switching model

2.3 Downturn Markets

Another model to deal with distressed markets is the heuristic approach defined by (Ernst et al. 2009). It allows for a separation into calm and crisis states in the time period between two 26 week highs. Let, again, R be a global market index. The set of all 26 week highs is defined as

$$26wh = \{t \in \{t_{start+26}, \ldots, t_{end}\} | R_t = max\{R_{t-26}, \ldots, R_t\}\}.$$

A crisis between two 26 week highs requires a minimum loss of 20% relative to the first 26 week high. Thus, the core crisis dates are defined to be

$$CCD_i = \left\{t \in \{26wh[i], \ldots, 26wh[i+1]\} | \frac{R_t}{R_{26wh[i]}} \leq 0.8\right\}.$$

If $CCD_i = \emptyset$ there are no turbulent states. Otherwise, the starting date of the crisis is set to the last day on which the 10% loss level is passed before the first core crisis date CCD_i [1] is reached, i.e. for all i with $CCD_i \neq \emptyset$, the start date for turbulent times is set to

$$t_S = 1 + max\left\{t \in \{26wh[i], \ldots, CCD_i[1]\} | \frac{R_t}{R_{26wh[i]}} > 0.9\right\}.$$

The next step is to determine the end date of a crisis. For this, t_L denotes the date of the lowest value of R_t before the next 26 week high is reached, i.e.

$$t_L = min\{t \in \{26wh[i], \ldots, 26wh[i+1]\} | R_t = min\{R_{26wh[i]}, \ldots, R_{26wh[i+1]}\}\}.$$

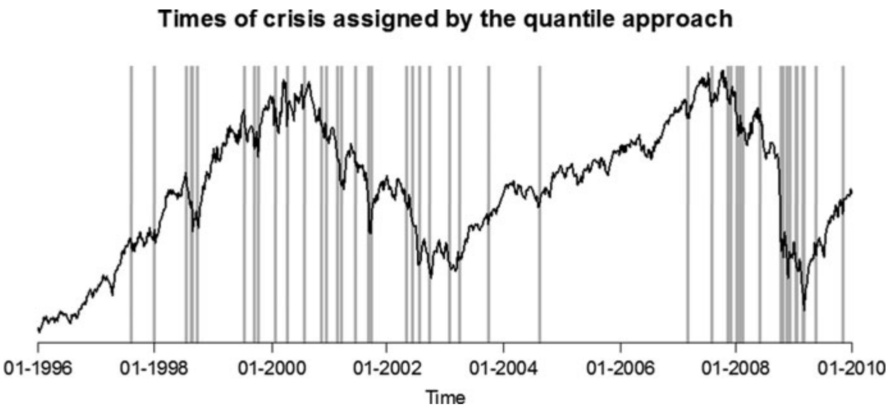

Fig. 3 Crisis (*shaded*) and non-crisis market periods as estimated via the method of Ernst et.al.

One exception is defined: in the case of a market which is upswing after the lowest index value, followed by a new downturn accounting for at least 10% of the upswing's highest value, the crisis is extended to the date of the lowest index value of the new downturn (t_D). The definition of t_D requires the latest possible end date t_{DE} and the latest possible start date t_{DS} of the new 10% downturn allowing t_{DE} to be the latest possible end, i.e.

$$t_{DE} = max\left\{ t \in \{t_L, \ldots, 26wh[i+1]\} | \exists\ \tilde{t} \in \{t_L, \ldots, t\} \text{with } \frac{R_t}{R_{\tilde{t}}} \leq 0.9 \right\},$$

$$t_{DS} = max\left\{ t \in \{t_L, \ldots, t_{DE}\} | \frac{R_{t_{DE}}}{R_t} \leq 0.9 \right\},$$

and

$$t_D = min\{t \in \{t_{DS}, \ldots, t_{DE}\} | R_t = min\{R_{t_{DS}}, \ldots, R_{t_{DE}}\}\}.$$

For the end of the crisis, $t_E = t_D$ if t_D is defined, and $t_E = t_L$ otherwise.

We define the financial market indicator $\mathcal{I}_t = 0$ if t is a crisis date, i.e. if it falls into one of the derived intervals $[t_S, t_E]$, and $\mathcal{I}_t = 1$ else. Crisis periods defined in this way are shown to match quite well with crisis periods mentioned in the public press. Consequently, the financial market is said to be in distress at time t, if the method signals a crisis date. The results for the crisis and non-crisis states of the S&P500 Index are shown in Fig. 3.

3 Measuring Systemic Risk

To calculate the contribution of a portfolio x to the systemic risk, we first define the risk measures in general as well as under the condition that the market indicator $\mathcal{I}$ indicates the financial market to be in distress. In the latter case, we use the conditional distribution $\mathbb{P}[R(x) \leq b|\mathcal{I} = 0]$ instead of the unconditional one to calculate all risk measures. To signal this distress condition, we use the front letter $\mathcal{D}$ or simply add the condition to the argument. Therefore, the risk of the portfolio x in a financial market under distress is denoted by

$$\mathcal{D}\Re isk(x) = \Re isk(x|\mathcal{I} = 0).$$

Example. *The Value at Risk of portfolio x in a market under distress, given a fixed time horizon and a significance level* $1 - \alpha \in (0, 1)$, *is calculated by*

$$\mathcal{D}VaR_\alpha(x) = \sup_b \{ \mathbb{P}[R(x) \leq b|\mathcal{I}= 0]<q\} = \inf_b \{ \mathbb{P}[R(x) \leq b|\mathcal{I}= 0] \geq q\}.$$

The Marginal Risk $M\Re isk_i(x)$ with respect to the individual asset i is defined by:

$$M\Re isk_i(x)=\frac{\partial \Re isk(x)}{\partial x_i} \approx \frac{\Re isk(x+\Delta x_i)-\Re isk(x)}{\Delta x_i}$$

with $x + \Delta x_i$ denoting the portfolio x increased by a small amount of Δx_i in position i.

Correspondingly, the Marginal Risk with respect to the individual asset i in a market under distress is given by:

$$\mathcal{D}M\Re isk_i(x) = M\Re isk_i(x|\mathcal{I}= 0).$$

Given the Marginal Risk, the risk contribution of the individual asset i to the overall risk of the portfolio x is defined as

$$\Re isk_i(x) = x_i \cdot M\Re isk_i(x).$$

Consequently, the risk contribution of the individual asset i to the overall risk of the portfolio x under distress is defined as

$$\mathcal{D}\Re isk_i(x) = \Re isk_i(x|\mathcal{I}= 0) = x_i \cdot \mathcal{D}M\Re isk_i(x).$$

If the function $x \mapsto \Re isk_i(x)$ is (positively) homogeneous of level 1, i.e.

$$\Re isk_i(\lambda \cdot x) = \lambda \cdot \Re isk_i(x) \text{ for all } \lambda \neq 0 (\lambda > 0),$$

it can be easily shown that

$$\Re isk(x) = \sum_{i=1}^{n} \Re isk_i(x) = \sum_{i=1}^{n} x_i \cdot M\Re isk_i(x).$$

This is also known as the Euler capital allocation principle [see (Embrechts et al. 2005)]. Obviously, the same holds true for the distressed formulation. In the end, homogeneity of level 1 guarantees that the individual contributions to (systemic) risk sum up to the overall (systemic) risk. Risk measures which are homogeneous of level 1 are, e.g. the standard deviation and the tracking error. Risk measures which are positively homogeneous of level 1 are, e.g. the Value at Risk and the Conditional Value at Risk.

Example (Normal Distribution). *Let us assume that the portfolio return R(x) is normally distributed and that we are considering a short-term horizon for the Value at Risk, i.e. we neglect the expected return. Furthermore, let the variance of the portfolio return be given by* $\sigma^2(x) = x'Cx$ *with C denoting the covariance matrix of the individual returns. Setting* $\mathfrak{R}isk(x) = VaR_\alpha(x)$, *the Marginal Value at Risk can be easily calculated by*

$$MVaR_\alpha(x) = (MVaR_\alpha(x))_{i=1,\ldots,n} = \frac{Cx}{x'Cx} \cdot VaR_\alpha(x).$$

We now have everything in hand to define the contribution of an individual asset to systemic risk. Therefore, we compare the risk contribution of an individual asset i in a market under distress with its unconditional risk contribution.

The systemic risk contribution $\mathfrak{S}\mathfrak{R}isk_i$ of an individual asset i is given by

$$\mathfrak{S}\mathfrak{R}isk_i(x) = (\mathcal{D}\mathfrak{R}isk_i(x) - \mathfrak{R}isk_i(x))^+ = (x_i \cdot (\mathcal{D}M\mathfrak{R}isk_i(x) - M\mathfrak{R}isk_i(x))^+.$$

The systemic risk contribution can be seen as an add-on to the unconditional risk. This should be accounted for due to the additional influence that an individual institution has on the risk of the financial system in case of distress. The following adjusted risk number accounts for this additional effect.

The Adjusted Risk $\mathfrak{A}\mathfrak{R}$iski of the individual asset i is given by

$$\mathfrak{A}\mathfrak{R}isk_i(x) = \mathfrak{R}isk_i(x) + c \cdot \mathfrak{S}\mathfrak{R}isk_i(x)$$

with c denoting the weight that is put on the systemic risk contribution of the individual asset.

Remark. *Note that the left-hand part* $\mathfrak{R}isk_i(x)$ *of the sum on the right of the previous equation might quite well be calculated using another historic time window as applied for the right-hand part. E.g., a rather short-term one-year historic window might be adequate for the calculation of* $\mathfrak{R}isk_i(x)$ *while a long-term historic window of ten years might be used to derive the contribution to systemic risk.*

Also note that, in an advanced model like the Markov-switching model from Sect. 2.2, we may want to allow the weight c to depend on time. To do so, we could use the probability of the indicator process being in distress.

Special Cases.

1. *Let* $\Re isk$ *be the Value at Risk. Using the market indicator to indicate the distress of an individual asset and setting the portfolio x to be the market index, we get the CoVaR as proposed in* (Adrian and Brunnermeier 2009). *It looks at the Value at Risk of a portfolio conditional on an individual asset i being under distress. The disadvantage of this measure is that the condition changes with each individual asset and therefore the measure is not additive with respect to risk contribution.*
2. *Let* $\Re isk$ *be the Conditional Value at Risk. Using the global market index to indicate the distress of the financial market and setting the portfolio x to be an individual asset i, we get a measure close to the one proposed in* (Huang et al. 2010). *It looks at the Value at Risk of an individual asset i conditional on the financial market being under distress. The advantage of this measure is that the condition does not change with each individual asset and therefore the measure is additive with respect to risk contribution.*

4 Results

For our market portfolio we use weekly market capitalization data from 395 institutions listed in the S&P500 Index from January 1996 to December 2009, which are then aggregated to the industry sectors Financials, Technology, Industrials, Consumer Service, Consumer Goods, Oil & Gas, Health Care, Basic Materials, Utilities, Telecommunications and Others. For a better overview, these industry sectors are used as individual assets as applied in Sect. 3. All portfolio weights therefore also refer to these industry sectors. The corresponding portfolio weights are shown in Fig. 4.

As risk measure $\Re isk$ we use the Value at Risk for a weekly time horizon, $\alpha = 5\%$, and a rolling historic time window of ten years. For the easy of exposition, we assume normally distributed returns, unconditional as well as conditional under market distress, i.e. in the tails, with different expected returns, standard deviations and correlations under both regimes. On display in the sequel are the results derived using the Markov-switching model, introduced in Sect. 2, to identify a market distress. Results for the other methods can be found in the appendix.

The relative contributions to systemic risk of the different industry sectors are analyzed at three points in time, 20.11.2007 representing a time period prior to or at the beginning of the financial crisis, 22.07.2008 representing the peak, and 20.10.2009 a period after the financial crisis. The results for the contributions to systemic risk are shown in Fig. 5. It can be seen that prior to the financial crisis, the risk contribution of the sector Technology was the highest. After the peak of the financial crisis 2007–2009, the sector Financials and even the sector Industrials are outrunning the sector Technology. The sectors Consumer Service and the Consumer Goods complete the list of the most relevant industry sectors regarding the contribution to systemic risk. These five sectors on their own account for more than 75% systemic risk over time.

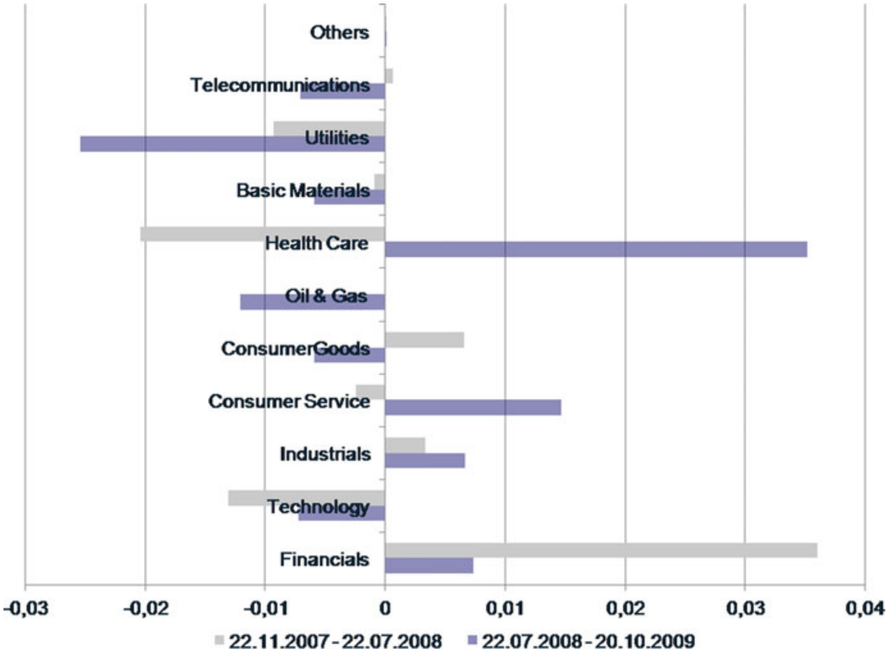

Fig. 4 Portfolio weights of the different industry sectors

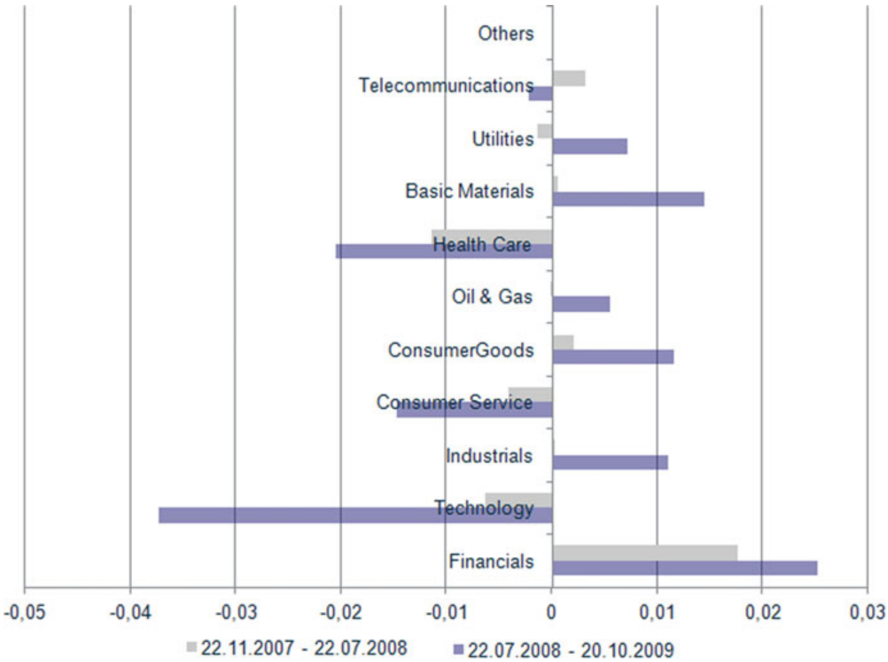

Fig. 5 Contribution to systemic risk (in%) with distress defined by a Markov-switching model

To identify the sources of the increasing contribution of the sector Financials we look at the change of the relative contributions to systemic risk of the industry sectors in Fig. 6. As you can see there the increasing contribution of the Financials in the first period is mainly driven by decreasing contribution in Technology, Consumer Service and Health Care. The second period exhibits the more interesting period with a conspicuous fall in contribution of the sector Technology of nearly 4%. Note that in this period every sector has a much higher change in contribution as in the period before. Beside Financials also Industrials, Basic Material and Consumer Goods increase their contribution by about 1.2%, Utilities and Oil & Gas by about 0.6%. On the other hand Consumer Service and Health Care decrease their contribution by about 1.5% and 2%.

If we compare Figs. 7 and 8, we see that Basic Materials increases it's Marginal Risk in distressed markets by roughly 2% in the second period while the increase in the risk contribution is less than 1%. This is due to the low weight of this industry sector in the market portfolio. It thus can be seen that the change of the relative contribution to systemic risk results from three different origins: the size effect, the effect of increasing correlations and comovement in distressed markets, and the change in the unconditional *VaR*.

As mentioned above we also tested the *VaR* approach to assign the times of a market crisis. As the results are roughly the same we do not explicitly discuss them here. Figures 9 and 10 in Appendix A show some of the graphics also used for our analysis above. With the *VaR* approach, the sector Financials also increases its

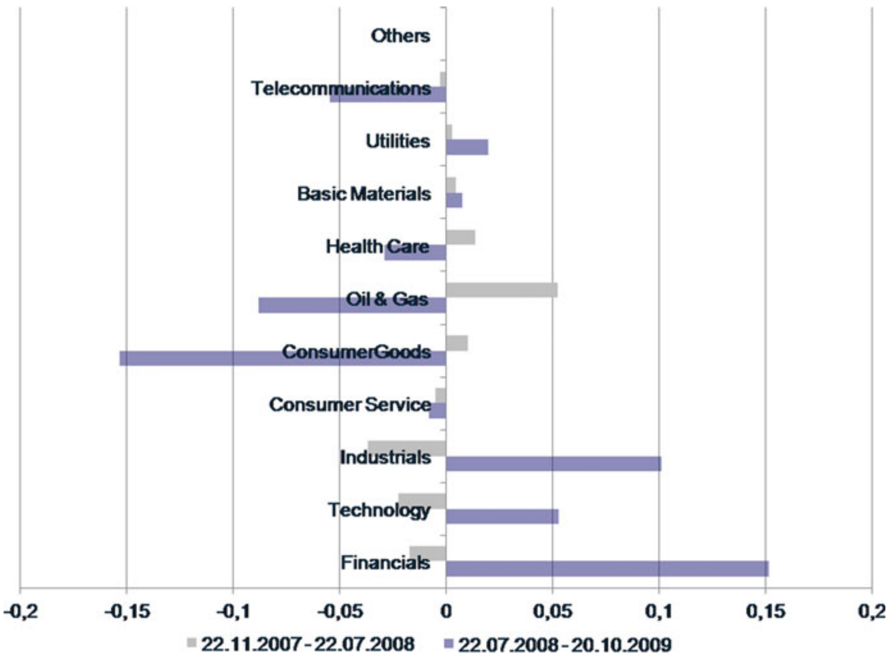

Fig. 6 Change of contribution to systemic risk with distress defined by a Markov-switching model

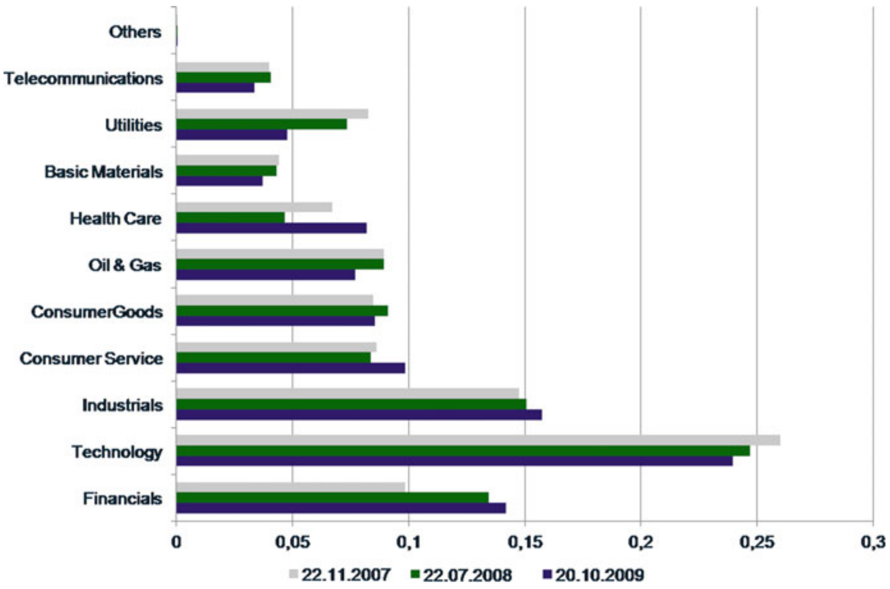

Fig. 7 Change of marginal risk in distressed market with distress defined by a Markov-switching model

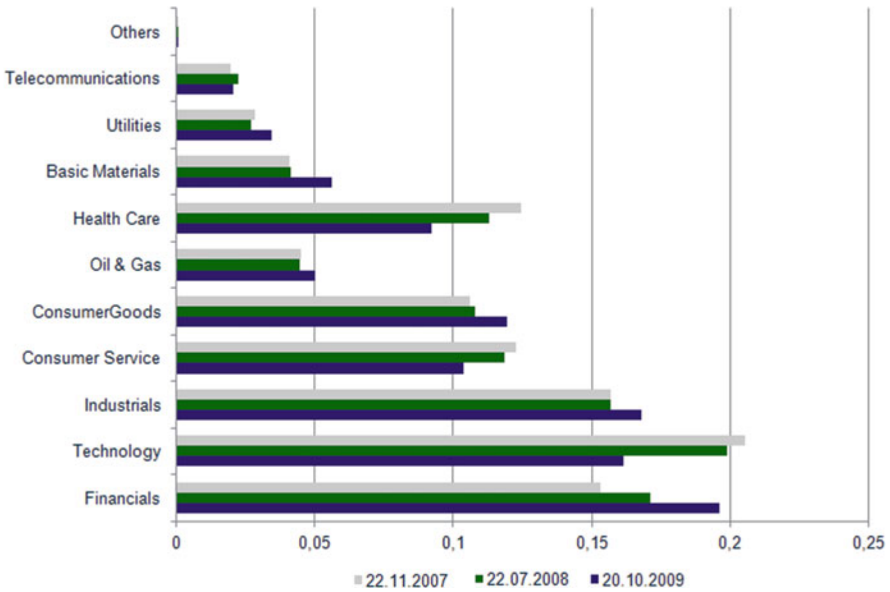

Fig. 8 Change of risk contribution in distressed market with distress defined by a Markov-switching model

contribution over time as well as Technology and Industrials, especially in the second period of the financial crisis. On the other hand, the contribution of the industry sectors Consumer Goods and Oil & Gas decreases. One difference concerning this approach is that the Financials do not outrun Industrials, even after the Financial crisis.

We also tested the heuristic approach as crisis indicator. Figures 11 and 12 in Appendix B show some of the graphics. With the heuristic approach, the sector Financials also increases its contribution over time as well as Health Care, Consumer Service and Industrials, especially in succession of the financial crisis. On the other hand, the contribution of the sector Technology decreases as well as Consumer Goods, Oil & Gas and Utilities, especially in the second period. One difference concerning this approach is that the Financials do not outrun the sector Technology, even after the Financial crisis.

To put it in a nutshell, the financial crisis generated a lot of changes in the contribution to systemic risk regarded to industry sectors. While the fragmentation of this contribution was almost constant over time the circumstances changed rapidly already in July 2008 – two month prior to the bankruptcy of Lehman Brothers. During the financial crisis, the contribution to systemic risk especially of the sector Financials featured a continuous growth even beyond May 2009, where it outruns, e.g., the continuously decreasing contribution of the sector Technology.

5 Conclusion

In this paper we introduced a measure for the systemic risk contribution of individual institutions or industry sectors. Due to the additivity of our measure we were able to not only look at the institutions separately but also calculate sector-specific systemic risk contributions. We showed that in succession of the dotcom bubble, the risk contribution of the sector Technology was highest. Hence, during the financial crisis 2007–2009 the sector Financials outruns the sector Technology.

It should be mentioned that there is a lot of flexibility in the proposed measure for systemic risk. We apply the Value at Risk as the risk measure used for our calculations. However, any risk measure which is homogenous of degree 1 could be utilized to still guarantee the additivity of the measure for systemic risk. Thus, the proposed method can also be used for risk measures like, e.g., the Conditional Value at Risk or even the marginal tracking error.

The last property we want to mention is that the proposed method allows calculating the contributions to systemic risk. This can be interpreted as the risk capital to be set aside for the increase of systemic risk due to an individual institution in case of a market distress. Thus, charging institutions relying on that measure as a compensation of their risk contribution might be an interesting future application.

Appendix A: Results VaR Approach

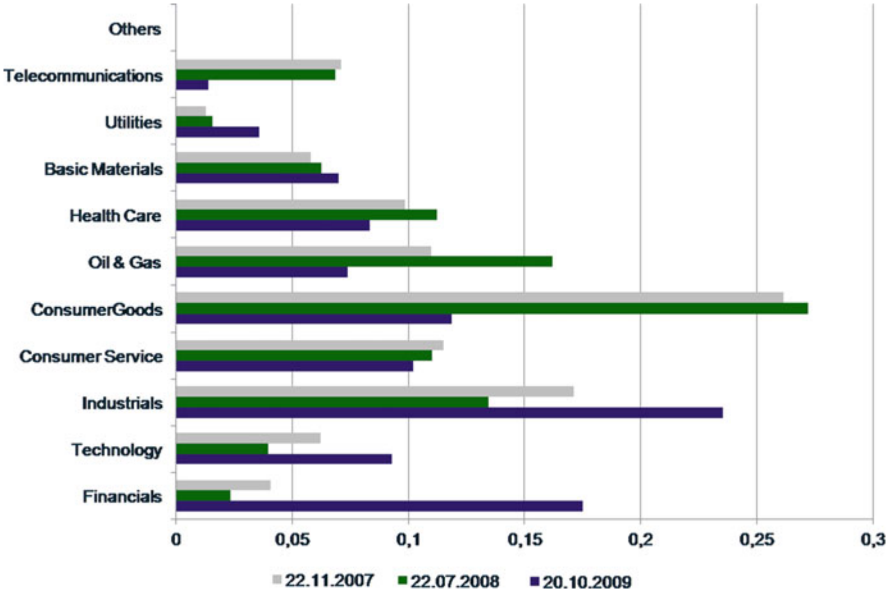

Fig. 9 Contribution to systemic risk (in%) with distress defined by the *VaR* approach

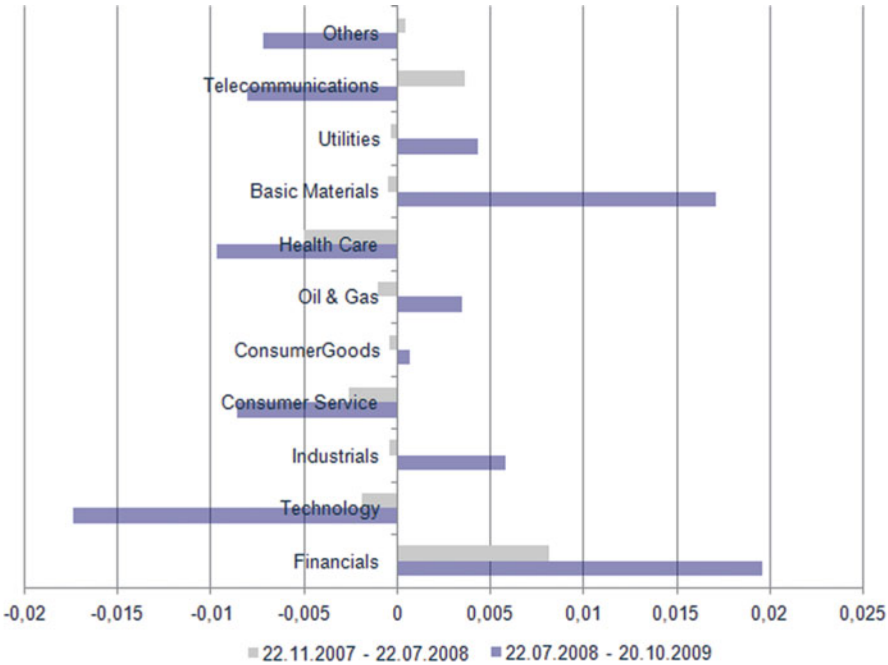

Fig. 10 Change of contribution to systemic risk with distress defined defined by the *VaR* approach

Appendix B: Results Heuristic Approach

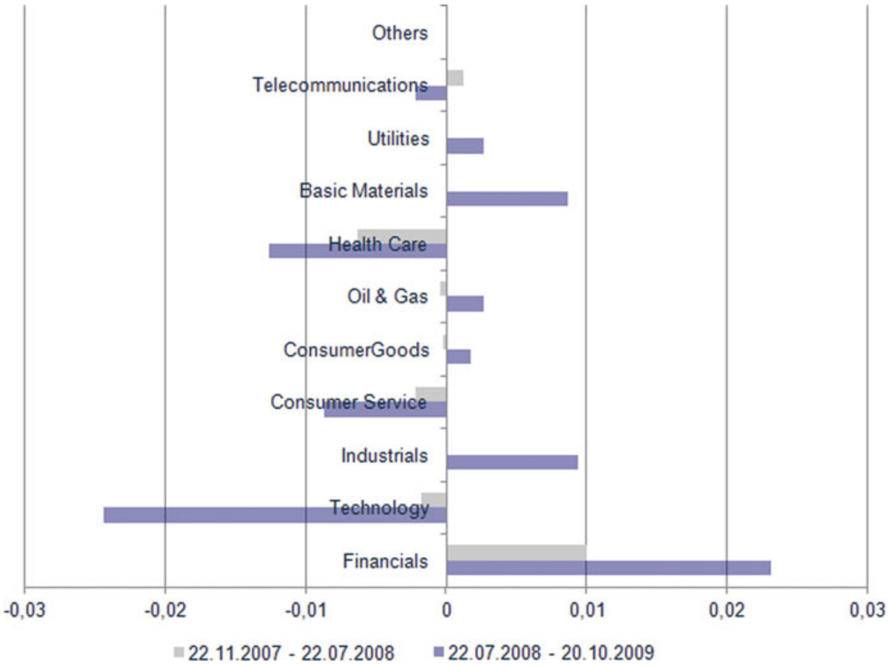

Fig. 11 Contribution to systemic risk (in%) with distress defined by the heusristic approach

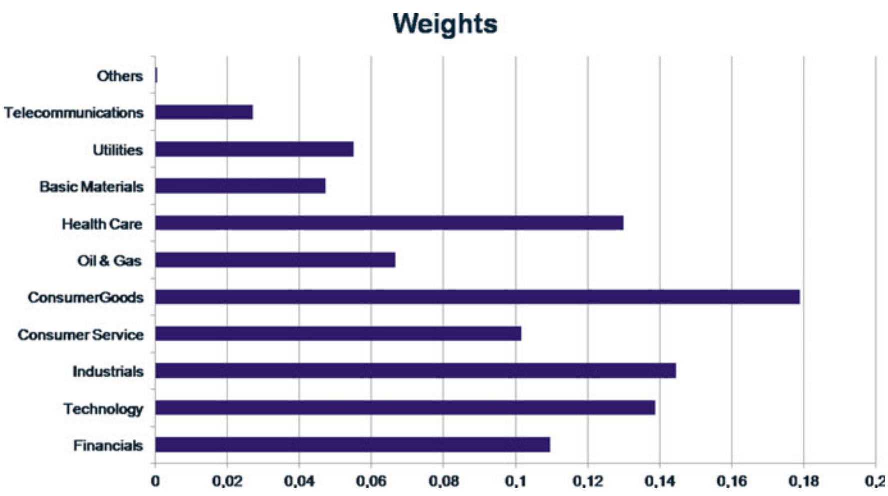

Fig. 12 Change of contribution to systemic risk with distress defined by the heusristic approach

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