EADN WORKING PAPER No. 50 (2012)

Macro Stress Testing through Sectoral Macrofinancial Risk Framework

Boontham Rajitpinyolert and Kanokwan Chancharoenchai

Faculty of Economics, Kasetsart University

Bangkok, Thailand

Final Report of an EADN Individual Research Grant Project

May 2012

Macro Stress Testing through Sectoral Macrofinancial Risk Framework

Abstract

Under macrofinancial risk framework, central bank responds to the economic uncertainty with the higher level of interest rate than traditional neoclassical model does, for guarding against the high magnitude of risk. As a result, it results in higher output loss and lower gap between inflation rate and its target.

Under the model with concentration risk, central bank has to assess the dynamic of macroeconomic variables in each sector simultaneously. In general, there would be less diversification effect for economic performance under this environment. As a result, central bank would adopt more conservative monetary policy. In addition, for the risk-transfer stress under concentration risk environment, interest rate would be higher and, henceforth, output and inflation rate would be lower than those without concentration risk.

Finally, the risky sector in the economy would have lower PD, after incorporating concentration risk under the risk-transfer stress, because of the more responsive policy interest rate to the change in inflation and output. As the finance sector plays a role as the financing source for others, based on the model with concentration risk, the shock from other sectors would have an impact on its asset value. Therefore, its PD would be higher than that under no concentration risk or one-sector model economy. In other words, without concentration risk incorporated, PD from the finance sector may be underestimated.

Macro Stress Testing through Sectoral Macrofinancial Risk Framework

Boontham Rajitpinyolert*

Kanokwan Chancharoenchai†

1. Introduction

Last year, the world financial crisis has left several economists with skepticism over the usefulness of the economics knowledge. There is no early warning sign over this perfect storm. Many attempts, after this crisis erupted, are set to prevent the future crisis or absorb the loss impact of the future crisis, if any. The most tangible initiative is to establish the institution called Financial Stability Board (FSB) by G-20 meeting in London during April 2009, in order to mainly build the 'early warning' system for the world economy. This paper aims to be in the similar tone of work. We would like to model the economy into four economic sectors: Corporate, Financial, Household, and Sovereign Sector. The macrofinancial risk framework is implemented by the one-factor model with full blown version of concentration risk approach (the plausibly most accurate concentration risk model at present).

This approach in modeling economy has the advantages over the traditional one in the following perspectives. First, it is able to determine the cut-off point of economy ready to enter in breaking down mode, in which it is not mentioned in the traditional model. Secondly, the capability of assessment in the probability and impact of the crisis eruption pinning down into each sector and industry is enhanced. Thirdly, the measurement in the impact of the default correlation level, in which it is skyrocketed during the crisis, is formulated based on the performance of the economy and used as the early indicator for the crisis occurrence. Finally, we can rely on the usage of stress testing concept as the tool for conducting policy implication.

2. Review Literature

There are at least two lines of research in the development of macrofinancial risk model: the explicit incorporation of financial sector with some risk management features into macroeconomic model in order to capture the behavior of agents in each financial institutions, pioneered by Brunnermeir and Sannikov (2009), and the utilization of contingent claim approach (CCA) to measure the asset value with respect to the threshold level according Merton (1974) for all sectors in the economy as the vehicle to run the dynamic of the economy led by Gray et al (2007).

* Research team leader: Department of Economics, Faculty of Economics, Kasetsart University, 50 Phahonyothin Road, Bangkok, 10900, Thailand. e-mail: boontham.r@ku.ac.th

† Corresponding researcher: Department of Economics, Faculty of Economics, Kasetsart University, 50 Phahonyothin Road, Bangkok, 10900, Thailand. e-mail: kanokwan.c@ku.ac.th

This paper would pursue the latter approach on the ground that the approach is more conducive to include and adapt the more realistic assumptions of risk management, such as concentration risk, in which it is not able to be incorporated under the former approach. In addition, the CCA framework provides a forward-looking market-based set of indicators to gauge the susceptibility of various sectors in the economy and is more oriented to quantifying the effects of asset-liability mismatches within and across institutions.

From the theory behind the chosen approach, in estimating the degree of risk for any institution from credit risk model perspective, the most common methodology is from J.P. Morgan (1997) based on Merton (1974) regarding to options pricing. The basic concept behind this approach is the one risk-factor model according to Vasicek (1987). However, in order to measure the degree of risk with the reasonable accuracy, the two conditions that no any single account is relatively large in comparison to others and the only single risk factor, which is the correlation between the return of the portfolio analyzed and its economic condition, must be presented in the portfolio.

Unfortunately, in the real world, these two conditions are not easily met. Suppose that if the first one is violated due to concentration risk from too low granularity of loan accounts within their portfolio, the 'name concentration' method to capture the granularity of all customers in the whole portfolio, pioneered by Gordy (2003), Martin and Wilde (2003), and Wilde (2001), is applied to resolve or alleviate this limitation.

For the second condition, violations of the "single systematic factor" assumption may be more difficult to discern, and also more difficult to address than imperfect granularity. In general, a particular bank may be heavily concentrated in its exposure to some of these risk factors and lightly concentrated to others. The extent to which a single-factor model understates economic capital depends on both the degree to which the bank is unbalanced in its industry exposures and the extent to which industry risk factors are correlated with one another. This form of credit concentration risk is known as sector concentration.

There is a growing body of literature that deals with the question of measuring the role of sector concentration on credit risk assessment explicitly through the analysis of multi-factor portfolio models. In other words, the approach comes from the realization that risk is inherently multi-dimensional and focuses on developing the simulation of multi-factor models. The approach used in this paper is to model concentration risk from Monte-Carlo simulations based on Duellmann and Masschelein (2006).

For the stress testing, BCBS (2005) has suggested using stress tests to identify the size of the capital buffers that banks would need under the new Basel regime. The suggestion contained no details on how stress testing should be done. While a typical stress test would be a deterministic move in the portfolio ratings distribution (corresponding to some historical period of credit distress, e.g. in Erwin and Wilde, 2001, or Catarineu-Rabell et al, 2002), stress testing in this paper, according to Trueck (2008), could be approached using probabilistic risk models with respect to conditional Value-at-Risk. In addition, we used risk-transfer stress approach in performing stress test.

3. Methodology and Dataset

There are three sub-sections in this section. Firstly, the asset value calculation from the one-factor model is described in conjunction with the explanation of four sectors in the economy. Next, the threshold value (barrier) of the default is calculated under both with and without transferring risk among economic sectors. From these inputs, the probability of default (PD) can be derived for each sector and entire economy.

Secondly, the output from the first section is incorporated with sector concentration risk by Multi-Sector Monte Carlo (MSMC) method, the plausibly most powerful approach, into the model.

Finally, stress testing, based on adjustment on factor model approach, is taken to analyze the impact of several shocks toward credit risk of each sector in the economy. From these, the impacts of unexpected events on major macroeconomic variables in the economy are used to measure the degree of risk for each sector from risk-transfer among sectors in stress testing exercise.

3.1 The Sectoral Macrofinancial Framework from One-Factor Model

The steps for the analysis of sectoral macrofinancial framework from one-factor model are taken as follows:

3.1.1 One Factor model

According to one-factor model based on Schonbucher (2000), the values of the assets of the obligors are driven by a common, standard normally distributed factor Y component and an idiosyncratic standard normal noise component ε_n .

$$V_n(T) = \sqrt{\varsigma}Y + \sqrt{1-\varsigma}\varepsilon_n \qquad \forall_n \leq N, \tag{1}$$

Where Y *and* ε_n with n ≤ N *are i.i.d. standard normally* $\Phi(0, 1)$*-distributed, and* ξ represents systemic risk factor measured by the correlation between gross domestic product (GDP) and the asset value of each sector.

Using this approach the values of the assets of two obligors n and m ≠ n are correlated With linear correlation coefficient ρ. The important point is that *conditional on the realization of the systematic factor* Y*, the firm's values and the defaults are independent.*

The probability distribution at time T is shown in figure 1 below.

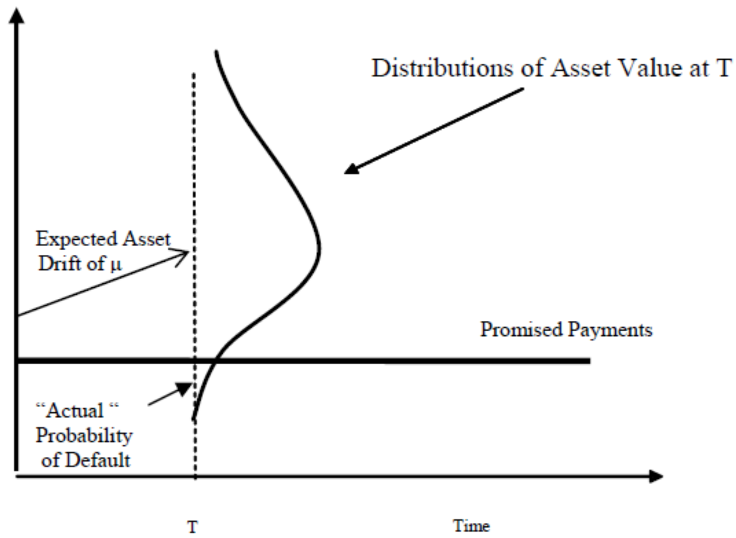

Figure 1: Distribution of Asset Value in Merton (1974) Framework

3.1.2 The Distribution of the Defaults

In the following Schonbucher (2000) assume that all obligors have the same default barrier $K_n = K$ and the same exposure $L_n = 1$

By the law of iterated expectations, the probability of having exactly n defaults is the average of the conditional probabilities of n defaults, averaged over the possible realizations of Y and weighted with the probability density function $\phi(y)$:

$$P[X = n] = \int_{-\infty}^{\infty} P[X = n | Y = y] \, \phi(Y) dy \tag{2}$$

Conditional on Y = y, the probability of having n defaults is

$$P[X = n | Y = y] = \binom{N}{n} (p(y)^n (1 - p(y))^{N-n} \tag{3}$$

where we used the conditional independence of the defaults in the portfolio.

The individual conditional default probability p(y) is the probability that the firm's value Vn(T) is below the barrier K, given that the systematic factor Y takes the value y:

$$P(y) = P[V_n(T) \langle K | Y = y]$$

$$= P\left[\sqrt{\varsigma} Y + \sqrt{1-\varsigma}\, \varepsilon_n \langle K | Y = y\right]$$

$$= P\left[\varepsilon_n \langle \frac{K - \sqrt{\varsigma} Y}{\sqrt{1-\varsigma}} | Y = y\right]$$

$$= \Phi\left(\frac{K - \sqrt{\varsigma}Y}{\sqrt{1-\varsigma}}\right)$$

Substituting this into equation (2) yields

$$P[X = n] = \int_{-\infty}^{\infty} \binom{N}{n} \left(\Phi(\frac{K - \sqrt{\varsigma}Y}{\sqrt{1-\varsigma}})\right)^{n} \left(1 - \Phi(\frac{K - \sqrt{\varsigma}Y}{\sqrt{1-\varsigma}})\right)^{N-n} \phi(y)dy$$

Hence the distribution function of the defaults is

$$P[X \le n] = \sum_{n=0}^{m} \binom{N}{n} \int_{-\infty}^{\infty} \left(\Phi(\frac{K - \sqrt{\varsigma}Y}{\sqrt{1-\varsigma}})\right)^{n} \left(1 - \Phi(\frac{K - \sqrt{\varsigma}Y}{\sqrt{1-\varsigma}})\right)^{N-n} \phi(y)dy \qquad (4)$$

In terms of calibration, for corporate, financial institutions and household sector, the inputs for one factor model are collected from profit for SET firms (except banking sector), firms in Banking sector from SET, and Gross Domestic Product (GDP) per capita under household sector, respectively.

CCA for Sovereign Sector

Under the sovereign sector, in order to calculate sovereign assets and asset volatility, the model combining money and local currency debt together to determine local currency liabilities (LCL).

Gray et al (2007) described the derivation of implied sovereign assets $V_{Sovereign}$ and asset volatility in a simple two-claim CCA framework as follows. The value of local currency liabilities in foreign currency terms, $LCL_{\$}$, is a call option of sovereign assets in foreign currency terms, $V_{\$Sov}$, with the strike price tied to the distress barrier for foreign currency-denominated debt, B_f, which is derived from the promised payments on foreign currency debt and interest payment up to time t.

To use this equation, we need to compute the value of local currency liabilities, in dollar terms, which appear on the left-hand side of the pricing equation. For that we will need the covered interest rate parity equation, which is:

$$X_S = X_F\, e^{(r_f - r_d)T}$$

Where X_S is the spot exchange rate and X_F is the forward exchange rate. A risk premium is ignored for a moment. The covered interest rate parity equation can be written as:

$$(1/ X_S) = (1/ X_F\, e^{(r_f - r_d)T}) = (e^{-(r_f + r_d)T} / X_F) = e^{-r_f T} e^{r_d T} / X_F$$

The value of local currency liabilities, in local currency terms, is written as $(M_{LC} + B_d e^{-r_d T})$. Base money has a value of M_{LC} at time 0, and local currency debt at time 0 has the value $B_d e^{-r_d T}$. The formula for the value of local currency liabilities, in foreign currency terms, is found by dividing by the spot exchange rate and applying the covered interest rate parity formula:

$$(M_{LC} + B_d e^{-r_d T})/X_S = (M_{LC} + B_d e^{-r_d T})(e^{-r_f T} e^{r_d T}/ X_F) = [(M_{LC}\, e^{r_d T} + B_d)\, e^{-r_f T}]/ X_F$$

So that

$LCL_{\$} = M + B_{d\$, t=0} = [(M_{LC}\, e^{r_d T} + B_d)\, e^{-r_f T}] / X_F$

Gray et al (2007) use the Covered Interest Parity (CIP) equation this gives us a current, market-based estimate of what the future spot rate will be. This model combines money and sovereign local currency debt together to get local currency liabilities (LCL). The book value of foreign-currency-denominated debt is used to define the distress barrier $B_{Sovereign}$. A simple two-claim CCA framework is used to calibrate the sovereign balance sheet by calculating two variables: implied sovereign assets $V_{Sovereign}$ and asset volatility.

These two variables are calculated by solving two equations in the two unknowns. The first equation in this pair is the equation stated above for the value of the sovereign "equity", and the second equation is derived by applying ito lemma to the above call option-pricing formula to derive a formula for the volatility of equity. The two equations as functions of the variables in this setting are as follows.

$$LCL_{\$} = f_1(V_{Sovereign}, \text{volatility of sovereign assets}, B_{Sovereign}\ r, t)$$
$$LCL_{\$}\, \sigma_{\$LCL} = f_2(V_{Sovereign}, \text{volatility of sovereign assets}, B_{Sovereign}\ r, t) \qquad (5)$$

3.1.3 Threshold (Barrier) Value Determination

According to Gray et al (2007), the economy consists of four sectors: Corporate, Financial Institutions, Households, and Sovereign.

Based on the macrofinance valuation identities, put-call parity relationships state that the asset value A of each sector is equal to the value of its equity plus the value of its risky debt. The function E_j refers to the period t value of sector j's equity (i.e. the junior claim), which is modeled as an implicit call option. The horizon period is T for the calculation of the implicit option values. Risky debt, D_j, is equal to the default-free value of the debt, denoted by $\underline{B}_i$ ($\underline{B}_i = B_i e^{-rT}$), minus the value of the implicit put option, which is denoted by P_j (the expected losses associated with the debt). Note that we use the same time horizon T *for* all sectors in the calculation of the CCA values at each point in time.

The following equations state the put-call-parity relationships for the four domestic sectors.

For the corporate sector (C), assets A_C equal equity E_C plus the risky debt $\underline{B}_c - P_c$:

$$A_C = E_C + (\underline{B}_c - P_c)$$

Dataset for Corporate Sector

E_c : The average of Common share for All companies except Banking Sector from SET between 2003 and 2009

$\underline{B}_c$: The average of Liabilities for All companies except Banking Sector from SET between 2003 and 2009

P_c : Provision for loan loss from corporate loan lent by Thai Commercial Banks from Bank of Thailand database between 2003 and 2009

For the financial sector (F), assets A_F plus contingent financial support from the sovereign aP_F equals equity E_F plus the value of risky debt/deposit ($\underline{B}_F - (1-a) P_F$)

$$A_F + a P_F = E_F + (\underline{B}_F - (1-a) P_F)$$

where P_F represents the implicit put option to the financial sector. The model assumes that value of explicit or implicit sovereign guarantee, is a fraction a of the expected losses associated with the debt or P_F, and the remainder, $(1-a) P_F$, is the credit risk remaining in the debt and deposits of the financial sector.

Dataset for Financial Sector

E_F : The average of common share for Banking Sector from SET between 2003 and 2009

$\underline{B}_F$: The average of liabilities for Banking Sector from SET between 2003 and 2009

P_F : Provision for loan loss from all loan from Bank of Thailand database between 2003 and 2009

a : the ratio of the more than 1 million baht deposits to all deposits
where Distress Barrier = ST Deposit + 0.5*(LT Deposit + Debt)

For the household,

The household asset A_H is the sum of the household sector's financial wealth A_{FIN},

Household assets = Financial assets + PV(labor income) + real estate "net worth"

$$A_H = A_{FIN} + A_L + E_{H, RE}$$
$$= A_{FIN} + A_L + (A_{H, RE} - (\underline{B}_{H, RE} - P_{H, RE}))$$

Dataset for Household Sector

A_{FIN} : The average of saving for Individuals from Bank of Thailand database between 2003 and 2009.

A_L : The income earned from wage projected 25 years taking the present value from Bank of Thailand database between 2003 and 2009.

$A_{H, RE}$: The outstanding value of residential house average between 2003 and 2009.

$\underline{B}_{H, RE}$: The outstanding value of residential mortgage average between 2003 and 2009.

$P_{H, RE}$: Non Performing Loan Amount from Mortgage lent by Thai Commercial Banks from Bank of Thailand database between 2003 and 2009

For the sovereign,

The sovereign sector combines monetary authority with the government balance sheet from the purpose that all items can be observed and are put into a common currency. This paper follow the simplified approach from Gray et al (2007) to get local currency liabilities (LCL) in a simplified two-claim CCA framework in order to calibrate the sovereign balance sheet by calculating implied sovereign assets and asset volatility.

The assets of sovereign A_s, based on Buiter (2000), include: foreign currency reserves R_{MA}, the net fiscal asset A_G (defined as the present value of taxes and revenues, including seigniorage, minus the present value of government expenditures); and other public assets A_{other}. The liabilities of sovereign include base money M_{BM}, risky local-currency debt ($\underline{B}_{SLC}$ - P_{SLC}), and risky foreign-currency debt ($\underline{B}_{SFX}$ - P_{SFX}), and financial guarantees/contingent liabilities or $a\,P_F$ as shown below.

$$
\begin{aligned}
A_S &= R_{MA} + A_G + A_{Other} \\
&= M_{BM} + (\underline{B}_{SLC} - P_{SLC}) + (\underline{B}_{SFX} - P_{SFX}) + a\,P_F
\end{aligned}
$$

Dataset for Sovereign Sector

M_{BM} or base money: from Bank of Thailand database.

$\underline{B}_{SLC}$ or default-free local-currency debt: the amount of local currency denominated Sovereign debt issuance from Bank of Thailand and Ministry of Finance database.

P_{SLC} : the probability of default for Thailand local currency sovereign debt rating from Moody's KMV.

$\underline{B}_{SFX}$ or default-free foreign-currency debt: the amount of foreign currency denominated government debt issuance from Bank of Thailand and Ministry of Finance database.

P_{SFX} : the probability of default for Thailand foreign currency sovereign debt rating from Moody's KMV.

Financial guarantees/contingent liabilities:

a : The maximum ceiling for Sovereign repayment ratio

P_F *:* Financial guarantees/contingent liabilities from Thai Sovereign from Bank of Thailand and Ministry of Finance database.

Note that table 1 summarizes the asset and liability structure for these four sectors as follows:

Table 1: Economy-wide Contingent Claim Balance Sheet with Risk Exposures across Sectors (Implicit Put and Call Options)

	Corp	Households	Financial	Sovereign
Asset	A_c	A_{FIN} $+A_L$ $+\left(A_{H,RE} \quad -\overline{B}_{H,RE} \quad P_{H,RE}\right)$	A_F	R_{FX} $+A_G$ $A_{S,other}$
Cont. A&L			$+\alpha F_F$	$-\alpha P_F$
Equity/ Jr. & Sub. Claims	$-E_c$	$-E_H$ $-c_D$	$-E_F$	$-M_{BM}$ $-\overline{B}_{SLC}$ $+P_{SLC}$
Barrier	$-\overline{B}_c$		$-\overline{B}_F$	$-\overline{B}_{SFX}$
EL (Put)	$+P_c$		$+(1-\alpha_G)P_F$	$+P_{SFX}$
Sum	**0**	**0**	**0**	**0**

Source: Gray et al (2007)

Under this section, for all four sectors, the liability or barrier values of asset are set without the transmission of risk among sectors. For the case of risk transmission, it is outlined in the next section.

3.1.4 Transfer Risk between Sectors

From the last section, the asset and liability consideration is operated under each sector separately. In reality, the economic result of one sector may affect that of others. For instance, the worsening situation in one particular corporate sector can hurt the financial institution sector through the higher non-performing loan amount. Based on Gray et al (2007),

Risk Transfer

Corporate Sector --→ Finance Sector

To be more specific, in case the corporate sector defaults their loan, this would make the value of risky debt lower by two channels: the lower $\underline{B}_c$ or average liabilities and the higher P_c or provision for loan loss from corporate loan. This would make the barrier asset level to be lower or make the corporate firms more likely to default.

The corporate sector problems would be transmitted to the financial sectors by making the loan amount in financial institutions lower or reduce the magnitude of $\underline{B}_F$ and make the expected loss amount of debt increase or P_F higher.

Alternatively, the systemic banking crisis and/or deposit runs can have an impact on the government by increase the value of the guarantees.

Risk Transfer

Finance Sector --→ Government

In case the financial sector loan turns to be non-performing loan (NPL) in the higher proportions, this would make the value of risky debt lower by two channels: the lower $\underline{B}_F$ or average debt from the written off process and the higher P_F or provision for loan loss from higher NPL. This would make the barrier asset level to be lower or make financial institutions more likely to default.

The financial sector problems would be transmitted to the sovereign sector by making financial guarantees/contingent liabilities (P_f) to be higher from the higher NPL. In addition, this would also make the risky local-currency debt ($\underline{B}_{SLC}$ - P_{SLC}) to be lower by increasing the magnitude of P_{SLC} from the higher likelihood of local currency debt to default.

In order to assess the impact from the risk transmission mechanism, the determination of barrier asset level in the second scenario will incorporate this impact into the analysis.

3.2 Incorporating Sector Concentration Risk

According to Duellmann and Masschelein (2006), the estimation of risk degree, henceforth the amount of capital, for financial institution is through Multi-Factor Monte Carlo simulation, based on the Merton-type credit model. This is under the viewpoint of corporate sustainability under the premise that the value of liability cannot exceed that of asset. The idea is to utilize the data in the sector level applying to Monte Carlo simulation with the multi-factor credit risk model.

In terms of terminology, let M denote the number of borrowers or loans in the portfolio, M_s the number of borrowers in sector s, where s the number of sectors and w_{si} the weight of the exposure of borrower i in sector s relative to the total portfolio exposure.

According to the multi-factor credit model, the unobservable, normalized asset return X_{si} of of the i-th borrower in sector s triggers the default event if it crosses the default barrier barrier γ_{si} . In other words, credit risk occurs only as a default event at the end of a one-year horizon, which is consistent with traditional book-value accounting. The corresponding unconditional default probability p_{si} is defined as

$$p_{si} = P(X_{si} \leq \gamma_{si}) \tag{6}$$

where X_{si} consists of two parts: the systematic part and the idiosyncratic part according to

$$X_{si} = r_s Y_s + (1 - r_s^2)^{0.5} \varepsilon_{si} \tag{7}$$

where $s \in \{1, \ldots, S\}$ and $i \in \{1, \ldots, M_s\}$.

The first part is estimated by the systematic sector risk Y_s where can be expressed as a linear combination of independent, standard normally distributed factors $Z_1, \ldots, Z_s$

$$Y_s = \sum_{t=1}^{S} \alpha_{st} Z_t \quad \text{with} \quad \sum_{t=1}^{S} \alpha_{st}^2 = 1 \text{ for } s \in \{1, \ldots, S\} \tag{8}$$

The matrix $(\alpha_{st})_{1 \leq s,\, t \leq S}$ is obtained from a cholesky decomposition of the factor correlation matrix.

The second or idiosyncratic part is represented by an idiosyncratic risk factor ε_{si}, where ε_{si} follows a standard normal distribution. For the weight to be allocated between systematic and idiosyncratic part is assigned by the value of r_s, where represented by the intra-sector asset correlation for each pair of borrowers.

The asset correlation ω_{st} for each pair of borrowers in sector s and t, respectively, can be shown to be given by

$$\omega_{st} = r_s r_t \rho_{st} = r_s r_t \sum_{n=1}^{S} \alpha_{sn} \alpha_{tn} \tag{9}$$

In this paper, the cholesky decomposition is performed by using net profit data for industry sectors in Thailand using the quarterly Thai data from 2003 to 2009.

If a firm defaults, the amount of loss depends on the stochastic loss severity ψ_{si} whose realization is assumed to be known at the time of default. The credit losses of the whole portfolio are given by

$$L = \sum_{s=1}^{S} \sum_{i=1}^{M_s} w_{st} \psi_{si} 1_{\{x_{si} \leq N^{-1}(p_{si})\}} \tag{10}$$

where $I_{\{.\}}$ gives the indicator function.

We assume the same expected loss severity $\mu = E[\psi_{si}]$ for all borrowers and that all idiosyncratic risk in loss severities is diversified away in the portfolio.

In summary, the model needs the following input parameters:

- relative exposure size w_{si} and default probabilities p_{si} of the i-th borrower in sector s
- the factor correlation matrix and
- the sector-dependent factor weight r_s

For Herfindahl Index (HHI) as the concentration risk indicator, we used market capitalization in stock market for 8 Thai industry sectors in SET to perform the concentration index. For intra correlation and inter correlation, earnings from 8 industry sectors are used to calculate correlation within and among sectors.

3.3 Stress Testing

This section would explain the framework of stress testing under macrofinancial risk setting as follows:

3.3.1 Stress Testing Framework

From financial sector, assets A_F plus contingent financial support from the sovereign aP_F equals equity E_F plus the value of risky debt/deposit ($\underline{B}_F - (1-a) P_F$)

$$A_F + a P_F = E_F + (\underline{B}_F - (1-a) P_F) \tag{11}$$

where P_F represents the implicit put option to the financial sector. The model assumes that value of explicit or implicit sovereign guarantee, is a fraction *a* of the expected losses associated with the debt or P_F, and the remainder, (1-a) P_F, is the credit risk remaining in the debt and deposits of the financial sector.

Dataset for Financial Sector

E_F : The average of common share for Banking Sector from SET between 2003 and 2009

$\underline{B}_F$: The average of liabilities for Banking Sector from SET between 2003 and 2009

P_F : Provision for loan loss from all loan from Bank of Thailand database between 2003 and 2009

a : the ratio of the more than 1 million baht deposits to all deposits

Where Distress Barrier = ST Deposit + 0.5*(LT Deposit + Debt)

3.3.2 The "Macrofinancial Risk Framework" Stress Test Method

In order to link the stress testing with the stressed macroeconomic variables, we follow the methodology of stress testing by the simulation of macroeconomic variables under the macrofinancial risk framework. This framework incorporates risk degree for each sector in the simulated economy. For IS equation, risk component in the economic sector is modeled through financial susceptibility indicator (fsi) by incorporating this into IS equation. Note that non-performing loan is used as the proxy for fsi based on the assumption that household, corporate, sovereign, and finance sectors have used debt financing as funding source of their operations. For the coefficients of risk component in IS equation, it is estimated based on empirical relationship between NPL and GDP across time, according to figure 2.

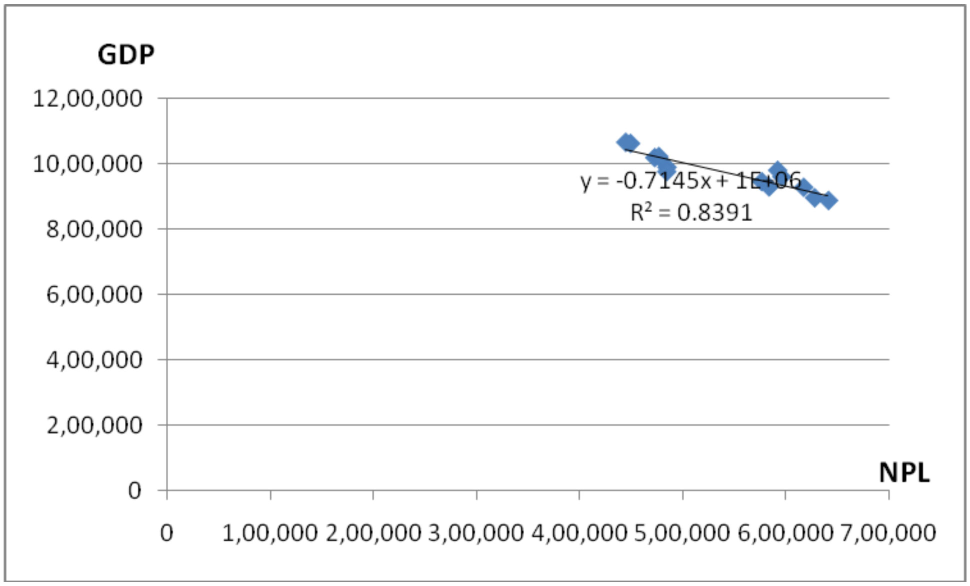

Figure 2: the relationship between NPL and GDP

Based on the result, it is found that the IS curve with risk component is as follows:

$y_t = 0.593\ y_{t-1} - 0.001\ r_{t-1} - 0.7\ fsi_{t-1}$

In addition, the law of motion for fsi is estimated from figure 3 and 4.

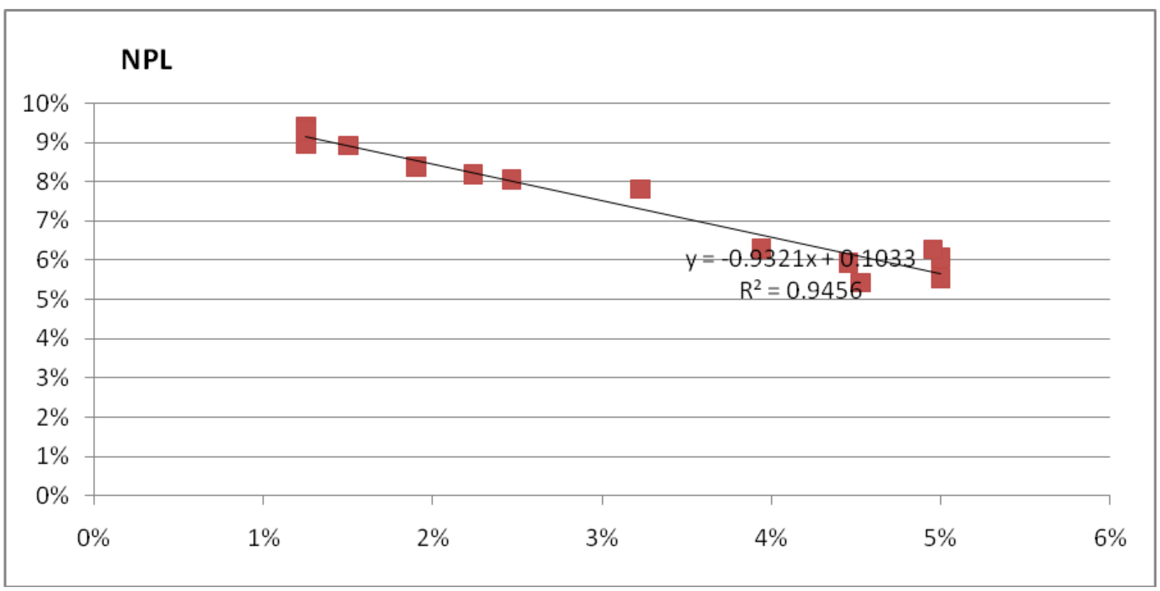

Figure 3: the relationship between interest rate and NPL

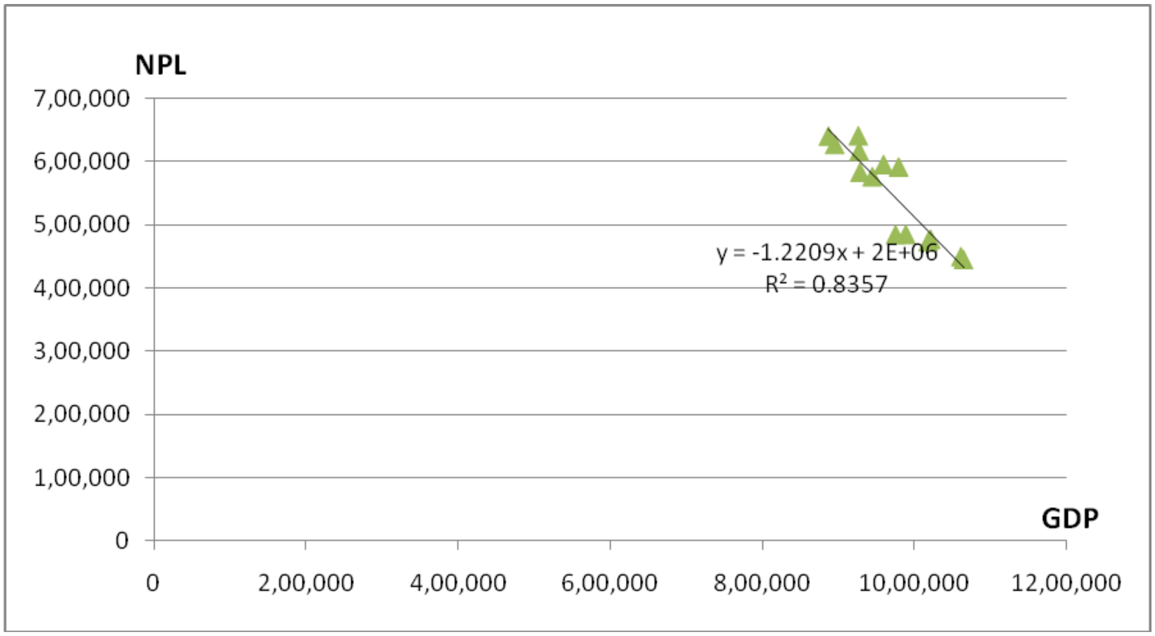

Figure 4: the relationship between GDP and NPL

Based on Figure 2 through 4, and Pongsaparn (2007), the IS and Phillips Curve in Thailand, estimated between 1996 and 2008, are demonstrated as follows:

IS Curve: $Y_t = -0.001\, r_t + 0.593\, Y_{t-1} + \varepsilon$

Phillips Curve: $\pi_t = \pi_{t-1} + 0.001\, Y_t + \eta$

The IS curve and Phillips curve when taken accounts into the degree of risk in the economy, the equations become:

IS Curve: $Y_t = -0.001\, r_t + 0.593\, Y_{t-1} - 0.7\, fsigap_{t-1} + \varepsilon$ (12)

Phillips Curve: $\pi_t = \pi_{t-1} + 0.001\, Y_t + \eta$ (13)

Financial Susceptibility: $fsigap_t = -0.93\, r_t - 1.22\, Y_{t-1} + fsigap_{t-1} + \varphi$ (14)

Under stress test based on risk transfer among sectors within macrofinancial risk framework, the method to perform the test is through utilizing an increase in non-performing loan (NPL) as the tool to transfer the damage among sectors. In performing the test, the 10 percent in NPL is used to be the event scenario for the risk-transfer type of stress test among sectors.

In this paper, probability of default (PD) is estimated by using NPL from Bank of Thailand database as shown in section 3.1 to do the analysis. Finally, all macroeconomic variables in table 1 based on section 3.1 is gathered from Bank of Thailand and Ministry of Finance.

- **Finance Sector under Macro Stress with 10% NPL in Loan from Household sector.**

In order to estimate the impact of interaction of risk transfer between sectors, we perform macro stress testing, regarding to the risk transfer from household to finance sector. It is based on the assumption that loan quality in the household is lower, given that 10 percent of all loan would become default. This would result in the erosion of asset quality in financial institution. From the economic modeling perspective, in order to account for such effect, either the magnitude of asset side or that of liability side in finance sector would need to decrease or increase, respectively.

Risk Transfer

Household Sector --→ Finance Sector

As the 10 percent increase in average loan for liability side of financial institution related with retail borrowers equivalent of 0.24 trillion baht, this stress scenario is attributed to 10 percent increase in threshold level for finance sector. Based on the economic simulation under macrofinancial risk framework, probability of default in finance sector, under stress event, would be higher, as illustrated in Figure 5. On average, the risk neutral PD under finance sector has raised from **0.215 to 0.237**.

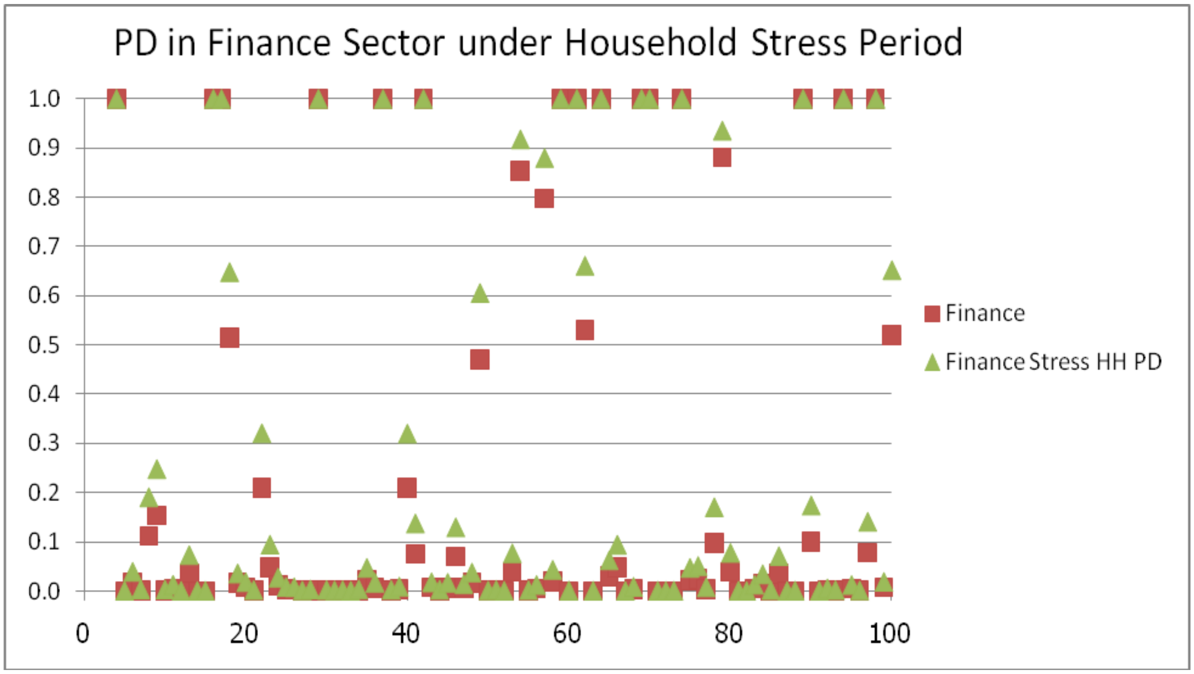

Figure 5: Probability of Default in Finance Sector under Household Stress Event

- **Sovereign Sector under Macro Stress with 10% NPL in Loan from Finance sector.**

As finance sector is under stress due to risk-transfer, this has an impact on sovereign sector, as the creditor, and on finance sector, as the debtor. This is due to the fact that there is correlation between quality of loan in the finance sector and that under sovereign sector. For instance, as the economy has shrunk from the worsening quality of private loan, the ability of government to repay the debt obligation is correspondingly lower due to their assistance to financial institution in cleaning up non-performing loan. In other words, sovereign debt obligation for this stress event is henceforth higher.

Risk Transfer

Finance Sector --→ Sovereign Sector

As the 10 percent increase in non-performing loan for asset side of financial institution is lent to borrowers, equivalent of 0.77 trillion baht, this stress scenario is attributed to 10 percent increase in threshold level for sovereign sector. The rationale is that this portion of loan is moved to sovereign sector, when sovereign or government uses their fund to help clean up the balance sheet of financial institution. According to the simulation under macrofinancial risk framework, probability of default in sovereign sector under the stress event would be higher, as illustrated in Figure 6.

On average, from such stress event, the risk neutral PD in sovereign sector has raised from **0.079 to 0.117**.

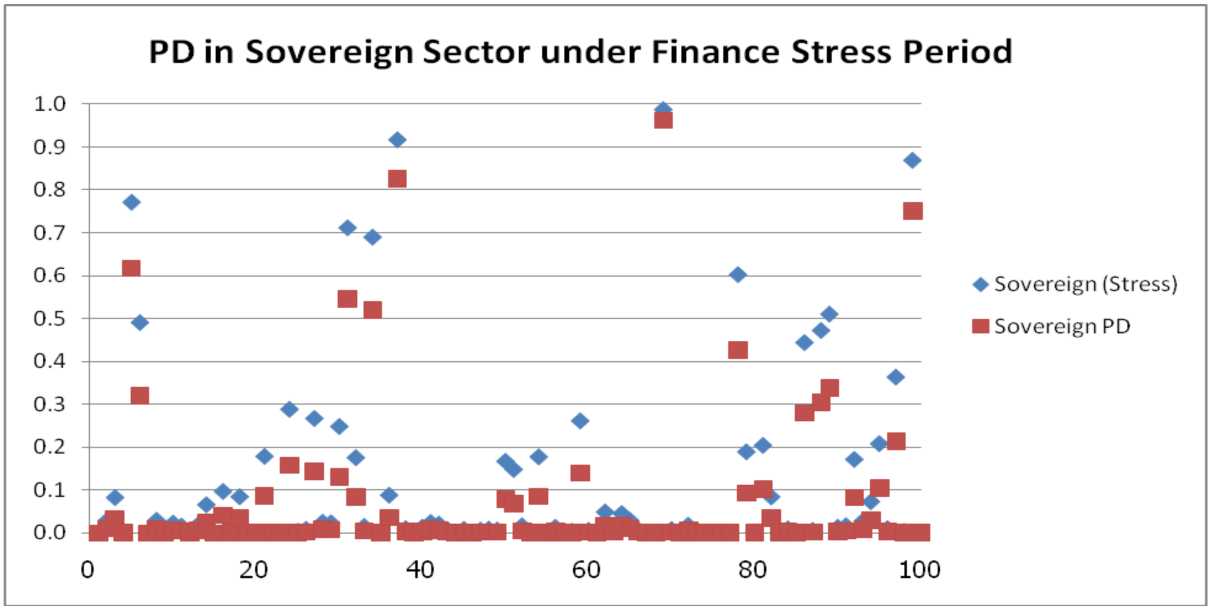

Figure 6: Probability of Default in Sovereign Sector under Finance Stress Event

In both stress test scenarios, the higher PD from the risk-transfer event stress in the corresponding sectors results in the higher coefficient of fsigap for IS equation with the same percentage as an increase in PD for these sectors.

4. Result

The result is divided into four sections: firstly, overview of risk degree for major economic sectors in Thailand is conducted under both normal and stress period; secondly, the analysis on seven sub-sectors in corporate sector will be performed from risk evaluation viewpoint. Thirdly, dynamic behavior of macroeconomic variables in macrofinancial risk framework under macro stressing is illustrated. Finally, the concept of sectoral concentration risk is incorporated into the macrofinancial risk framework in order to evaluate the impact on behavior of macroeconomic variables**.**

4.1 Degree of Risk for Major Economic Sector in the Economy

This section will demonstrate the outlook of risk degree for major economic sectors in Thailand through Merton-type risk model simulation. It is divided into two parts: the first one is to assess and quantify the risk degree for major economic sectors under normal economic period, including their interaction effects among economic sectors. For macro stress testing, the second part is to perform the test, via risk transfer, both from household to finance sector and finance to government sector.

4.1.1 Overview of Risk Degree for Economic Sectors under Normal Period

The following demonstrates the overview of probability of default diagrams for sovereign, corporate, finance, and household sectors.

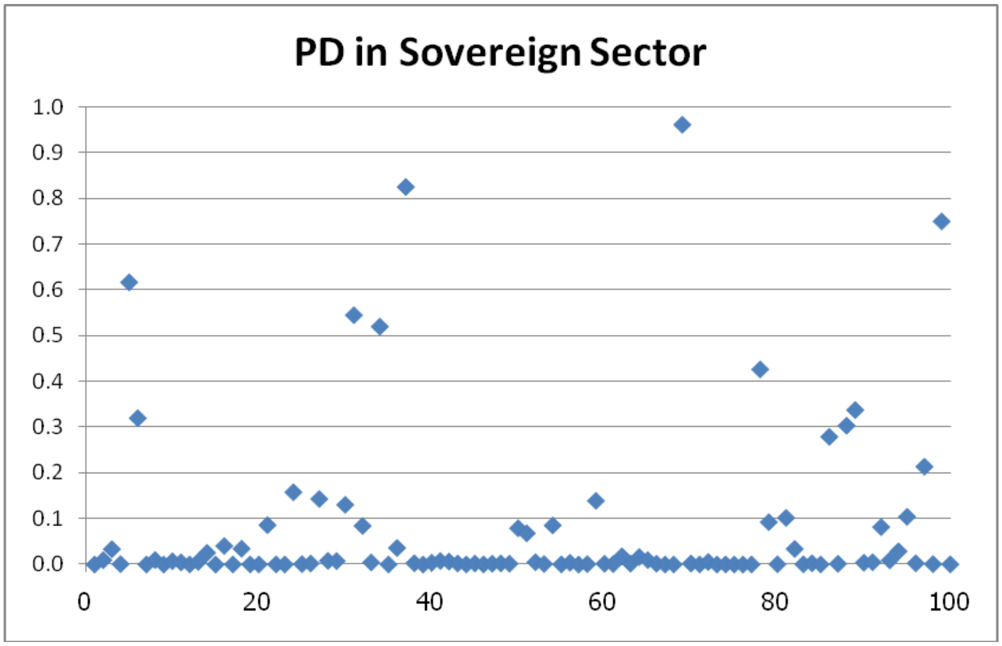

Figure 7: Probability of Default in Sovereign Sector

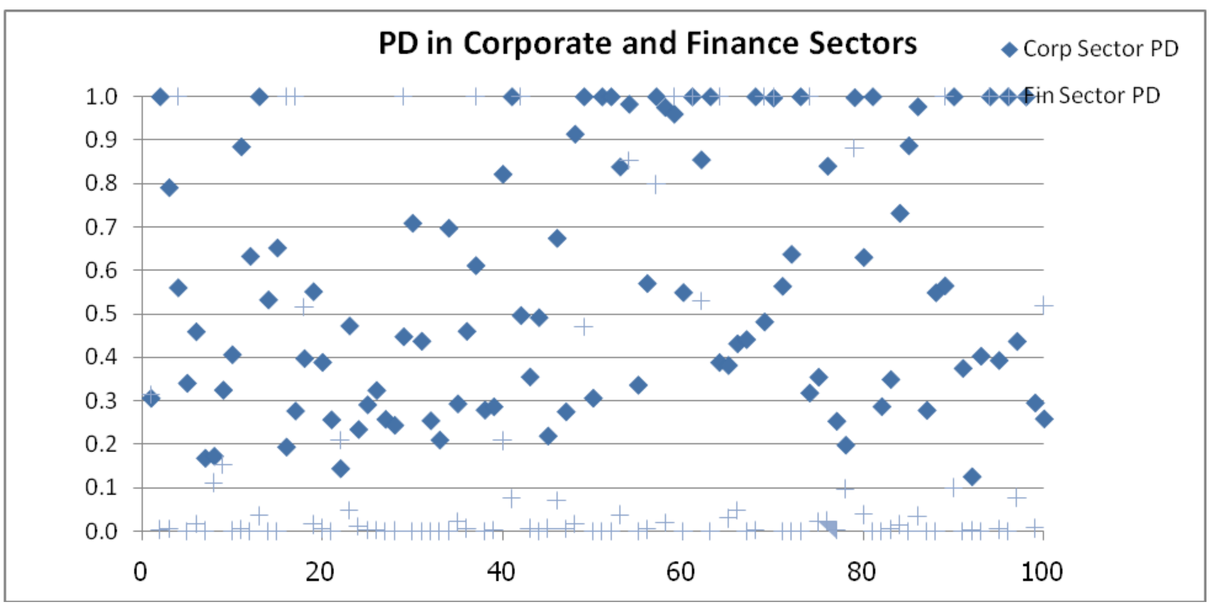

Figure 8: Probability of Default in Corporate and Finance Sector

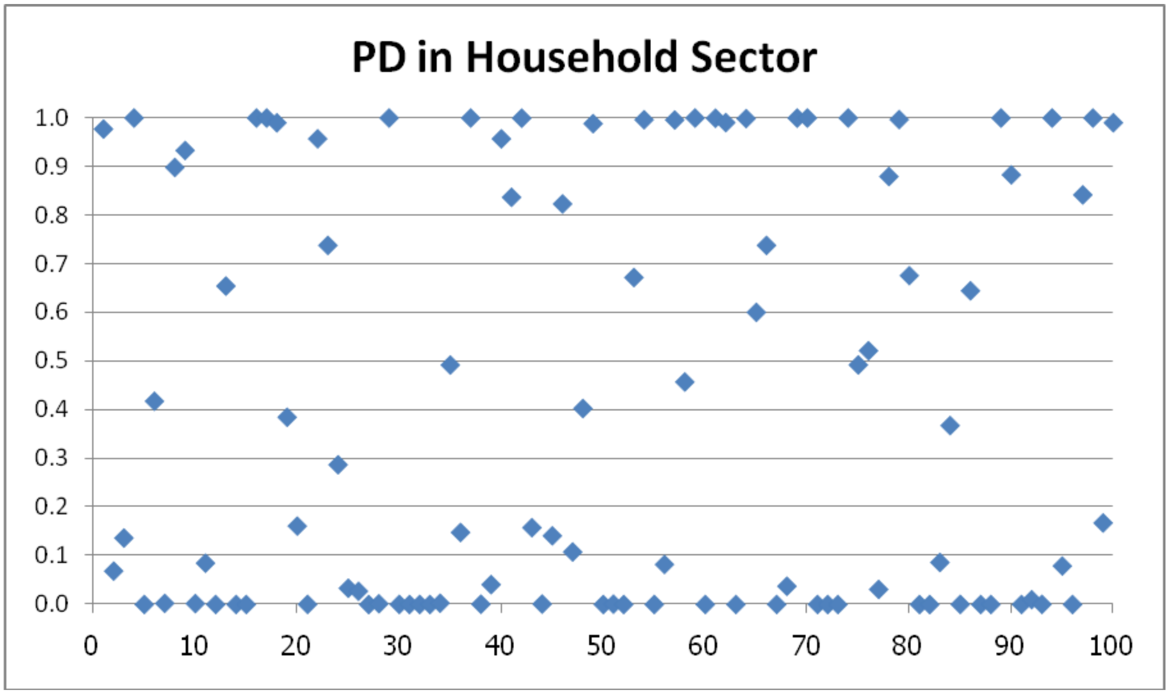

Figure 9: Probability of Default in Household Sector

Table 2: Mean and Standard Deviation of PD for Major Economic Sectors

Sector	Mean	Standard Deviation
Corporate	**0.56**	**0.29**
Finance	**0.22**	**0.37**
Household	**0.41**	**0.43**
Sovereign	**0.08**	**0.18**

According to Figure 7-9 and Table 2, when assessing the *risk magnitude* of each sector in the economy, the most risky sector is *corporate sector,* following with *household, finance,* and *sovereign sector*, respectively.

This should be in line with expectation. First, in terms of risk degree among sectors, while corporate sector has the most activities of risk-taking, household sector has encountered large portion of ups-and-downs from corporate sector, due to laying off workforce. As a result, corporate and household sector has highest degree of risk. On the other hand, under finance sector, based on the fact that banking regulation requiring capital cushion against future uncertainty, their degree of risk is lower, in comparison with former two sectors. Finally, since the ability to tax and maintain foreign reserve plays a key role in providing the country's balance sheet with loss cushion, degree of risk under sovereign sector is henceforth the lowest.

However, the most volatile sector, in terms of risk degree, is household sector, followed by finance, corporate, and sovereign sector, respectively. This should be in line with expectation, as household sector has smallest level of cushion in fighting off economic uncertainty. Under finance sector, it also has relatively high degree of risk volatility, as they play a role as funding source to other sectors in the economy. Even though such effect is partially alleviated by capital requirement, their residual risk is still significant. As a result, standard deviation in probability of default (PD) under finance sector is still large.

Unlike their highest degree of risk, corporate sector has equity to buffer against economic shock. This would henceforth result in relatively small volatility of risk. Finally, as sovereign sector would normally face the less frequent period of bankruptcy from taxing capability by the government, the sector has a small amount of volatility in PD.

Table 3: Correlation Matrix among Sectors

Sector	Household	Sovereign	Corporate	Finance
Household	**1**	**0.06**	**0.186**	**0.774**
Sovereign	**0.06**	**1**	**-0.094**	**0.14**
Corporate	**0.186**	**-.094**	**1**	**0.177**
Finance	**0.774**	**0.14**	**0.177**	**1**

From the interaction of risk among sectors standpoint, the correlation between finance and household sector has the highest magnitude. This should be justified by the fact that when the economy is in a downward trend, corporate sector would strive to get rid of their employees. As a result, unemployment rate would henceforth be skyrocketed. From this, non-performing loan in financial institution would be higher. By this line of logic, the correlation between household and finance sector should be relatively high, as demonstrated in Table 3.

In addition, from the viewpoint of corporate sector, their correlation with household sector is also not negligible. This results from their relationship as the exchange of goods/service and labor to each other. By this means, this is translated into positive correlation between corporate and household sector.

Finally, from the viewpoint of sovereign sector, finance sector has the highest degree of correlation with the government. Historically, contagion effect among sectors is mainly channeled through finance sector. By this means, it justifies this relatively high degree of positive correlation. However, their correlation with other sectors is relatively small because of their different nature in probability of default, with respect to other economic sectors. In particular, sovereign sector is likely to have limited and rare times of default in comparison with other sectors.

4.2 Analysis on Sub-sector in Corporate Sector

To better understand the distribution of PDs among sub-sectors under corporate sector, this section would provide policy-makers with an advantage over allocating economic resource to cope with external uncertainty and promoting growth.

Table 4: Mean and Standard Deviation of PD within Corporate Sector

Sector	Mean	Standard Deviation
1. Resource and Energy	**0.472**	**0.316**
2. Service	**0.402**	**0.159**
3. Real Estate and Construction	**0.311**	**0.142**
4. Technology	**0.294**	**0.096**
5. Agriculture and Food Industry	**0.293**	**0.042**
6. Consumer Goods	**0.085**	**0.004**
7. Raw Material and Industrial Goods	**0.182**	**0.035**

Table 4 would demonstrate the average and standard deviation of PDs in each sub-sector under corporate sector in Thailand, based on data set from SET. The result shows that the sub-sector of consumer goods has lowest magnitude in terms of average and standard deviation of risk degree. This results mainly from the fact that their products are mainly staple goods, in which they are not susceptible to volatility of economic cycles. On the other hand, resource and energy sector, service sector, and real estate and construction sector have very high degree of risk, both in terms of magnitude and volatility. The reason is that, under resource and energy sector, their business in Thailand, and henceforth profitability, is very sensitive to the unpredictability of energy price from worldwide market. In addition, the sheer size of companies, coupled with the small number of players in this sector, results in the sizable magnitude of risk contributing to the economy.

For service sector, when the economy starts to slow down, consumers are likely to cut back or cancel their purchase in this sector, due to the fact that consumers are able to frugally live without using output from this sector. As a result, probability of default in this sector is therefore relatively high from relatively large amount of volatility in revenue from this sector.

Finally, for real estate and construction sector, it is most inherently sensitive to economic cycle because price of land and housing plays a key role as the leading indicator of the economy. In so many times, their significant portion of its price level is purely speculative and very volatile. From the model simulation result, the distribution of PDs among sub-sectors under corporate sector is shown in Figure 10.

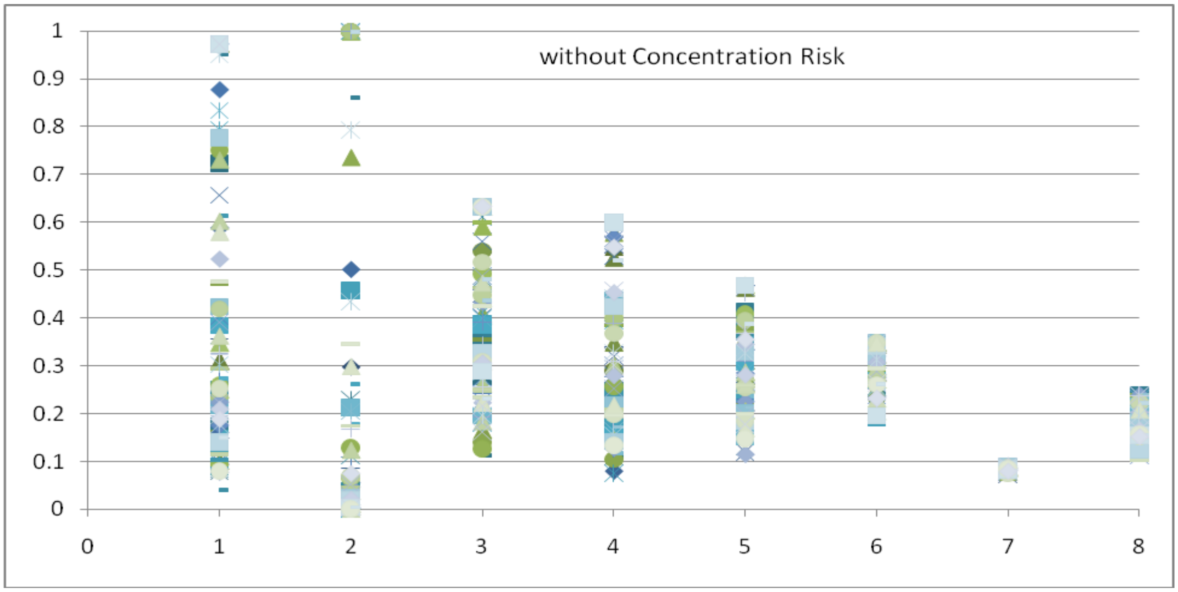

Figure 10: Distribution of PDs among sub-sectors under Corporate Sector

4.3 Effects on macroeconomic variables in Macrofinancial Risk Framework under Macro Stressing

This section will demonstrate the result of stress test for both traditional model and macrofinancial risk model based on risk-transfer stress events.

4.3.1 Result of Macroeconomic for Macrofinancial Risk Framework (Base Case)

The result of base case simulated macroeconomic variables in macrofinancial risk framework (with risk indicator in each sector) is shown in this section. For the result of macro stress scenario from risk transfer, it is demonstrated in section 4.3.2.

For simulation under traditional model (without risk indicator), it is shown in Figure 11. In the dynamic simulation, when the shock hits the economy, according to the policy rule, interest rate will be higher. This, henceforth, results in output to be directly lower.

For the model simulation with risk indicator, its channel for interlinkage between state variables (output and inflation) and interest rate (policy tool for central bank) is through the indirect path. The fsigap would play a vital role in the simulation as follows. As the shock hits the economy, interest rate responds in a positive relationship with output and inflation rate by lowering the rate, when encountering the negative external shock. With risk incorporated into IS equation, output would decrease more rapidly from its impact of fsigap. By this, interest rate cannot be raised very rapidly since output, and inflation based on its relationship in Phillips curve, is already low, as shown in Figure 12.

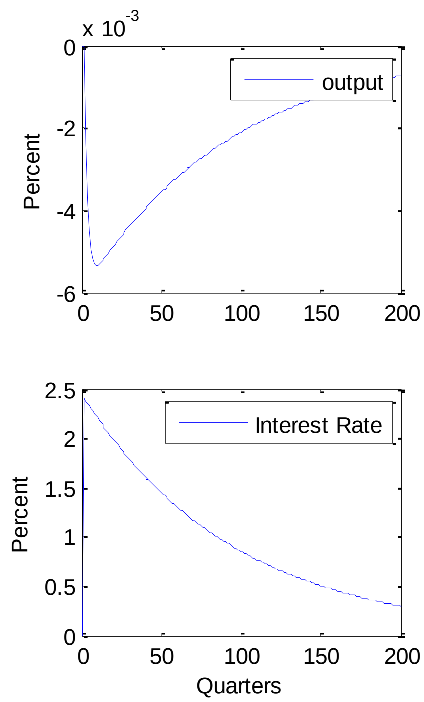

Figure 11: Macroeconomic Variables Simulation under Traditional Model

(without risk degree)

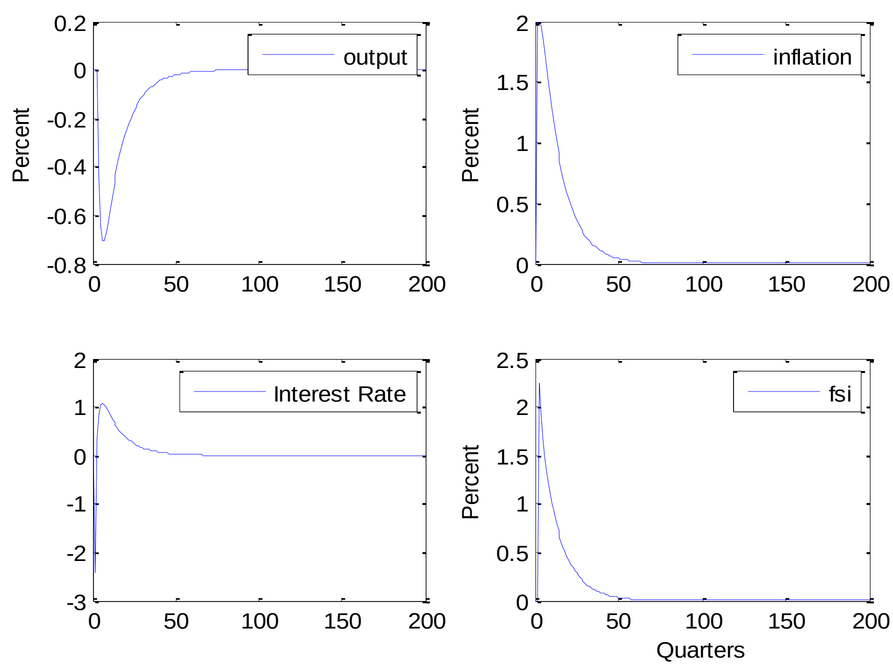

Figure 12: Macroeconomic Variables Simulation under Macrofinancial Framework

(with risk degree)

In conclusion, the comparison between the model with and without risk indicator is summarized as follows:

- Model with risk indicator results in *higher magnitude of output loss* than the one without risk indicator, due to risk component in IS equation.
- Model with risk indicator results in the faster return of inflation back toward the steady state level, from the Phillips curve with lower output.
- While model with risk indicator results in the reduction of interest rate before increasing interest rate for 1 %, interest rate under model without risk indicator suddenly jumps to 2.5% and then would taper off

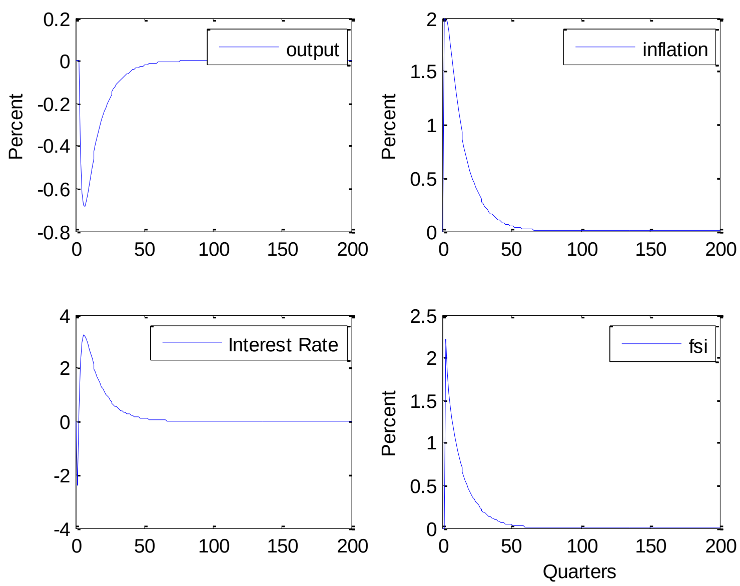

Figure 13: Macroeconomic Variables Simulation under Macrofinancial Framework (with risk degree) when fsi is more sensitive to output

The degree of risk in the economy from Figure 13 is more sensitive to the change in economic output, in the sense that an increase in output leads to the smaller degree of risk in the economy, than that in Figure 12. In other words, the coefficient of -1.22 in Figure 12 increases toward -4.22 in Figure 13 under financial susceptibility law of motion equation, according to (14). On the other hand, from the IS equation, as the risk degree in the economy is higher, this would result in the output level to be lower 70 percent, according to (12).

As a result, high level of risk degree in the economy is hazardous to the economic growth. In doing this, one way to circumvent this situation is through lowering risk degree in the economy. The central bank has the discretion in achieving this through the rise in interest rate, according to (14), with more aggressive manner from about 1 percent in Figure 12 to nearly 3.5 percent in Figure 13. This is justified by the fact that policy rule for interest rate is set by 1.9848* (Output) + 1.2162* (Inflation Rate)

-1.2218* (Financial Susceptibility Index). As the latter case has lower value of fsi and higher magnitude of output, this means that its responding interest rate would be higher than the former case did.

Not only could the rise of interest rate able to cool down inflation and make the economic growth much smoother, but it also has an impact on pushing the lending policy of financial institution in a more conservative manner. The reason is that under the high interest environment, financial institution is aware that the interest payment in which borrowers are burdened with is likely to increase, henceforth; non performing loan or degree of risk in the economy (modeling through fsi) would tend to be higher. In order to prevent such scenario, financial institution would be more selective in screening borrowers. This would dampen the degree of risk in the economy and tends to lower the magnitude of fsi.

The fact would be utilized by central bank when dealing with the times when economic condition is very fragile; in other words, given that economic growth is very susceptible to the worsening of riskiness in the economy, central bank would respond by raising up the interest rate level to tame the higher degree of risk in the economy. As a consequence, output would be moved in a smoother pace than the times under low interest rate environment, as both output and inflation are back toward steady state more quickly when fsi is more responsive to output change.

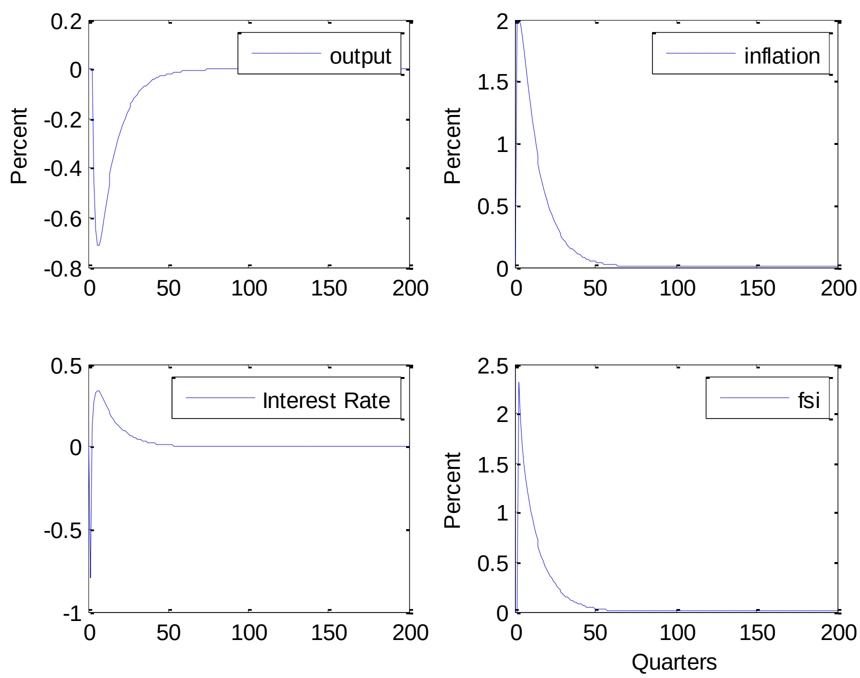

Figure 14: Simulation of Macroeconomic Variables under Macrofinancial Framework (with risk degree) when fsi is more sensitive to interest rate

However, as the impact from the rise in interest rate to dampen the degree of risk in the economy is more pronounced as illustrated in Figure 13, the coefficient between interest rate and fsigap rises from -0.93 to -2.93, according to (14). Based on this favorable relationship for central bank, they need not to raise the interest rate in such big degree enough to optimally lower the risk degree in the economy. As shown in figure 14, interest rate, under financial susceptibility law of motion equation, is lower from 1 percent to 0.4 percent.

4.3.2 Different Scenarios on Stress in each economic Sector on Macroeconomic Variables (Interaction Effect)

In Section 4.1, the PD based on stress test exercise through risk transfer from finance sector toward government sector increases from 7.9% to 11.7%. This means that the PD under finance sector is higher approximately 49 percent. In other words, the coefficient of fsigap in the IS equation should increase from -0.7 to -1.1. The result of simulated macroeconomic variables is shown in Figure 15, with Figure 16 as the base case scenario.

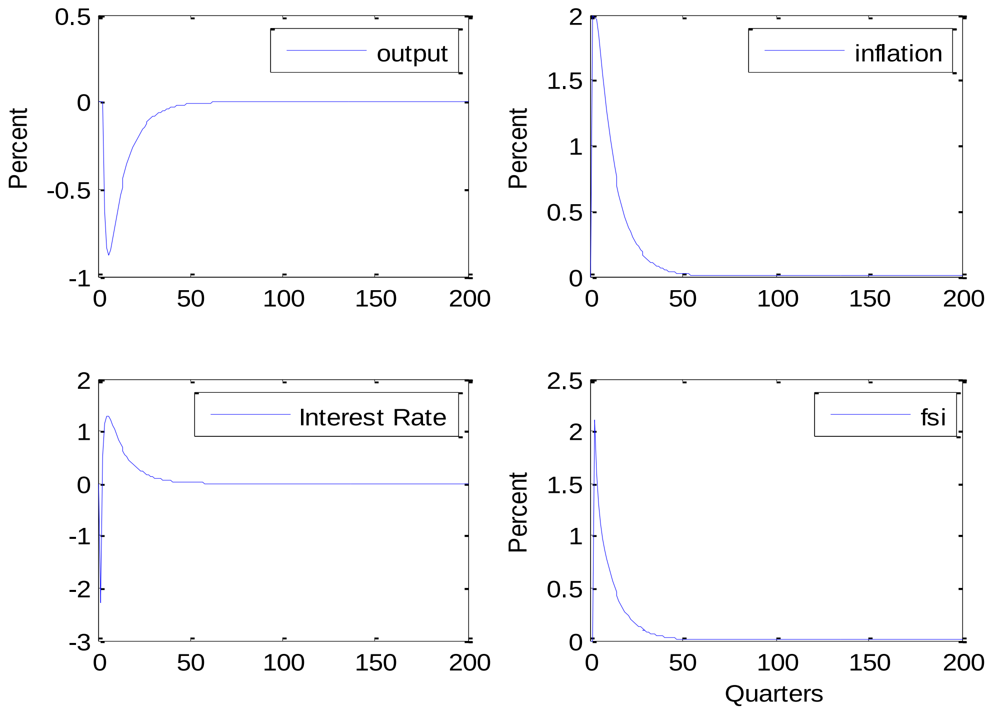

Figure 15: Simulation of Macroeconomic Variables under Macrofinancial Risk Framework (with risk degree) under Risk-transfer Stress Scenario

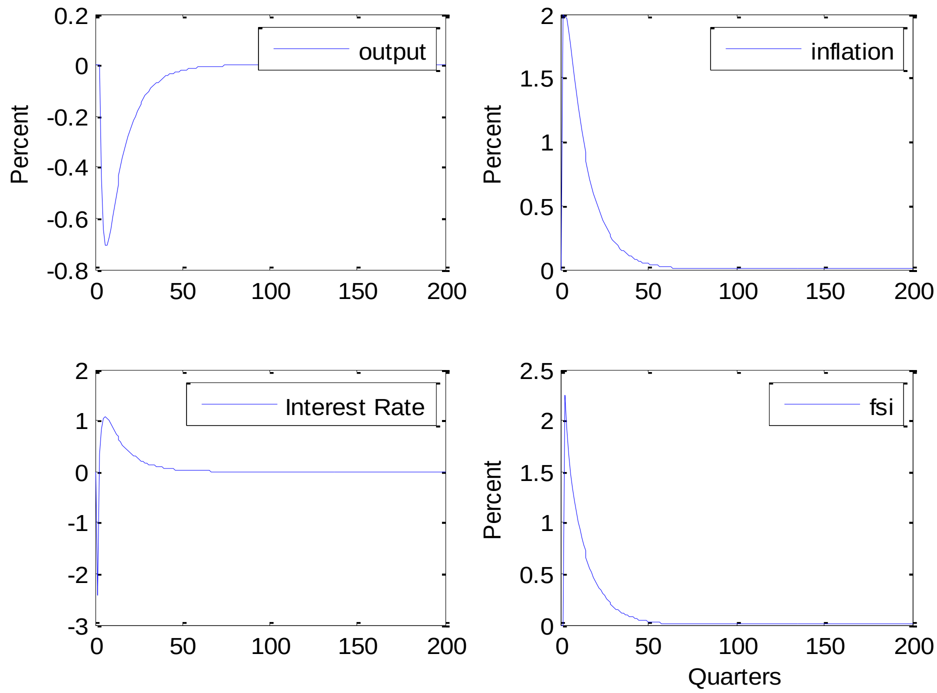

Figure 16: Simulation of Macroeconomic Variables under Macrofinancial Risk Framework (with risk degree) without stress

Generally, interest rate under risk-transfer stress is higher than that without stress on account for concerning about the higher responsiveness of risk in macrofinancial risk framework toward the output level, in comparison base case model. The higher level of interest rate results in the lower output under stress environment.

Table 5 illustrates the summation of macroeconomic variables based on stress and non-stress model.

Table 5: Summation of Macroeconomic Variables based on One-Type Stress and Non-Stress model.

	Non-Stress	Stress from Finance Sector	Non-Stress	Stress from Finance Sector	Non-Stress	Stress from Finance Sector
	Output		Inflation		Interest Rate	
max	**0.002**	**0.002**	**2**	**2**	**1.068**	**1.296**
min	**-0.708**	**-0.882**	**0**	**0**	**-2.432**	**-2.283**
avg	**-0.056**	**-0.058**	**0.149**	**0.128**	**0.072**	**0.075**
SD	**0.145**	**0.166**	**0.398**	**0.376**	**0.281**	**0.297**

Stress from Two Types of Risk Transfer

With stress on risk transfer of (1) Finance to Government Sector and (2) Household to Finance Sector as discussed above, Table 6 illustrates the summation of macroeconomic variables based on stress and non-stress model. In comparison with the risk transfer stress, output and inflation become slightly lower. However, interest rate is nearly the same with the higher level of volatility.

Table 6 : Summation of Macroeconomic Variables based on Two-Type Stress and Non-Stress model

	Non-Stress	Stress from Finance Sector	Non-Stress	Stress from Finance Sector	Non-Stress	Stress from Finance Sector
	Output		Inflation		Interest Rate	
max	0.0024	0.0022	2	2	1.068	1.352
min	-0.7079	-0.9171	0	0	-2.432	-2.230
avg	-0.0561	-0.0578	0.149	0.124	0.072	0.075
SD	0.145	0.170	0.398	0.372	0.281	0.299

In the same token, inflation, under two types of risk transfer stress, is lower than that without stress and one type of risk transfer stress, on account for higher interest rate from concerning about the higher responsiveness of risk in macrofinancial risk framework toward the output level.The higher volatility of interest rate results in the lower output under this stress environment.

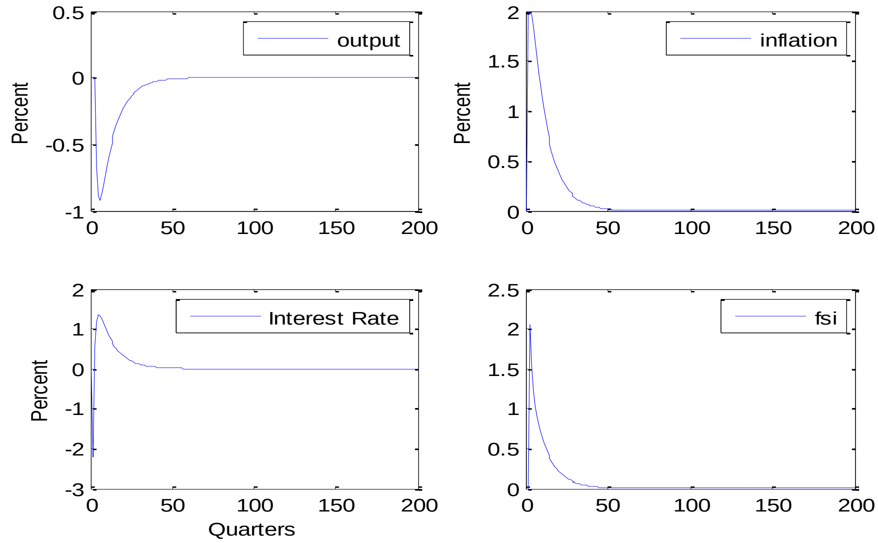

Figure 17 Simulation of Macroeconomic Variables under Macrofinancial Risk Framework (with risk degree) with Two Types of Risk Transfer stress

4.4 Effects on Macroeconomic Variables in Macrofinancial Risk Framework under Macro Stressing Environment, incorporating Concentration Risk

For Corporate

Risk Transfer

Household Sector --→ Banking Sector

As the 10 percent increase in average loan for liability side of financial institution equivalent to 0.24 trillion baht, the stress scenario in this non-performing loan is ascribed to 10 percent increase in threshold level for default in finance sector. As the economic simulation under macrofinancial framework turns out, probability of default in finance sector under the stress event would be higher. Figuratively, the risk neutral PD in finance sector has raised from **0.215 to 0.237**.

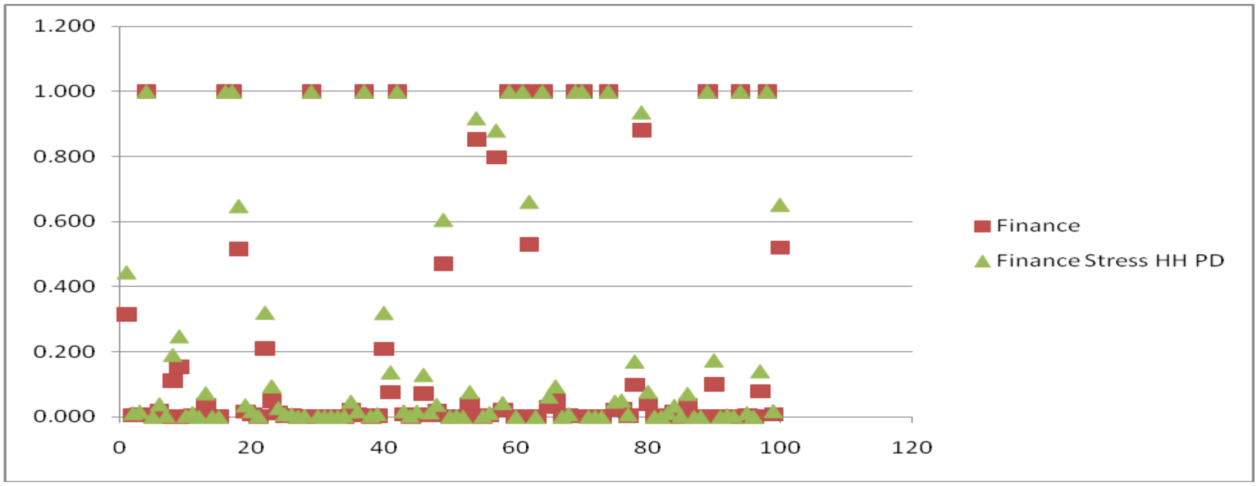

Figure 18: Probability of Default in Finance Sector with and without Household Stress Event

Table 7: Mean and Standard Deviation of PD in Corporate Sector (Stress without Concentration Risk)

Sector	Mean	Standard Deviation
1. Resource and Energy	**0.425**	**0.286**
2. Service	**0.395**	**0.166**
3. Real Estate and Construction	**0.326**	**0.163**
4. Technology	**0.305**	**0.108**
5. Agriculture and Food Industry	**0.293**	**0.038**
6. Consumer Goods	**0.085**	**0.004**
7. Raw Material and Industrial Goods	**0.188**	**0.038**

Table 8: Mean and Standard Deviation of PD with Corporate Sector (Stress with Concentration Risk)

Sector	Mean	Standard Deviation
1. Resource and Energy	0.391	0.292
2. Service	0.369	0.164
3. Real Estate and Construction	0.308	0.156
4. Technology	0.319	0.113
5. Agriculture and Food Industry	0.296	0.039
6. Consumer Goods	0.085	0.004
7. Raw Material and Industrial Goods	0.187	0.037

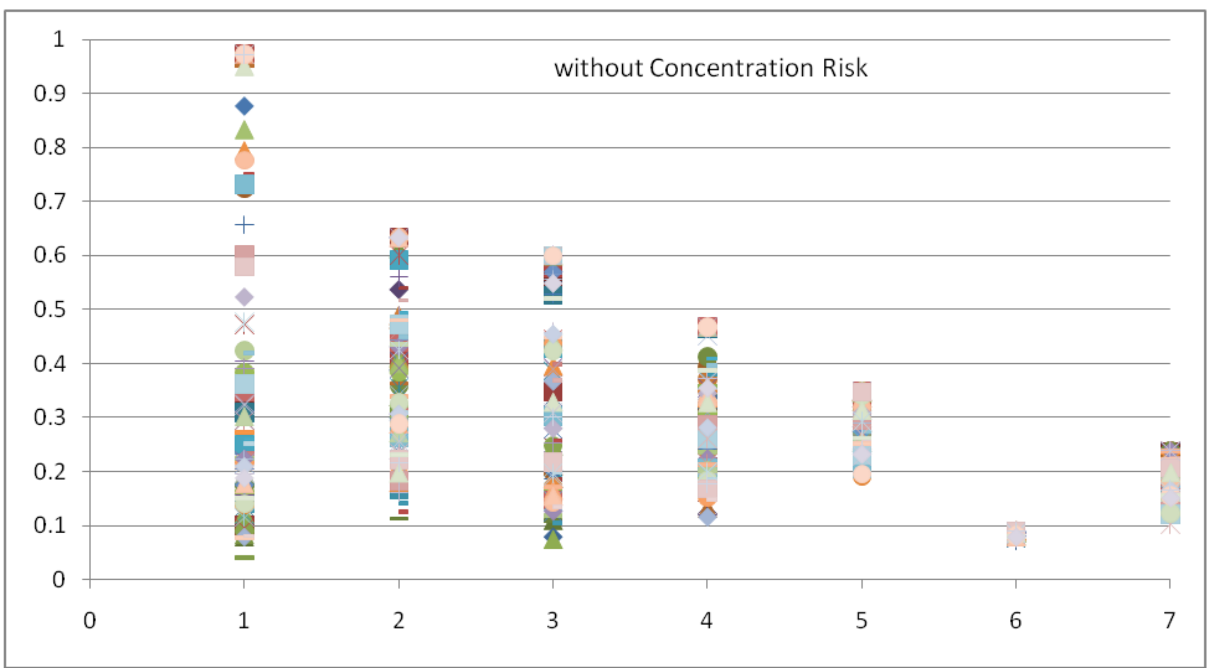

Figure 19: Distribution of PDs among sub-sectors under Corporate Sector

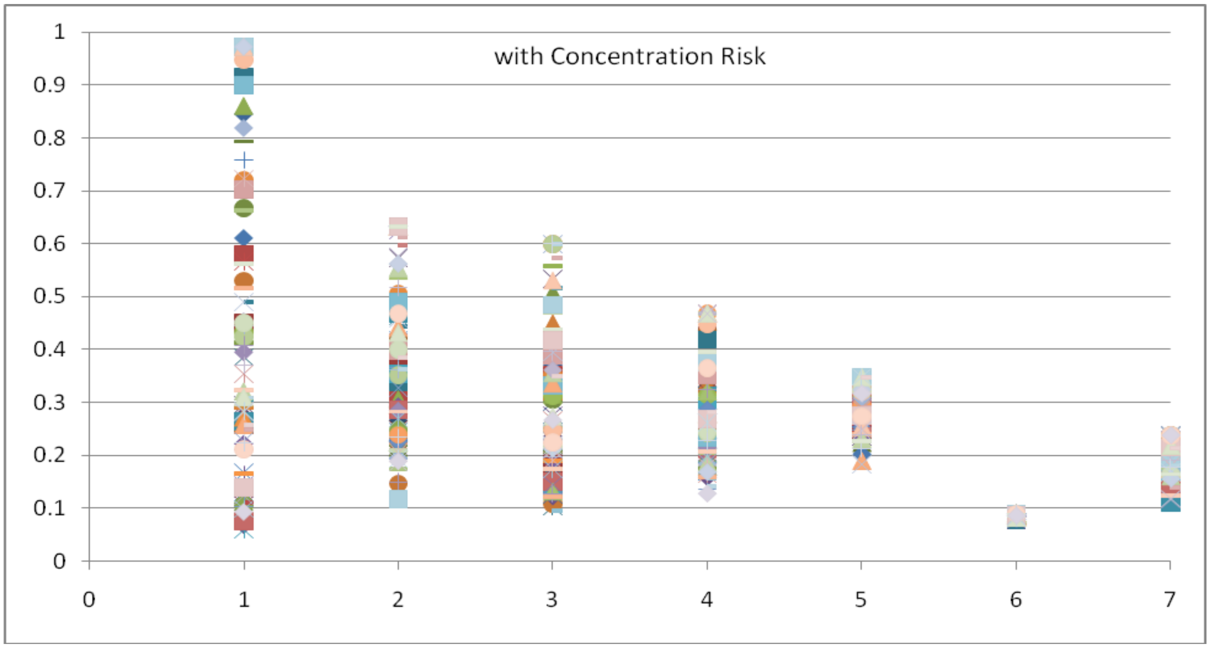

Figure 20: Distribution of PDs among sub-sectors under Corporate Sector with Concentration Risk

Under the economic model incorporating concentration risk, the central bank has the obligation to assess the dynamic of macroeconomic variables in each sector simultaneously. In general, the diversification effect for economic performance is lessened under this environment. As a result, the central bank has to become more conservative regarding to the implementation of monetary policy. From Table 9, we found that for risk transfer stress under concentration risk environment, interest rate is higher and, henceforth, output and inflation rate is lower than that without concentration risk.

Table 9: The Statistics of Macroeconomic Variables with and without Stress and Concentration Risk

	Non-Stress	Stress without Concen-tration Risk	Stress with Concen-tration Risk	Non-Stress	Stress without Concen-tration Risk	Stress with Concen-tration Risk	Non-Stress	Stress without Concen-tration Risk	Stress with Concen-tration Risk
	Output			Inflation			Interest Rate		
max	0.002	0.002	0.002	2	2	2	1.068	1.296	1.448
min	-0.708	-0.882	-0.978	0	0	0	-2.432	-2.283	-2.107
avg	-0.056	-0.058	-0.058	0.149	0.128	0.118	0.072	0.075	0.076
SD	0.145	0.166	0.177	0.398	0.376	0.364	0.281	0.297	0.302

In terms of each economic sector, the risky sector would have lower PD, after incorporating concentration risk, under risk-transfer stress. This is due to the fact that, under macrofinancial risk framework, higher interest rate by central bank makes fsi more responsive to output in risky sectors, with the incorporation of concentration risk. By this setting, homogeneity of the economy is replaced by sectoral concentration or more granular nature. Henceforth, risky sectors will have lower PD from their more responsiveness. On the other hand, less risky sectors would have higher PD, on vice versa.

Finally, Figure 21 and 22 demonstrate that PD for Finance sector is higher under for risk transfer stress under concentration risk environment than that under without concentration risk.

Table 10: PD in Finance Sector

Finance Sector	Mean of PD	Standard Deviation of PD
Stress without Concentration Risk	0.237	0.335
Stress with Concentration Risk	0.248	0.393

The reason is that finance sector is the one that provides other sectors with financing source. With incorporation of concentration risk (multi sectoral model), shock from other sectors would have an impact on the asset value (mostly lower). Therefore, its PD would be higher than that under no concentration risk or homogenous one-sector model economy.

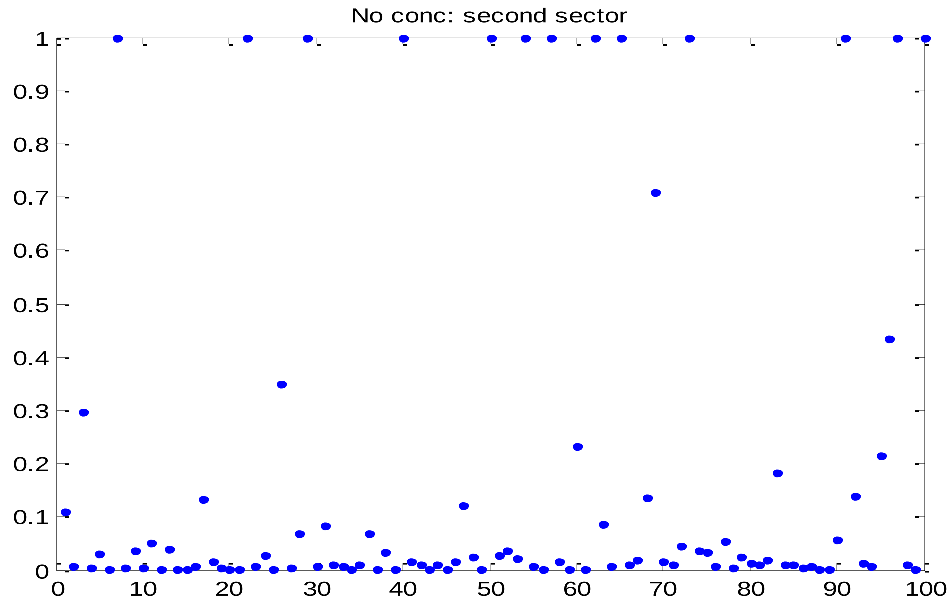

Figure 21: PD Plot in Finance Sector under Model without Concentration Risk

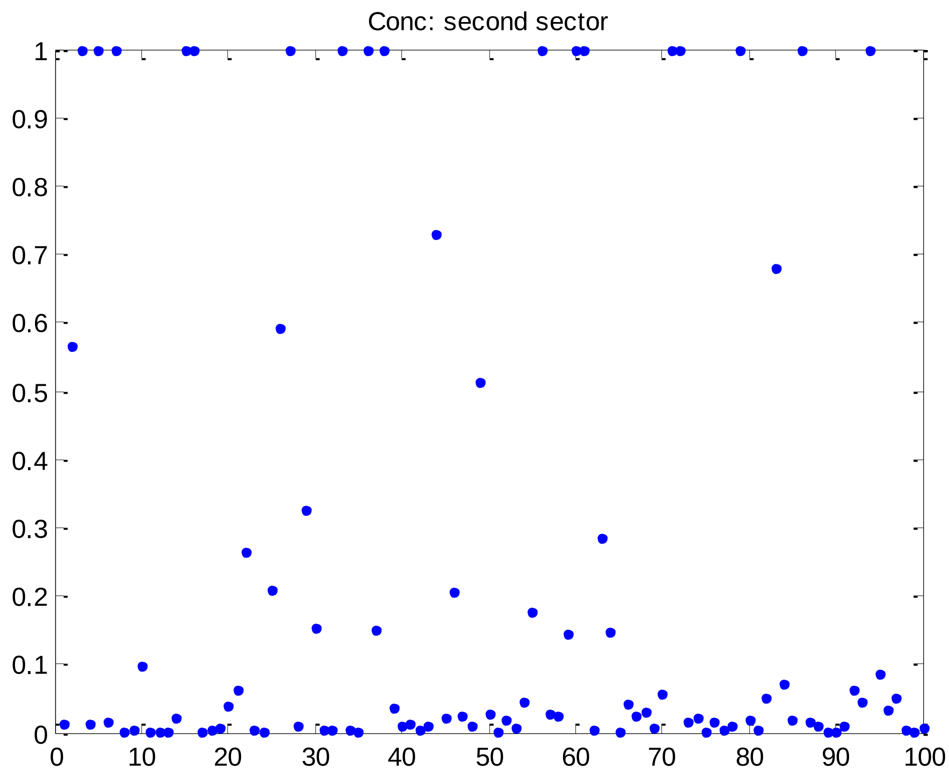

Figure 22: PD Plot in Finance Sector under Model with Concentration Risk

4.5 Conclusion and Policy Recommendation

Sector PD Analysis

- The most risky and most volatile sector is corporate and household sector, respectively.
- The most correlated pair of sectors is between finance and household sector.

Sub-Sector PD Analysis

- With corporate sector, while resource & energy and service sub- sector is the most risky sector, consumer goods sub-sector is the least risk sector.

Between macrofinancial risk and traditional model

- Under macrofinancial risk framework, central bank responds to the economic uncertainty with the higher level of interest rate than the traditional neoclassical model does, for guarding against the high magnitude of risk with the proxy of fsi.

- Under macrofinancial risk model, from the more responsiveness with economic uncertainty through tighter monetary policy, it results in higher output loss and faster return of inflation back toward steady state level.

Under the domain of macrofinancial risk model

- The best way to utilize macrofinancial risk model is through make fsi indicator more responsive to change in output with the inverse relationship (lower output leads to higher fsi), in order for central bank to more actively use interest rate as the policy tool to optimally manage output and inflation. In other words, it is better off for central bank to make linkage of risk indicator in economy-wide basis with the output level and uses this as the gauge responsive to output level.
- On the other hand, when central bank, under macrofinancial risk model, passively manages the economy, it is likely to allow fsi to be high enough to thwart the output in the economy.

When incorporating concentration risk under macrofinancial risk model

- Under the economic model incorporating concentration risk, the central bank has the obligation to assess the dynamic of macroeconomic variables in each sector simultaneously. In general, the diversification effect for economic performance is lessened under this environment. As a result, the central bank has to become more conservative regarding to the implementation of monetary policy. In addition, for risk transfer stress under concentration risk environment, interest rate is higher and, henceforth, output and inflation rate is lower than that without concentration risk.
- When assessing each economic sector, the risky sector would have lower PD, after incorporating concentration risk, under risk-transfer stress. This is due to the fact that, under macrofinancial risk framework, higher interest rate by central bank makes fsi more responsive to output in risky sectors with the incorporation of concentration risk. Henceforth, risky sectors will have lower PD from their more responsiveness. On the other hand, less risky sectors would have higher PD.
- As finance sector is the sector that provides the financing source for others. With incorporation of concentration risk (multi sectoral model), the shock from other sectors would have an impact on their asset value (mostly lower). Therefore, its PD would be higher than that under no concentration risk or homogenous one sector model economy. In other words, without concentration risk incorporated, PD from finance sector may be underestimated.

Bibliography

Basel Committee on Banking Supervision (2005): International Convergence of Capital Measurement and Capital Standards, A Revised Framework.

Bernanke, B., M. Gertler and S. Gilchrist (1999) "The Financial Accelerator in a Quantitative Business Cycle Framework", ***Handbook of Macroeconomics*** (Chapter 21), 1341-1393.

Brunnermeier, M. and Sannikov, Y. (2009) "A Macroeconomic Model with a Financial Sector", Working Paper.

Buiter, W. (2000) Measurement of the Public Sector Deficit and its implication for Policy Evaluation and Design, in ***How to measure in fiscal Deficit***, M. Blejer and A. Cheasty (eds), IMF, Washington, DC.

Duellmann, K. and Masschelein, N. (2006) "Sector Concentration in Loan Portfolios and Economic Capital", ***Discussion Paper*** No.09/2006, Deutsche BundesBank.

Erwin, W. and Wilde, T. (2001) Pro-cyclicality in the new Basel Accord. ***Risk***, October.

Gordy, M., A Comparative Anatomy of Credit Risk Models**.** ***Journal of Banking and Finance*****,** January 2000, *24* (1–2), 119–149.

Gordy, M. (2003) "A Risk Factor Model Foundation for Rating-Based Bank Capital Rules," J***ournal of Financial Intermediation***, vol 12, pp 199-232.

Gray, D., R.C. Merton, Z. Bodie. (2007) "A New Framework for Analyzing and Managing Macrofinancial Risks of an Economy," ***NBER paper*** #13607.

Martin, R. and Wilde, T. (2003), "Unsystematic Credit Risk," Working Paper.

Merton, R. (1974), "On the Pricing of Corporate Debt: The risk structure of interest rates", ***Journal of Finance***, 29, 449-470.

Morgan, J.P. (1997) ***CreditMetrics***™ – Technical Document. New York.

Schonbucher, P. (2000), Factor Models for Portfolio Credit Risk, Working Paper.

Vasicek, O. (1987), "Probability of Loss on Loan Portfolio", KMV Corporation.

Wilde, T. (2001), Probing Granularity, In ***Risk Magazine*** 14 (8), 103-106.