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Macroeconomic Stress-Test and Sensitivity Analysis of Financial Industry Credit Risk: An Example from The US Market

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Abstract

This paper seeks to implement simple stress-test analysis using OLS method to understand banking industry sensitivity to macroeconomic risk in US financial market from 2005 to 2008.Some observations made upon a couple of variables such as exchange rates of five world currenciesto US dollar, short and long-term US Treasury Bills rates, US inflation rate, the central bank's discount rate, and other two sort of banks' interest rates being bank primeloan and home mortgage rate.These independent variables were estimated in four different constructs for their influence to delinquency risk,, the type of credit risk that banking industry is basically dealing with in common. The findings resulted in fact that Australian Dollar (AUD) is the riskiest currency to banks's credit loss during the period. Similar positive impact were aalso shown by the bank primeloan rate, and federal funds rate, meaning that US central bank's monetary policy still has significant impact to the industry's basic risk.. When exchange rates observation window was extended to further previous year, Japanese Yen was found the most volatile.

Keywords: Credit Risk, Stress-Test, Macroeconomic Risks, Delinquency Rate, Sensitivity Analysis, Central Bank Discretion.

1. Introduction

Condition of the economy matters greatly to banking industry and financial institutions in raising new money and funds holding. In his Bundesbank Spring Conference speech paper titled Macroeconomic Risk and Policy Response (2005), member of the bank's Executive Board Herman Remsperger argued that economy is subject to large negative shocks which could trigger extremely unfavorable developments. This includes in practical instances the cost of money supply, interest rate shock, inflation and foreign exchange rate. Some other crucial macroeconomic risk are for example the rise of oil price and tax cut by government, not to mention the recent fear of derivatives trading including forward market efficiency.

Financial institutions experience uncertainty due to some unexpected particular events that cause their value to decrease. Delhaise (1998) pointed out that regional macroeconomic shock such as past 1998 Asian Crisis can bring systemic risk and contagious effect to banking system. Quite currently, Chan-Lau, Mitra, and Ong (2007) found that inter-linkages between foreign bank is increasingly higher, whereas certain local bank such as Barclay in the UK may become the single which spread contagious effect the most. This inter-linkage is found to be primarily caused by macroeconomic linkages between areas.

Among various type of risk, macroeconomic factors generally cause risk at a widely scope. These factors consist of inflation risk, currency risk and interest rate risk. In many cases, oil price is associated closely with heightening inflation. Whereas interest rate risk and currency risk are factors which are contributed by financial markets. Rosenberg (IMF, 2008) reported 15 percent increase of foreign currency-denominated loans distributed by local banks in Europe's emerging markets, causing the regional economy's increasing exposure to significant currency risk.

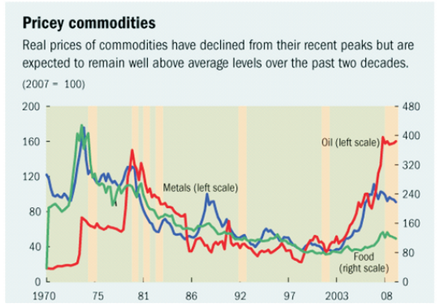
Interest rate risk is another macroeconomic factor which can cause substantial risk exposure. India had experienced serious interest rate risk exposure to its banks in 2002, due to government's easing interest rate policy (Patnaik and Shah, 2004). It was found that interest rate volatility was the primary source of shocks that needs to be monitored, since it causes banks to suffer losses at times when interest rate moves to disadvantaging direction. To banking industry and financial institutions, such a risky volatility demands time-varying monitoring and realignment (Caramazza, 1993).

General price level (inflation rate) is also fundamental macroeconomic factor that drives risk. Since inflation erodes value of money, it corrects financial institution's profit purchasing power as well. According to the IMF (2008), inflation has three dimensions, which are level, volatility and convergence. IMF's piece of research further found that oil was the highest inflation commodity, accompanied by metal (moderate) and food (lowest) (Helbling et al, 2008). Oil price trend was found to be historically increasing since 1970, whereas the rest commodities tend to be moving the other way around (Exhibit 1). Given this fact, it is substantial to take oil into account as well as an endogenous factor that impact on inflation rate and macroeconomic risk as a whole.

IMF (2008) further reminds, that macroeconomic conditions are continuously becoming the main source of risk threatening financial industry ahead. After US invasion to Iraq in particular, global economy has been much affected by increasing interest rates in the US, causing US dollar supply to squeeze and its exchange rate to soar up against many currencies. This shock has, in turn, led all transactions in US

dollar denomination to suffer from repayment problem and hit the banking industry. Along with the housing price shocks and worsening economic conditions that lead to higher unemployment rate, Federal Reserves economists Mark Doms, Fred Furlong and John Krainer (2007) especially pointed out high delinquency rate in US borrowing market as the cause of recent subprime mortgage crisis.

Exhibit 1. General World Prices of Oil, Metal and Food 1970 - 2008



Note: Prices are deflated by US CPI
Source: International Monetary Fund (IMF), 2008

This study seeks to explore and observe macroeconomic risk in banking industry, especially the impact of risk to delinquency rate and how these risk factors behave. With respect to that, dimensions of these risk factors such as volatility, persistence and impact are investigated.

This paper will examine the impact of a number of macroeconomic factors such as foreign exchange, interest rate and inflation rate, to banking industry delinquency risk in US market.

2. Literature Review

As business in general believes in, value maximization objective in banking industry and financial institutions is achieved through minimizing risk, while maximizing returns to shareholders (Hempel and Simonson, 1999). Among various risk, they put environmental risk, one of which is economic risk, as the first category that impacts systematically.

Rose and Hudgins (2005) identify six primary risk that banking and financial services are mainly prone of:

1. Credit risk, which is the probability that some of its assets will decline in value, especially its loans. To measure up or monitor it, delinquency rate or non-performing loans are generally used as proxies.
2. Liquidity risk, relates with the financial institution's ability to cover its immediate cash needed, for example when cases of rush take place.
3. Market risk, deals with market-oriented economies where banking and other financial institutions operate systematically. This risk includes changes of currency prices, shifting public demand, and shocks due to monetary policies.

4. Interest rate risk, is related to losses caused by the movement of interest rates in the market. Generally, economies refer to their central bank's rate and 30-day or 180-day government bond rate.
5. Earnings risk, is the one that takes form of decreasing financial earnings after all expenses. It is caused by internal factors such as operational inefficiency and external factors such as changes in economic conditions or in laws and regulations.
6. Capital risk, refers to insufficient capital needed to sustain long-term survival. After Bank of International Settlement proposed the use of Capital Adequacy Ratio (CAR) under Basel II Accord, the banking and financial institutions are currently applying risk-weighted assets as a measure of capital sufficiency.

2.1. Macroeconomic Factors as Cause of Risk in Banking Industry

Rose and Hudgins (2005) identify some macroeconomic factors that generally cause risk to banking and financial institutions. They are inflation risk, interest rate risk and currency price (or foreign exchange) risk. This study will focus on those risks accordingly.

2.1.1. *Inflation Risk*

Inflation risk relates to probability of increasing general price level for goods and services leads to weakening purchasing power of financial institution's earnings and return to its shareholders. In investment cases, financial institutions need to take this risk into account as it may erode return from this activities. For example, when a bank is involved in an investment syndication, a project must be valued appropriately using a proper discount rate to reflect current estimation of inflation rate.

However, in general sense, inflation results in weakening purchasing power that causes the entire economy to contract and shift its demand equilibrium. To banking and financial institutions, this lower purchasing power leads to fall in demand and GDP growth, contraction in business activities and difficulties in repayment that ends up in higher delinquency rate.

2.1.2. *Currency or Exchange Rate Risk*

Exchange rate risk is caused by fluctuations of currencies relative to one another or the financial institution's home currency. This fluctuation may create losses due to declining value of assets which are managed in terms of foreign exchange value. Some of examples are foreign government securities, assets-backed Eurodollar, exchange reserves, and liabilities or loans in various exchange denominations.

When a bank operates internationally, it is becoming prone to foreign exchange exposures. If the home currency becomes lower in terms of exchange rate, the bank will experience difficulties in fulfilling its obligations in foreign currencies. Another impact may happen through different transmitting channel. When domestic currency becomes weak relative to others, business and importers will experience difficulties and profit is hard to obtain. During such a condition, non-performing loans or higher delinquency rate are much possible to follow.

Moreover Rose and Hudgins (2005) noted that foreign currency risk exposure may come up through the following manners:

a. Making foreign currency-denominated loans to their customers
b. Issuing foreign currency-denominated interest rate-based products (such as deposits) to raise new funds
c. Purchasing foreign-issued securities
d. Trading in foreign currencies for a bank's own currency position as well as the currency needs of its customers

2.1.3. *Interest Rate Risk*

This risk is caused by movements in market interest rates that may cause the banks' profit margin to decline especially in cases where interest liabilities from borrowed money exceeds interest revenue from loans and security assets. In other sense, the rise of central bank's primary rate for example, may cause cost of funds to increase, leading public borrowers to repayment problems. Indirectly, previous debtors could possibly experience difficulties in repaying their previous loans due to current increasing cost of funds caused by contractionary monetary policy or business declining conjuncture. Rose and Hudgins (2005) specifically mention volatility of market interest rates as a risk driver that needs to be examined.

II.2. The Need For Macroeconomic Risk Management: Theoretical Framework

Bernanke (2008) noted worsening US macroeconomic conditions as the main cause of global economic downturn and declining performance of banking industry throughout the year. The collapse of some financial institutions, varying from insurance companies to big global banking industry such as Lehmann Brothers are some instances of the significant impact of macroeconomic risk to financial sector. Therefore some writers such as Hempel and Simonson (1999) classified economic risk as part of environmental risk that impact the whole industry systematically and put the risk on top priority among others.

Williams, Smith and Young (1998) further reminded that risk management effort does not have to necessarily relate with purchase of insurance. There are many risk forms that cannot be fully insured nor eliminated by insurance yet can be avoided. For example, managers can collect data comprehensively at regular basis to defend their organizations against legal liability and fulfill compliance. In other form, a cost reduction program can also be understood as a risk management effort since it prevents the company from further losses or wasted funds. Based on this understanding, macroeconomic risk is not a sort of pure risk that can be shifted to insurance company, yet rather to be managed internally through proper monitoring and anticipating efforts.

2.3. Macroeconomic Risk Among Other Type of Risk

Harrington and Niehaus (2004) differentiate three basic type of risk which are commonly found in business. They are price risk, credit risk, and pure risk (Exhibit 2). The first two can be deemed as diversifiable risk, or those which can be minimized. Whereas the latter can only be insured or shifted to third party. This risk deals with impacts of macroeconomic policy and conditions to business.

For banks, the level of interest rate, central bank's discretion on credits policy, inflation rate, exchange rate or number of employment, are some of such risk (Mishkin, 2006). For instance when the central bank decides to rise up interest rate, number of unserviced loans level (non-performing loans) would likely to increase. Interestingly, Williams, Smith and Young (1998) identified macroeconomic variables as risk factors which broadly affect group of securities.

Credit risk refers to any risk that is borne as a consequence of capital borrowing or money lending. When a bank or financial institution lends capital through loans mechanism, there is possibility that repayment rate is not made as expected. There are obstacles causing borrowers to extend or restructure repayment period such as when sales drops significantly or economic crisis happened to hamper. Moreover, the banks may also experience similar difficulties when borrowing capital from other financial institutions under LIBOR mechanism or overnight procedures.

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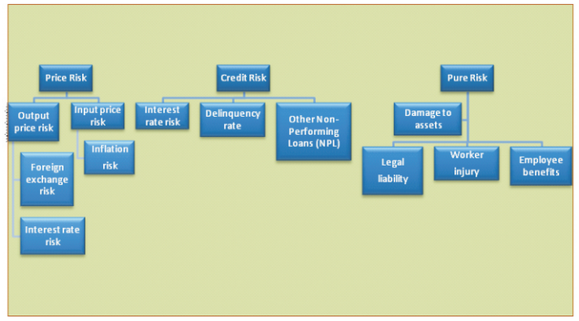
Exhibit 2. Type of Potential Risks Affecting Banking Sector



When dealing with price risk, financial institutions will have to consider the price of their products or services offered to consumers. For example, high cost of capital (interest rate) charged to potential borrowers may lead to refusal of potential credit card buyers or loans applicants to withdraw from commitment and shift their application to other competitors. Similar case may happen when some peripheral services such as electronic banking is very expensive to be afforded and IT cost is relatively high. If inflation rate is currently high, banks may also expect difficulties to afford raw material supply therefore produced output will also tend to be expensive and less competitive in the market.

Thirdly, the pure risk is related to risk which is generally caused by pure uncertainty. Some of the examples are fire, accidental power spark that causes damaged equipment, earthquake and down IT system. Such risk is subject to insurance coverage.

More detailed classification of risk is shown by Hempel and Simonson (1999), who extends the list to ten kinds of risk, one of which determined as macroeconomic risk. The following is some elaboration of this classification.

2.4. Previous Studies On Stress-Test Issues

When dealing with stress-testing mechanism, the term is usually understood as the process of estimating macroeconomic or other systematic risks. To financial institutions such as banking industry, this process relates largely to macroeconomic risk and its impact on default credit risk. As banking business basically manages a sum of loans portfolio, regular stress-testing basis is important to overlook current shocks exposure under different macroeconomic conditions. However to be more insightful, this study entails stress-testing, GARCH volatility measure, latent factor investigation using Generalized Method of Moments (GMM), forward market efficiency and Value-at-Risk (VaR) monitoring. Some previous studies corresponding to these constructs are to be reviewed below.

Thoraval (2006) demonstrates some stress-test methodological approaches to measure impact of macroeconomic factors to credit risk in French banking industry. He took scenarios of oil price, world demand, current interest rates and current US dollar exchange rate into account. Some proposed methods are the margin model by using Ordinary Least Squares (OLS) which consists of panel data and structural modeling, and capital requirement model (risk-weighted assets estimation). He found that past information on historical credit margin has significant positive relationship with the current one. In contrast, risk-free interest rate volatility shows different direction of relationship. However, he admitted some limitations such as absence of contagious effect among banks and risk concentration that may impact calculation.

In their IMF publication, Basurto and Padilla (2006) proposed two methods of undertaking stress-testing of portfolio credit risk when assessed under data constraints such as when loans are channeled to unlisted firms. These methods are Conditional Probability of Default (CoPoD) and the consistent information multivariate density optimizing (CIMDO). The first deals with macroeconomic shocks effect on credit risk, and the latter seeks to recover credit portfolio multivariate distributions imperfections due to limited information of borrowers.

Under the condition, Probability of Default (PoD) is put as a function of macroeconomic variables such as prices (inflation rate), interest rate (monetary policy) and GDP to measure macroeconomic factors impact on credit risk (default rate). Having classified borrowers into their sectors, the authors found that credit to GDP ratio and house prices are the most significant explanatory variables of PoD. Additionally, GDP growth and foreign exchange rate show negative relationship with the PoD. This research also seeks to replicate what was once promoted by the Denmark monetary authority recently with the same framework.

Similarly, Virolainen (2004) conducted a macroeconomic credit risk stress-testing for Finnish six corporate sector in 1986-2003. Using Seemingly Unrelated Regression (SUR) method, author found significant relationship between credits default rate and macroeconomic factors which are the GDP, interest rates and corporate indebtedness. In comparison with other various studies on macro stress-testing, this study is much interesting since it takes into account the corporate indebtedness as well. It also further highlights industrial average default rates by sector across the period, so that business policymakers can recognize business sector that is highly prone to credit risk..

In Hong Kong, similar stress-testing studies are undertaken quite recently for example by Fong and Wong (2008), who applied Mixture Vector Autoregressive (MVAR) technique to estimate macroeconomic credit risk of bank's loans portfolio. By using Hong Kong retail banks' credits default rate data from 1997 Q1 to 2007 Q3 and the country's GDP, interest rate and general housing prices level, authors found that the loans default rate in previous period affects interest rate and property/housing prices at the current period. Interestingly, the study can differentiate default risk condition under two different situations such as steady-adjusting macroeconomic condition (before and after Asian Crisis). Before the crisis, the previous relationship was found. Yet subsequently during it, default rate was determined mainly by property prices. This evolving movement recognition is chief benefit of the study.

Other evidence was suggested by Kalirai and Scheicher (2005) from their study on Austria's experience. They differently emphasize the importance of monitoring Value-at-Risk (VaR) at daily basis, and provision of loan loss. By applying Ordinary Least Squares (OLS) regression method, they entailed comprehensive macroeconomic factors, such as inflation rate, money supply (M1), the GDP, interest rates and balance of trade. It also encompasses corporate and financial market sector with respect to caital market index and companies' industrial production and accumulated investment expenditure.

Uniquely, the loans loss provisions (LLP) variable as main indicator advised by Austrian law is put as dependent variable. It results in the finding that industrial production is the best predictor of current LLP, indicating strong relationship between corporates' production capacity with the default risk. Further scenario analysis reveals the short-term nominal interest rate to be the single factor that has highest impact on LLP as percentage of core capital available.

3. Data and Methodology

Oviedo (2003) argued that measuring macroeconomic risk, shocks and uncertainty is actually measuring its volatility. Similar concern is discussed by Jorion (2006), Crouhy, Galai and Mark (2006) and Van Deventer et al (2004) who emphasized methodological research in monitoring and observing the issue.

This study seeks to investigate current general macroeconomic risk in US economy. Table 6 presents structure of study consisting of five Chapters. All data including historical delinquency rate, currencies to US dollar exchange rate, interest rate, and crude oil prices are obtained from US Federal Reserves website which are updated periodically. Whereas US historical inflation is observed through US Department of Labor, Bureau of Labor Statistics.

The paper construct examines macroeconomic factors and its impact to credit risk in banking concern, chief of which is represented by delinquency rate. These risk-bearing factors are currency risk, interest rate risk, inflation risk and central bank policy through US federal funds rate (later on to be noted FEDFUNDSRATE). To measure up, the delinquency rate is applied as a proxy which define as:

$$DELINQUENCY\ RATE = \left[\frac{STOCK\ OF\ LOANS\ IN\ DELINQUENCY}{TOTAL\ NATIONAL\ LOANS\ CHANNELED}\right] X100\%$$

The US Federal Reserves monthly national banking data ranging from September 2005 to February 2008 is used to obtain historical performance of delinquency rate. As Bernanke (2008) pointed out, this soaring rate of delinquency had caused banking industry to suffer loss and entire economy to experience downturn growth.

To estimate the research objective, statistical models are constructed by applying *Autoregressive Moving Average* (ARMA(*p*,*q*)) model to capture the time-varying random walk and error term impact across time:

$$X_t = \emptyset + \alpha_1 X_{t-1} + \cdots . + \alpha_p X_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \cdots . + \beta_q \varepsilon_{t-q} \quad \ldots\ldots\ldots\ldots (1)$$

being specification of its *Autoregressive* or denoted AR(*p*) process:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \cdots + \alpha_t X_{t-r} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

and *Moving Average* MA(*q*) process as follows:

$$X_t = \beta_0 + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \cdots + \beta_m \varepsilon_{t-m} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where the error term $\{\varepsilon_j\}$ is a purely random process with mean zero and variance of σ^2.

The AR term containing random walk of X_t in the form of a regression of its past value (Equation (2)). To control the impact of error terms across historical series, ε_t is observed by its random walk process as well in the model (Equation (3)). This integration provides the construct of ARMA (p, q) (Equation (1)). This method is suggested to lead to parsimonious representations of higher order AR(p) or MA(q) process (Maddala, 2001).

ARMA modeling can further reveal seasonal cyclicality of the error term in the trend estimation of dependent economic variable. Tests of this example can be seen for instance in the works of Backus, Routledge, Zin (2010) in their observation of assets return in the US market, or Rodriguez and Gomez (2005) on external indebtedness in Colombian banking sector, both of which control the ARMA process to calibrate their models.

Following the data arrangement procedures suggested by Gujarati (1995) and Maddala (2001) to avoid spurious regression, all historical series are inspected for their unit root whose presence may cause non stationarity that further result in parameter inefficiency due to inconstant variance. The Augmented Dickey-Fuller (ADF) Test is conducted to fulfill such requirement, undertaken by estimating the following equation:

$$y_t = \gamma + \delta_t + \alpha y_{t-1} + \sum_{j=1}^{k} \theta_j \Delta y_{t-j} + e_t \qquad e_t \sim N(0, \sigma^2)$$

in which the $\Delta y_{t-1\,t}$ term is involved to contain the time-varying ARMA error processes. Should the trend contains a unit root, it can be concluded that its variance is not homoskedastic.

Table 1 shows the result of unit-root test, exhibiting that all non stationary variables are generally found stationary at second-differenced lag. This findings further applied in the model becoming controlled variables.

Table 1. Summary of Stationarity Test

Variables	Status	ADF t-Statistic	Stationary at
AUD	Not stationary	0.9452	1-differenced
EURO	Not stationary	0.7697	1-differenced
Yuan	Stationary	0.0004***	
Yen	Stationary	0.0091***	
Poundsterling	Not stationary	0.9636	1-differenced
Bank Prime Loan Rate	Stationary	0.0025**	
Inflation Rate	Not stationary	0.3631	1-differenced
Home Mortgage	Not stationary	0.3280	1-differenced
30-day Treasury Bills	Stationary	0.0007***	
180-day Treasury Bills	Stationary	0.0013***	
Delinquency Rate	Not stationary	0.4316	2-differenced
Federal Funds Rate	Stationary	0.0006	

**) Stationary, MacKinnon one-sided p-value at α=0.01*

We also seek to observe volatility of variables across history. To shortly put this in the context, a simple look at the standard deviation as a mean of measure is taken (Jorion, 2006). All data availability except the delinquency rate, which was available in monthly format from the central bank, can be extended to August 2007 in daily basis. Hence, wider observation is achieved.

4. Research Findings: Stress Test and Sensitivity Analysis

The role of stress test is to capture the impact of a change in the value of one particular variable to other observed variable (Jorion, 2006; Crouhy, Galai and Mark (2006)). In monitoring financial day-to-day risk level overtime, Crouhy, Galai and Mark (2006) advises to undertake such test particularly to banking sector. For this study, it suffices to limit the scope only on loans delinquency risk which banking industry in general widely cope with. Similar approach is proposed by Van Deventer et al (2004) as well to overlook urgent impact of financial risk. Observing that today's financial crises in the US was largely caused by this risk, it is very relevant to count the issue in this study.

The delinquency rate is actually percentage of current outstanding non-performing loans relative to total loans channeled to the market. By using US total delinquency rate monthly data provided by The Federal Reserve from September 2005 to February 2008, the impact of some exogenous and endogenous factor on delinquency loans can be assessed. In this study, estimated control variables are five hard currencies (Australian dollar, Yuan, Yen, Euro, and Poundsterling) exchange rate against US dollar, the Bank Prime Loan credits interest rate, 30-day and 180-day T-Bills rate, the interbank overninght Federal Funds rate, Home Mortgage Service Ratio, and US inflation rate. All data are monthly-based.

To capture these two kinds of variables and sterilize estimation from possible autocorrelation between dependent and independent variables residuals, correlograms are inspected and ARMA process is controlled to improve the OLS. This sort of stress-testing has been used in some previous research.

For example Souto, Tabak and Vazquez (2007) conducted a stress-testing to measure macroeconomic factors impact on credit risk of 39 Brazilian banks during 2001-2007 by using simple Ordinary Least Squares (OLS) method. List of control variables can be used interchangeably as instruments to hold for exogenous variables. However, a bank's historical non-performing loans can be too technical and confidential information. The following assessment may not necessarily reflect US condition (due to insufficient data availability), yet can give it a broad outlook over the whole US financial market risk and how to respond to some critical variables.

4.1.1. Foreign Exchange to Loans Delinquency

Saunders and Lange (1995) as well as Delhaise (1998) propose that there is an impact of fluctuating foreign exchange rate on loans delinquency. Learning from Asian Crisis experience in 1998, the stunning attack of currency rate may spread contagiously to Asian countries through monetary mechanism and harm the banking sector. The impact of depreciation, as illustrated by Blanchard (2003), can hamper balance of trade and balance of payment as a whole, causing banks' non-performing loans to increase at microeconomic level.

To estimate the impact of foreign exchange rate on loans delinquency risk (or NPL risk), the following econometric model is constructed:

$$DELINQUENCY\_RISK = \alpha + \beta_1 AUD_t + \beta_2 EURO_t + \beta_3 POUNDSTERLING_t + \beta_4 YEN_t + \beta_5 YUAN_t + \varepsilon$$

4.1.2. Interest Rates to Loans Delinquency

As happened with foreign exchange rate, interest rate fluctuation can also affect the rate of loans delinquency. The rising interest rate may have contractionary effect to inflation (Blanchard, 2003), yet lead clients to difficulties in repaying their loans, therefore causes delinquency rate to increase. The case of worsening subprime mortgage loans service ratio due to increasing interest rate caused by war in Iraq is the real instance.

Estimation model can be constructed with the following equation:

$$\begin{aligned} DELINQUENCY\_RISK \\ = \alpha + \beta_1 BANK\_PRIMELOAN_t + \beta_2 HOME\_MORTGAGE_t + \beta_3 FED\_FUNDSRATE_t \\ + \beta_4 TBILLS\_180_t + \beta_5 TBILLS\_30_t + \varepsilon \end{aligned}$$

However, inspecting the correlogram of residuals, there is possible third order autoregressive AR(3) and first order moving average of MA(1) process that leads the model to high heteroskedasticity. By including those ARMA terms as control variable, the model is improved and heteroskedasticity recovered.

4.1.3. Inflation Rate to Loans Delinquency

Inflation diminishes assets value due to rising general prices level (Blanchard, 2003). There are two transmission with respect to banks' delinquency rate. First, in reducing the effect of inflation on public purchasing power, the central bank will usually increase interest rate that may gradually hamper clients'

service ratio. Secondly, inflation will lead to lower aggregate demand that causes business (clients) to suffer from lower sales (due to lower consumption level) and experience loans service difficulties.

The econometric model is as follows:

$$DELINQUENCY\_RISK = \alpha + \beta_1 LOG\_CPI_t + \varepsilon$$

Again, AR(*p*) and MA(*q*) were found to be problems leading to heteroskedasticity. To improve and recover this effect, the three control variables are included.

4.1.4. Discretionary Monetary Policy to Loans Delinquency

The role of central bank is to regulate monetary policy through transmissions of interest rate (Mishkin and Eakins, 2006). In the US, this interest rate is known as the Federal Funds rate. Its set up level will certainly influence interbank loans offering. Thus, by increasing the rate, banks credits rate will possibly increase as well (Mishkin and Eakins, 2006; Saunders and Lange, 1995; Delhaise, 1998), all variables held constant. The following model estimates the impact of changing level of central bank's interest rate on possible change delinquency rate:

$$DELINQUENCY\_RISK = \alpha + \beta_1 FED\_FUNDSRATE_t + \varepsilon$$

To estimate all the preceding equations, The Federal Reserves monthly data containing 30 observations from September 2005 to February 2008 is used. It is rather unfortunate that The Fed's observation of delinquency rate was not quite extensive recently, since the only available observation extends from that period. Yet, Gujarati (1996) allows relatively limited observation, as far as number of controlled parameters (*k*) does not exceed the number of observations (*N*). All series have undergone Unit Root Test, and are generally stationary at lag 1 to 4 as commonly happen with economic variables (Dickey and Fuller, 1979). In summary, all estimation results are given below (standard errors in parentheses):

Table 2. Estimated Equation of Four Models
September 2005 – February 2008

Variable	Coefficient	t-Statistic		Goodness of Fit	
		Model A: Endogenous variable (exchange rates)			
Constant	90.78844	0.187639		R-squared	0.889050
		(483.8471)		Adjusted R-squared	0.848173
AUD(-1)	0.347621	0.305209			
		(1.138959)			
EURO(-1)	0.082441	0.289614			
		(0.28466)			
POUNDSTERLING(-1)	-8.259674	-2.321153	**		
		(3.558436)			
YEN	-0.032861	-1.466017			
		(0.022415)			
YUAN	-9.691615	-0.165964			
		(58.39595)			
AR(1)	0.871811	7.746121	***		
		(0.112548)			
MA(2)	0.905599	14.03199	***		
		(0.064538)			

Table 2. Estimated Equation of Four Models
September 2005 – February 2008

Variable	Coefficient	t-Statistic		Goodness of Fit	
Model B: Endogenous variable (interest rate)					
Constant	-6.931918	-1.180877		R-squared	0.866940
		(5.870145)		Adjusted R-squared	0.812151
BANK_PRIMELOAN	1.504314	1.917065	*		
		(0.784696)			
HOME_MORTGAGE(-1)	0.370629	1.075067			
		(0.344750)			
TBILLS_180	-1.407191	-1.817091	*		
		(0.774420)			
TBILLS_30	-0.520894	-0.460218			
		(1.131841)			
AR(3)	0.470794	2.486296	***		
		(0.189356)			
MA(1)	0.997497	77218.14	***		
		(1.29E-05)			
Variable	**Coefficient**	**t-Statistic**		**Goodness of Fit**	
Model C: Endogenous (inflation rate)					
Constant	2.152509	4.788635	***	R-squared	0.904257
		(0.449504)		Adjusted R-squared	0.891769
LOG_CPI(-1)	-0.000324	-0.001811			
		(0.178867)			
AR(1)	0.889222	10.34150	***		
		(0.085986)			
MA(3)	1.089278	5.477993	***		
		(0.198846)			
Variable	**Coefficient**	**t-Statistic**		**Goodness of Fit**	
Model D: Endogenous (central bank's discretion)					
Constant	1.971135	3.934728	***	R-squared	0.902157
		(0.500958)		Adjusted R-squared	0.889395
FED_FUNDSRATE	0.09596	0.387748			
		(0.247481)			
AR(1)	0.898780	9.252542	***		
		(0.097139)			
MA(3)	0.923766	17.06696	***		
		(0.054126)			

*Note: *) significant at 10% level, **) significant at 5% level, ***) significant at 1% level. Standard error in parentheses*

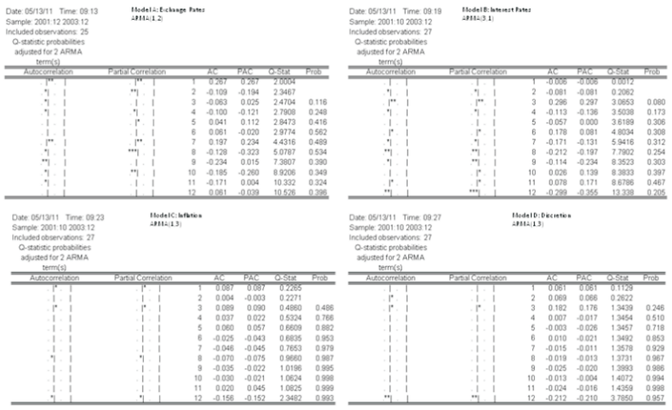
Rewriting those estimated parameters, hence we have:

Models	Controlled ARMA (p,q) Terms	Coefficient of Determination Before ARMA	Coefficient of Determination After ARMA	Estimated Equations
Model A	ARMA (1,2)	0.788192	0.848173	*DELINQUENCY_RATE = 90.78844 + 0.347621 AUD(-1) + 0.082441 EURO(-1) - 8.259674 POUNDSTERLING(-1) - 0.032861 YEN - 9.691615 YUAN* *0.871811 AR(1) + 0.905599 MA(2)*
Model B	ARMA (3,1)	0.760099	0.812151	*DELINQUENCY_RATE = -6.931918 + 1.504314 BANK_PRIMELOAN + 0.370629 HOME_MORTGAGE(-1) -1.407191 TBILLS_180 - 0.520894 TBILLS_30* *0.470794 AR(3) + 0.997497 MA(1)*
Model C	ARMA(1,3)	0.860487	0.891769	*DELINQUENCY_RATE = 2.152509 -0.000324 LOG_CPI(-1)* *0.889222 AR(1) + 1.089278 MA(3)*
Model D	ARMA(1,3)	0.861515	0.889395	*DELINQUENCY_RATE = 1.971135 + 0.09596 FED_FUNDSRATE* *0.898780 AR(1) + 0.923766 MA(3)*

All models' explaining power improved when ARMA (p,q) term was taken into account, as experiments undertaken for lags containing AR and MA process to improve the models. This proves the presence of cyclicality across the time-series lags and provides results for considerable goodness of fit when applied for modeling calibration. As empirically seen, the results strengthen Gujarati's (1996) opinion that economic variables usually achieve stationarity at 1st to 3rd differenced lag.

Moreover on the estimation result, Table 2 shows that Poundsterling exchange rate is statistically significant in the t-test, and some parameters show interesting coefficients sign. Out of five hard currencies, only the Euro and Australian dollar (AUD) that have positive relationship with delinquency risk. A unit increase in Euro and AUD exchange rate will increase delinquency rate by 0.31 and 0.29 respectively. Hence with respect to impact to delinquency risk, Australian Dollar is the riskiest foreign exchange to be monitored appropriately. Interestingly, shock from previous (*t*–1) period has the most significant impact on delinquency rate, as proven by significant AR(1) term at 1% level. The following Exhibit 3 provides correlogram inspection results from the four models after estimation. All results indicate variance stationarity across all lags.

Exhibit 3. Post-Test Correlogram Inspection



In interest rate model, Bank Prime Loan rate and the 180-day T-Bills rate show significant impact on delinquency rate (at 10% critical value level). Out of four interest rates estimate, the 30-day and 180-day T-Bills rate show negative relationship with the delinquency risk. These variables tend to be high when delinquency rate declines and vice versa, indicating clients presumed different risk premium preference between investing and borrowing purposes. Certainly, the Bank Prime Loan rate has the highest sensitivity on delinquency rate because of its direct impact to repayment capacity. The positive relationship between Home Mortgage loan rate with the delinquency rate is consistent with recent situation that led the US into financial crises. In addition to that, significant AR(3) process indicate possible 3-month cyclicality of information shock that influence the risk.

Inflation shows negative relationship with delinquency risk. This is inconsistent with the theory that high inflation will gradually weaken public spending and clients' capacity to repay. A one percent increase in inflation rate results in decline of delinquency rate by 0.000324 unit. A very strong AR(1) process is found indicating possible cyclical impact of information shock at past one month-lagged period. Interestingly, when author excluded some previous exogenous factors from estimation, inflation becomes more statistically significant and the model's goodness improves as well although the negative coefficient remains.

In the last Chapter, the Federal Funds Rate representing central bank's discretionary shows positive relationship with the delinquency rate, which is consistent with general macroeconomic theory. A unit rise of the rate will increase delinquency rate by 0.09 unit or roughly 9 percent. When interest rate turns high, people will reduce consumption spending and chose to save. In the same consequence, borrowers will be reluctant to propose for loans and the outstanding ones may experience higher difficulty. Interestingly also, significant impact of previous information from lag 1 and 3 of ARMA(1,3) term shows same pattern with those of preceding inflation estimation. We can presume this could be caused by the central bank's inflation targeting agenda that might have worked effectively.

5. CONCLUSION

Banking industry is exposed to several variables that have must be identified as primary sources of risk in each of determinants like foreign exchange risk, interest rate risk, and inflation risk. They are British Poundsterling, the Bank Prime Loan Rate and 180-day US Treasury Bills rate.

Table 3 summarizes all statistical findings to be reported in this study. Due to unequal range of various data provided by The Fed, the only available observation from September 2005 to February 2008 is utilized for the stress-test and all the rest macroeconomic variables are adjusted to follow. This specific note is made only for stress test on delinquency rate, whereas the rest volatility tests apply more extended daily observations from August 17, 2007 to October 10, 2008.

Table 3. Proposed Macroeconomic Stress Test Report

Variable	By Volatility Daily Data Aug 17, 2007 – Oct 10, 2008			By Impact on Delinquency Monthly Data September 2005 – February 2008		
	Std. Dev.	Rank	Interpretation	Relationship	Rank*)	Significance
	0.053737	9	Less volatile	+ 0.347621	3	Not significant
	0.031394	10	Less volatile	+ 0.082441	5	Not significant
	0.021293	11	Less volatile	-8.259574	10	Significant
	4.6654	**1**	Very volatile	-0.032861	7	Not significant
	0.260485	8	Less volatile	-9.691615	11	Not significant
	0.444820	7	Less volatile	+0.370629	2	Not significant
	0.742293	5	Less volatile	+1.504314	**1**	Significant
	1.052855	3	Volatile	-1.407191	9	Not significant
	1.00195	4	Volatile	-0.520894	8	Significant
	0.004682	12	Less volatile	-0.000324	6	Not significant
	0.724311	6	Volatile	+0.09596	4	Not significant

Note:*) arranged by order, from the most positive relationship (impact) to the most negative one, at 1% and 5% level

First, the Japanese Yen is found to be currency that presents highest volatility. This shock is caused by information effect that has wide time span impact especially (*t*-1) month. Secondly, the 30-day US Treasury Bills is the most volatile interest rate relative to the 180-day one, US Federal Funds rate, and Bank Prime Loan rate. The rate is also proven to be significantly influencing the level of delinquency rate in the US since September 2005. This high risk of risk-free rate will possibly impact the long-term general interest rates in the US.

The preceding findings lead to some implications to business policymakers. First, to the banking business institution for instance, the management can recognize factors that have high volatility in the market, such as the Japanese Yen, although its impact on delinquency rate is not significant. This leads to possible anticipation when coping up with any transactions involving those two instruments. For example, implement hedging when dealing with Yen, and keep up monitoring oil price and its impact to general levels comprehensively.

Secondly, since the bank prime loan and home mortgage rate are two variables affecting credit risk (here represented by the delinquency rate) most significantly, the banking business will have to take a proper look at them. Banks can, in progress, improve their interest policy on those two subjects by gradually lowering the rates to reduce credit risk. Having seen that Australian dollar (AUD)/USD is a third significant factor affecting the risk, banks can suggest borrowers to hedge more carefully against the currency when dealing with their business to reduce their further possible credit loss exposure due to shocks from currency market. However, these findings are temporary. As observation window extends, the banking business will have to update this stress-testing regularly and find out which factors appear to affect significantly most current.

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