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The paper benefitted from discussions with Pontus Rendahl, Petra Geraats, Ryoko Ito, and participants at the ADB seminar series, and the 2013 Singapore Economic Review Conference.

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Abstract

Events surrounding the global financial crisis have brought to light the potential role of monetary policy in precipitating the crisis. Numerous studies on advanced economies have documented a significant negative relationship between interest rates and bank risk-taking. This paper also finds the presence of the risk-taking channel based on a panel of publicly listed bank data in Asia. Using both annual and quarterly data, "too low" interest rates are found to lead to an increase in bank risk-taking.

Keywords: Bank risk-taking, interest rates, panel data, monetary policy, Asian banks

JEL Classification: E43, E52, G21

1. Introduction

Of the many causes of the global financial crisis, one that strikes a particular discord among central bankers is the notion that an accommodative monetary policy can be harmful to the economy. For many, it is unsettling to realize that the role of monetary policy, which has long been considered a stabilizer or stimulant of short-term business cycles—the solution—could in fact be the problem. Still, the literature that implicates the role of monetary policy is not completely new or unknown. Fisher (1933), Hayek (1939), and Kindleberger (1978) are some studies that highlight easy monetary conditions as classical ingredients in boom-bust business fluctuations. Hayek (1939) of the Austrian business cycle theory fame espouses that excessive credit expansion accommodated by lax monetary policy precedes and lays the groundwork for recessions. Meanwhile, Minsky's (1992) financial instability hypothesis posits that during periods of high economic growth, the income-debt arrangements of economic units shifts from hedge finance (completely hedged debt) toward speculative and Ponzi finance (highly unstable leverage and higher risk). This tendency is heightened by protracted low interest rates when a growing number of investors seek higher yields despite increasing risk. Thus, loose monetary and credit policy play an important role in the evolution from financial stability to crisis.

This paper focuses exclusively on the risk-taking behavior of financial intermediaries in response to loose monetary conditions. A prolonged period of relatively low interest rates can induce financial imbalances by reducing risk aversion of banks and other investors. In the context of the global financial crisis, it is said to have contributed to the credit boom, asset price increases, a decline in risk spreads, and a search-for-yield that eventually saw the bust in the US subprime and housing markets, the collapse of major financial institutions, and ultimately, the Great Recession (Hume and Sentance 2009; Taylor 2009; Diamond and Rajan 2009). This, until recently, missing link in the monetary policy transmission mechanism—known as the risk-taking channel (Borio and Zhu 2008; Rajan 2005)—relates to how changes in interest rates affect either risk perceptions or risk-tolerance of financial intermediaries.

Empirical literature on the risk-taking channel has thus far focused mostly on the US and the euro area. This study therefore fills an important void in examining the impact of low interest rates in 10 Asian economies (the People's Republic of China (PRC); Hong Kong, China; India; Indonesia; the Republic of Korea; Malaysia; the Philippines; Singapore; Taipei,China; and Thailand) from 2000 to 2011. Based on both quarterly and annual data, we find the presence of the risk-taking channel in Asia. In addition, we find more nuanced results using the quarterly data. In particular, we find contemporaneous impact of low interest rates reduces bank riskiness mostly likely in lowering the default probability of existing loans. Yet over time, banks become more aggressive and tend to lend less to creditworthy borrowers. As a result, the overall risk level of banks rises.

The rest of this paper is organized as follows. Section two reviews the theoretical and empirical literature on the bank risk-taking channel. Section three discusses the model specification of the bank risk-taking channel with a focus to delineate it from other channels of monetary policy transmission mechanism. Section four delves on data and estimation issues. Results are presented in section five, while section six concludes.

2. Literature: Theory and Evidence

The relatively new concept of the risk-taking channel of monetary policy transmission mechanism is reflected in the scarcity of its theoretical contributions. Giavazzi and Giovannini (2010) build on the work of Tirole (2011) to model the interactions between monetary policy and liquidity transformation. They claim that optimal monetary policy consists of a modified Taylor rule, which takes into account the possibility of liquidity crises and thus adjusts to changes in risk-taking. Diamond and Rajan (2011) present a model where the fiscal authority is able to affect real interest rates, arguing that ex ante regulation may not be effective if the extent of ex ante promises are hard to observe. They suggest raising real interest rates in normal times to prevent banks from making excessive liquidity promises. Cao and Illing (2012) model how financial intermediaries' incentives for liquidity transformation are affected by the central bank's reaction to financial crisis. They demonstrate that interest rate policy as financial stabilizer is dynamically inconsistent, and imposing ex ante liquidity requirements can increase efficiency.

More specifically, low interest rates can lead banks to take on more risk in several ways. First, low interest rates boost prices and collateral values of assets on banks' balance sheets, which in turn modify banks' estimates of probabilities of default, losses in the case of default, and overall volatility of bank returns.[1] Measured volatility tends to decrease in rising markets,[2] which relaxes banks' budgetary constraints and leads to even more risk-taking (Borio and Zhu 2008). According to Adrian and Shin (2009), low short-term rates may lead to more risk-taking because they improve banks' profitability and relax their budgetary constraints. Second, low interest rates may influence banks to search-for-yield (Rajan 2005). Financial institutions often enter into long-term contracts committing them to produce high nominal rates of return. In a period of low interest rates, these contractual rates may exceed the yields available on safe assets. To earn higher returns, banks therefore will have to search for higher yields from the more risky assets. Third, banks' perception that the central bank will ease monetary policy in bad economic times can lower the expectations of large downside risks—the moral hazard problem. This implies that changes in interest rates can have an asymmetric impact on risk-taking, that is, reductions encourage risk-taking by more than the equivalent increases in discouraging risk-taking. Fourth, Dell'Ariccia and Marquez (2006) point out that low interest rates reduce adverse selection in credit markets, which decrease banks' incentives for screening loan application. Fifth, Akerlof and Shiller (2009), in turn, suggest that, due to money illusion in periods of low interest rates, investors take higher risks to increase returns.

Most single or multiple-economy empirical studies have tended to find the presence of risk-taking channel. Jimenez et al. (2008) examine the case of Spanish banks before the

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1 This is in close spirit to the familiar financial accelerator mechanism, which argues that increases in collateral values reduce borrowing constraints (Bernanke et al. 1996). Adrian and Shin (2009) claim that the risk-taking channel is distinct but complementary to the financial accelerator because it focuses on amplification mechanisms due to financing frictions in the lending sector.

2 The literature suggests that short-term volatility is directional, that is, it tends to fall in rising markets and rise in falling markets. For instance, for equity returns, see Schwert (1989) and, for bonds, Borio and McCauley (1996).

introduction of the euro. They find that low interest rates affect the risk of bank loan portfolio in two opposing ways. In the short-term, low interest rates reduce the probability of default of the outstanding loans; in the medium term, however, banks act more aggressively, that is, they lend to borrowers with a worse credit history and grant more loans with a higher probability of default. In the same vein, Gaggl and Valderrama (2010) look at Austrian banks and find that the expected default rates of banks' business loans increased during the period of low refinancing rates from 2003 to 2005.

On the other hand, Ioannidou et al. (2009) take a slightly different approach by examining the quantity and quality of loans, as well as the price of loans. Based on data from 1999 to 2003, they find that when the federal funds rate was reduced, Bolivian banks not only increased the number of risky loans, they also reduced the rates they charged to risky borrowers relative to the rates for less risky ones.[3] Using a similar methodology, in addition to the loan and bank specific characteristics as per Ioannidou et al. (2009), Paligorova and Santos (2012) also control for borrower specific characteristics and find over the period of 1990 to 2010, when the US federal funds rates were low, banks demanded relatively lower spreads on their loans to riskier borrowers than to safer ones.

In terms of multi-economy studies, Maddaloni and Peydro (2011) use credit standards surveys and find periods of low short-term rates are associated with softening of lending standards by banks in the euro area and the US. Altunbas et al. (2012) also find low interest rates over protracted periods lead to an increase in bank risk as captured by banks' expected default frequencies. They use publicly available quarterly information of 600 banks from 1999 to 2008, of which about two-thirds are US listed entities, the rest, European. Using a similar panel generalized method of moment (GMM) methodology but with annual euro bank data from 2001 to 2008, Delis and Kouretas (2011) also find substantive evidence of bank risk-taking. Our paper is closest to Altunbas et al. (2012), but with the major exception of being Asian focused. In addition to using quarterly data as per Altunbas et al. (2012), which helps provide a more nuanced analysis of the dynamics of bank risk-taking, we also use annual data as they present a longer time-series and larger cross-sectional dimension. Unlike Altunbas et al. (2012), however, we explicitly derived our bank risk dependent variable, whereas their main bank risk indicator is obtained from a proprietary data provider.

For many emerging economies, it is instructive to note that low interest rates abroad especially in advanced economies can also translate to lower than appropriate interest rates in the domestic economy (Bank for International Settlements (BIS) 2012; Taylor 2012). The centrality of the US dollar in the world trading system means that many emerging economies tend to peg their currencies to the US dollar (McKinnon 2013; McKinnon and Schnabl 2004). With capital mobility, this implies that their monetary policies will typically track the monetary policy of the US. A particular problem arises when the emerging economies' business cycles do not synchronize with the US business cycle. BIS (2012) highlights a specific scenario during the global financial crisis, when despite the decline in world interest rates, persistent interest rate

[3] Bolivia is a highly dollarized economy with the exchange rate pegged to the US dollar. Hence, the US federal funds rate was used in their study.

differentials remained between the relatively higher interest rates in the emerging economies and that of the advanced economies. The search-for-yield in this case led to a surge in capital flows into the emerging economies buoying domestic economic and financial conditions. The appropriate stabilization strategy would be to tighten policy (let interest rates rise), yet this was seldom done in order to discourage further capital inflows and hold the exchange rate relatively steady.

3. Model Specification

This paper follows the modeling spirits of Altunbas et al. (2012) and Delis and Kouretas (2011), which is based on the literature of the determinants of bank risk and monetary policy transmission mechanism. In essence, besides the interest rate variables of focus, the model also includes a set of bank specific controls, and a set of structural, macro, and regulatory controls pertinent to a particular economy. These controls are aimed to better delineate the impact of bank risk-taking channel from other monetary policy transmission channels.

The model with annual data is:

$$br_{i,j,t} = \alpha br_{i,j,t-1} + \beta ir_{j,t} + \gamma ig_{j,t} + \delta gr_{j,t} + \theta yc_{j,t} + \rho cg_{j,t} + \tau er_{j,t} + \square sm_{j,t} + \varphi_1 sz_{i,j,t} + \varphi_2 cp_{i,j,t-1} + \varphi_3 lq_{i,j,t-1} + \varphi_4 pr_{i,j,t-1} + \mu_1 sp_{j,t} + \mu_2 md_{j,t} + \mu_3 cs_{j,t} + \varsigma ce_j + \varepsilon_{i,t}. \quad (1)$$

On the other hand, the quarterly model is:

$$br_{i,j,t} = \alpha br_{i,j,t-1} + \sum_{k=0}^{1} \beta_k ir_{j,t-k} + \sum_{k=0}^{1} \gamma_k ig_{j,t-k} + \sum_{k=0}^{1} \delta_k gr_{j,t-k} + \sum_{k=0}^{1} \theta_k yc_{j,t-k} + \sum_{k=0}^{1} \rho_k cg_{j,t-k} + \sum_{k=0}^{1} \tau_k er_{j,t} + \sum_{k=0}^{1} \square_k sm_{j,t-k} + \varphi_1 sz_{i,j,t} + \varphi_2 cp_{i,j,t-1} + \varphi_3 lq_{i,j,t-1} + \mu_1 sp_{j,t} + \mu_2 md_{j,t} + \mu_3 cs_{j,t} + \varsigma ce_j + \varepsilon_{i,t}. \quad (2)$$

$br_{i,,j,,t}$ is a measure of bank risk of bank i in economy j at time t. For the annual model, we use four measures of bank risk: (1) the idiosyncratic risk of a simple capital asset pricing model (CAPM), $br1$; (2) the ratio of non-performing loans to total loans, $br2$; (3) the z-score, $br3$; and (4) the standard deviation of the return on assets, $br4$. For the quarterly model, due to data constraints, we only use the idiosyncratic risk.[4]

$ir_{j,,t}$ is the change in short-term interest rates that proxy for the change in the monetary policy stance. $ig_{j,,t}$ is the interest rate gap that measures the difference between the policy rate and a benchmark rate. It is the variable of main interest that captures the bank risk-taking channel, specifically the phenomenon of search-for-yields as discussed in Section 2. If the bank risk-taking channel is operational, we expect γ to be negative, meaning higher interest rates (above some benchmark) reduce bank risk-taking or, conversely, lower interest rates increase bank risk-taking. We follow Altunbas et al.

[4] Derivations of these measures will be discussed later. See also the appendix and Table 1 for summary statistics of variables used.

(2012) in using this indicator as a measure of the bank risk-taking channel.[5] In addition, as per Altunbas et al. (2012), we use both the change in interest rates and the interest rate gap in the estimations. The latter is a sharper measure of bank risk-taking channel as it better captures the phenomenon of search-for-yield, while the former is a coarse measure that also incorporates the financial accelerator effect or the balance sheet channel. Specifically, any change in interest rates will affect borrower's collateral value (the balance sheet effect), and in turn the riskiness of bank loans portfolio.[6]

The Taylor benchmark rates are consistently higher than the natural rates (or more accurately the trend rates) in all economies (Figure 1). The interest rates in most of the economies, although higher than the rates in developed countries, are still low against the background of their trend output growth rates over the past several years. This reinforces BIS (2012) which argues that policy rates in emerging market economies, particularly in Asia, appeared unusually accommodative by the end of 2011. Following the global financial crisis of 2007, there was a downward movement in the interest rates in line with the near zero-interest rate policy in the developed world with some signs of reversal post 2010. Output and inflation also followed a downward trend, most notably between 2008 and 2009, followed by a quick recovery thereafter. This is also reflected in the rising Taylor benchmark rates post 2009.

$gr_{j,,t}$ is the real GDP growth rate of economy j. $yc_{j,,t}$ measures the slope of the yield curve of economy j. Both these variables are included to capture the effects of the expectations channel of the transmission mechanism. As a priori, the coefficient of gr is expected to be negative—better economic conditions raise the profitability of a larger number of projects in accordance with the expected net present value, which reduces the overall credit risk to banks (Kashyap et al. 1993). Similarly, the coefficient of yc should be negative—the steeper the slope of the yield curve, the higher the bank profits (Viale et al. 2009; Entrop et al. 2012) and the lower the bank risk.

$cg_{j,t}$ is bank credit to GDP of economy j (Delis and Kouretas 2011; Mannasoo and Mayes 2009). Previous studies have found mixed signs. For example, Gonzalez-Hermosillo et al. (1997), Mannasoo and Mayes (2009), and Delis and Kouretas (2011) find that financial deepening increases the vulnerability of the banking sector—a positive relationship. This lends support to evidence from the global financial crisis particularly in the developed economies where excessive finance was found to have harmed the economy (Taylor 2009; Diamond and Rajan 2009; Turner 2012). On the other hand, other studies consider financial deepening as a sign of economic maturity and therefore expect a negative coefficient (Hutchison and Mc-Dill 1999; Gonzalez-Hermosillo 1999).

[5] Delis and Kouretas (2011) use levels of interest rates in their main estimations, and changes in interest rates as a robustness check. They acknowledge that the changes in interest rates are a measure of the bank risk-taking channel.

[6] It is important to distinguish the risk-taking channel from more widely understood channels relating to credit market, namely, the financial accelerator or the balance sheet and bank lending channels, which together constitute the broad credit channel. The risk-taking channel goes beyond the change in the net worth of both lenders and borrowers (which is incorporated in the broad credit channel). It focuses on "the impact of changes in policy rates on either risk perceptions or risk-tolerance and hence on the degree of risk in the portfolios, on the pricing of assets, and on the price and non-price terms of the extension of funding" (Borio and Zhu 2008). In other words, it accounts for the amount of uncertainty a lender is willing to hold in its portfolio.

$er_{j,,t}$ measures exchange rate volatility of economy j to account for the exchange rate channel. As the countries studied in this paper are mostly small and open economies, they tend to be susceptible to volatile capital flows. Hence, the more volatile the economic environment, the more volatile is the exchange rate and the higher is the bank risk.

$sm_{j,t}$ measures changes in the broad stock market index of economy j that captures the wealth channel. We expect the coefficient to be negative. An increase in the asset prices would increase the collateral value, thereby reducing bank risk.

$sz_{i,j,t}$ size; $cp_{i,j,t}$, capitalization; and $pr_{i,j,t}$, profitability; are the bank specific variables of bank i in economy j included to control for the bank lending channel effects. The bank lending channel focuses on the financial frictions derived from the balance sheet situation of banks.[7] The signs on these variables are expected to be negative as bigger, more capitalized, highly liquid and more profitable banks would be as less risky. Bank specific characteristics, except size, which is considered as a predetermined variable, are lagged to deal with endogeneity (Delis and Kouretas 2011).

$sp_{j,t}$, capital stringency index; $cs_{j,t}$, supervisory power index; and $md_{j,t}$, market discipline index; represent the regulatory indexes of economy j (Barth et al. 2013).[8] They are included as per Delis and Kouretas (2011) to avoid the problem of omitted variable bias, that is, to account for the bank regulatory environment. The higher the value of each index, the greater the capital stringency, the stronger the supervisory power, and the greater the market disclosure faced by banks. As such, we expect these indices to have a negative impact on bank risk.

ce_j is individual economy effects to account for unobserved cross- economy differences. Time dummies are also included which vary according to the frequency of the data. This is to account for technological change that occurs over time, which may influence bank risk-taking behavior.

Both equations (1) and (2) are a dynamic model that includes the lagged bank-risk variable as an explanatory variable. This can be justified on several grounds (Delis and Kouretas, 2011). First, the persistence may reflect the existence of intense competition, which tends to alleviate bank risk-taking. Second, the importance and prevalence of relationship-banking with customers means bank risk is likely to persist. Third, given that bank risk is likely to follow business cycles, we may find a persistent bank risk behavior

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7 The bank lending channel contends that a monetary policy tightening can affect the supply of bank loans due to a decline in their total reservable deposits. This can be offset by raising non-reservable funding. However, the cost of non-reservable funding would be higher for smaller and low-capitalized banks if the market perceives them as riskier. Similarly, illiquid banks will be more adversely affected by a monetary tightening due to a lower possibility of being able to liquidate their assets. See Bernanke and Blinder (1988), Kashyap and Stein (1995), Kishan and Opiela (2000), among others, for a good analysis of the specific effects of the variables on the bank lending channel.

8 See the appendix for detailed definition of each index.

in line with the dynamics of business cycle. Hence, if risk is persistent, a static model would be biased, and a dynamic model is preferred.[9]

The main difference between the annual model and the quarter model is the inclusion of persistence or one-period lagged macroeconomic variables in the latter (Altunbas et al. 2012). In addition, the quarterly model excludes bank profitability because of the unavailability of quarterly profitability data. Treatment of stock variables (bank specific characteristics and regulatory indices) remains unchanged in the two specifications.

4. Data and Estimation Issues

This paper samples ten economies in Asia with a sizeable and relatively developed banking sector, namely, the PRC; Hong Kong, China; India; Indonesia; the Republic of Korea; Malaysia; the Philippines; Singapore; Taipei,China; and Thailand. The panel is unbalanced due to different data availability for the chosen economies. The largest panel for annual data runs from 2000 to 2011. For quarterly data, the longest period is from 2003Q1 to 2011Q4. There are no quarterly data available for Hong Kong, China and India, therefore they are not included in the quarterly model.

This paper uses four measures of bank risk.[10] Idiosyncratic bank risk, $br1_i$, is calculated as follows: $br1_i = \sum_{t=1}^{m} \varepsilon_{i,t}^2 / m$, where $\varepsilon_{i,t}$ is the bank specific residual derived from an estimated CAPM. m is the number of daily trading days in a year (for the annual model) or quarter (for the quarterly model). As the variable name suggests, this indicator measures the risk specific to a bank after accounting for the broad market effects. Daily individual bank return index and daily stock market return index for each economy used in the CAPM estimation are obtained from Datastream.

The z-score, $br2_i$, which measures bank soundness in terms of insolvency risk or distance to default is calculated on the basis of a three-year moving average (De Nicolo 2000; Ivičić et al. 2008; Maechler et al. 2007). In essence, the z-score measures the lower bound in which expected returns need to drop in order to exhaust the bank's equity. So a higher level of z corresponds to a greater distance to equity depletion and therefore greater bank stability. Data used to calculate the score are obtained from Bankscope.

Two other measures of bank risk are accounting data obtained from Bankscope. The ratio of non-performing loans to total loans, $br3_i$, is taken as a proxy of credit risk in a bank's portfolio. Since some proportion of non-performing loans will result in losses for a bank, a higher ratio indicates a higher level of bank risk. The other measure is a simple standard deviation of asset returns, $br4_i$, which measures the volatility of return on bank assets. We use a three-year rolling time window to compute the standard deviation.

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9 The coefficient of the lagged bank risk may be viewed as the speed of convergence to equilibrium. A statistically significant value of zero implies that bank risk is characterized by a high speed of adjustment; while a value of one means that the adjustment is very slow. Values between 0 and 1 suggest that risk persists, but will eventually return to its mean.

10 See the appendix for detailed derivations of the bank risk variables and sources of data.

In terms of interest rate gaps, we use two measures as per Altunbas et al. (2010) in calculating the deviation of policy rate from some benchmark levels.[11] The first known as the Taylor gap ($ig1$) is the difference between the actual nominal interest rates and that generated from a Taylor-type equation.[12] For data comprehensiveness, we use the 3-month money market or interbank rate from the International Monetary Fund's *International Financial Statistics* (IFS) as a proxy of the policy rate. (The change in interest rates, ir_j, included in the specification is therefore the first difference of this series). The second measure, for simplicity, called the natural gap ($ig2$) is the difference between the real short-term interest rates and the natural interest rates calculated using the Hodrick-Prescott filter. The first measure is more of an ad-hoc rule. And since not all central banks of the sampled economies follow the Taylor type rule, we also rely on the estimates that generate natural rates, which remove the long-run trend of the interest rate series.

Raw data for the macro variables—growth rate (gr); yield curve (yc); exchange rate volatility (er); changes in stock market index (sm); and bank credit to GDP (cg)—are obtained from the IFS, Datastream, Bloomberg, and CEIC, depending on economies and availability. Growth rate is obtained directly from the IFS as period-on-period change in the GDP volume index. Yield curve measures the difference between the 10-year government bond yield and the 3-month treasury bill rate. Changes in stock market index are the first differences in the natural log of the index. Exchange rate volatility is calculated as the standard deviation of the first differences of the daily natural log exchange rate. Bank credit to GDP is the ratio of bank lending to the private sector over nominal GDP.

For the bank specific variables: size, sz_i, is the log of total assets (Kashyap and Stein 1995, 2000); liquidity, lq_i, is the liquidity to-total asset ratio (Stein 1998); capitalization, cp_i, is the capital to asset ratio (Kishan and Opiela 2000; Van den Heuvel 2002). In the annual model, profitability, pr_i, as measured by the return on equity is also included. These are data obtained directly from Bankscope (for the annual model), and Bloomberg (for quarterly model), except the variable, lq in the quarterly model, where it is calculated based on the raw data obtained from Bloomberg.[13]

Table 1 provides descriptive statistics for the variables used. Note the sample shows a large variability as measured by bank size, which implies that the sample includes both large and small banks that reduce the potential of selection bias. Table 2 provides the descriptive statistics of the data sorted by economy. The average size of bank (as measured by total assets) is largest in the PRC and lowest in Taipei,China. In general, the banks included in the sample cover roughly the top 85% of the banking sector (publically listed) in each of the countries.[14]

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[11] See the appendix for detailed estimations of the interest rate gaps.

[12] The Taylor equation estimated is $ti = c + 1.5(\pi - \pi^*) + 0.5y$, where measures the inflation rate, π^* measures the average inflation rate from 2000Q1, y measures the output gap, and c is the sum of the average inflation and real GDP growth since 2000Q1. See the appendix for more details.

[13] See the appendix for the derivation.

[14] According to Datastream, the stock market data typically cover the top 85% of firms in each industry group.

This paper uses the dynamic general method of moments (GMM) to estimate Equations (1) and (2) (Arellano and Bond 1991; Arellano and Bover 1995; Blundell and Bond 1998). The dynamic modeling approach has been used in various studies, such as, measuring economic growth convergence (Caselli, Esquivel, and Lefort 1996), estimating labor demand (Blundell and Bond 1998), estimating the relationship between financial intermediary development and economic growth (Beck, Levine, and Loayza 2000), and more recently in the literature dealing with bank risk-taking channel (Altunbas et al. 2010; Delis and Kouretas 2011).

One possible identification challenge of testing whether monetary policy affects bank risk is that there could be, in principle, a two-way relationship between monetary policy and bank risk. If financial stability is an important goal of monetary policy, then interest rate setting is also affected by overall changes in financial fragility and bank risk. Ioannidou et al. (2009) and Jimenez et al. (2008), using data for Bolivian and Spanish banks, respectively, find that bank risk-taking and interest rates are endogenous in the economies. That said, for the economies studied in this paper, the objective of monetary policy is generally focused on achieving stable prices or the dual mandate of stable prices and sustainable growth. We are unaware that maintaining low bank risk is an explicit monetary policy objective in any of the economies. Hence, the issue of monetary policy being endogenous to bank risk is less of a problem.

Another possible source of endogeneity is unobserved heterogeneity, whereby there are factors unobservable to researchers that can affect both bank risk and the explanatory variables. Econometrically, unobservable heterogeneity exists in the baseline equation if $E\left(\eta_i \middle| \mathbb{X}_{i,t}\right) \neq 0,$ where η_i is the individual bank specific fixed effect, and $\mathbb{X}_{i,t}$ is the vector of explanatory variables. Given the greater co-movements of macroeconomic data, the problem of unobservable heterogeneity is likely going to be an issue, which means that the OLS estimators are both biased and inconsistent. To address this and given the availability of panel data, fixed-effects estimation is the solution. Still, fixed-effects estimation is biased if past values of the dependent variable are used as an explanatory variable—if there is dynamic endogeneity, where past values of the dependent variable are correlated with the current values of other explanatory variables.[15]

Therefore, to obtain consistent and unbiased estimates in the presence of unobserved and dynamic endogeneity, a dynamic GMM panel estimator is used. This method uses the dynamic endogeneity inherent in the explanatory variables, that is, lags of endogenous variables as instruments. In the difference GMM estimator, lagged levels of endogenous variables are used as instruments for the difference equation. Arellano and Bover (1995) and Blundell and Bond (1998) show that the difference GMM estimator can be improved by also including equations in levels in the estimation procedure or what is known as the system GMM estimator. System GMM estimator is an improvement over the difference estimator in two main ways. First, Beck, Levine, and Loayza (2000) note that if the original model is conceptually in levels, differencing may attenuate the signal-to-noise ratio and reduce the power of statistical inferences. Second, Arellano and Bover (1995) suggest that variables in levels may be weak instruments for first-differenced equations. Thus, in system GMM estimation, difference equations are complimented with

[15] See Wooldridge (2001) for more details on the nature of the bias.

equations in levels, wherein lagged levels of endogenous variables as well as lags of first-differenced variables are used as instruments for difference and level equations, respectively.

In the estimations, besides the interest rate variables (ir and ig), we treat as endogenous the following variables: yield curve (yc), lagged bank return on equity (pr), lagged bank liquidity (liq), and lagged bank capitalization (cp). For annual model, therefore, the second to fifth lags of these variables are used as instruments.[16] All the regulatory indices and bank size are treated as predetermined variables (Delis and Kouretas 2011). This implies that banks already have information on the size and regulatory environment before making their decisions. This suggests that the first to fifth lags of these variables are included as instruments. For the quarterly model, since first lag of endogenous variables is included in the estimation, we employ as instruments third to fifth lags of endogenous variable and second to fifth lags of predetermined variables.

5. Results

5.1 Annual Model

Table 3 and 4 present the results of the annual model with the two measures of interest rate gaps, the Taylor gap ($ig1$) and the natural gap ($ig2$), respectively. The different columns indicate the different bank risk variables: idiosyncratic bank risk ($br1$); ratio of non-performing loans to total loans ($br2$); z-score ($br3$); and volatility of return on assets ($br4$).

Several key results can be gleaned from Table 3. First, the significant lagged dependent variables show that bank risk is highly persistent (first four rows). This result also lends support to the choice of a dynamic model. Given that the coefficient is less than one, this implies that the risk, while it persists, eventually returns to its equilibrium.[17]

Second, changes in short-term interest rates (ir) do not have a significant impact on most measures of bank risk, except in the case of the ratio of non-performing loans to total loans ($br2$), where the coefficient is positive. A positive coefficient is expected, as a rise in interest rates increases the likelihood of loans turning non-performing. Given that a non-performing loan is an ex-post measure of credit risk, it is likely to capture the effects from the balance sheet channel—higher interest rates reduce the creditworthiness of borrowers, and thus increase the proportion of non-performing loans. This is consistent with the findings of Jimenez et al. (2008) and Altunbas et al. (2010) that higher rates make loan repayment harder by increasing the interest burden of borrowers, which in turn, lead to higher loan default rates.

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16 The lags used refer to both the difference and levels equations. Given the limited number of observations, especially in the annual model, we restrict the number of instruments to avoid falling into the trap of "too many instruments" as pointed out by Roodman (2006).

17 We also included higher lags of the bank risk variables, but found no evidence of persistence beyond the first year.

Third, the coefficient of the main variable of interest, the Taylor gap (*ig*1) is significant and has the expected negative sign in all bank risk variables. (Since the z-score as a measure of bank risk is interpreted as the opposite of other measures, the correct a priori sign is positive). This means that higher interest rates above the Taylor-rule benchmark decreases bank risk or, conversely, lower interest rates below the benchmark increases bank risk—supporting the phenomenon that "too low interest rates" can be harmful.[18] In terms of magnitude, if interest rates are 100-basis point lower than the benchmark, then, for instance, the idiosyncratic bank risk is expected to increase by 0.01%, and the probability of bank default as measured by the z-score by 0.02%.

Fourth, of the four bank specific variables, only profitability (*pr*) as measured by return on equity is statistically significant and correctly negatively signed in two measures of bank risk—idiosyncratic risk (*br*1) and volatility of the return on assets (*br*4). This implies that more profitable banks have a lower riskiness measure. On the other hand, both bank size (*sz*) and bank liquidity (*lq*) are appropriately negatively signed in each case of idiosyncratic bank risk measure (*br*1) and ratio of non-performing loans to total loans (*br*2), respectively.

Fifth, in terms of accounting for the expectations channel, the output growth rate (*gr*) is statistically significant and correctly signed in three measures of bank risk— idiosyncratic risk (*br1*), ratio of non-performing loans to total loans (*br*2) and z-score (*br*3). Better economic conditions increase the profitability or net present values of projects, which reduce the overall credit risk of banks (Kashyap et al. 1993; Altunbas et. al. 2010). This result is consistent with the findings of Gambacorta (2009) and Altunbas et al. (2010). The steepness of the yield curve (*yc*), however, has a significant negative impact only for idiosyncratic bank risk (*br*1).

Sixth, there is some evidence to suggest that financial deepening reduces bank risk. Bank credit to GDP (*cg*) is statistically significant and appropriately signed in the case of *br*3 and *br*4.

Seventh, there is also limited evidence to suggest that exchange rate volatility raises bank risk, and that better stock market performance reduces bank risk. Both exchange rate volatility (*er*) and changes in broad stock market index (*sm*) are statistically significant and appropriately signed in the case of *br*2.

Eighth, there is also some evidence to suggest that regulatory environment ameliorates bank risk-taking. Greater capital stringency is statistically significant and reduces bank risk in the case of *br*1 and *br*2.

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[18] Taken together with the preceding result, it is clear that the interest gap variable is a better measure of risk-taking channel. Take for instance the current situation where interest rates in emerging economies are not close zero-bound (unlike the case in many advanced economies); in this environment, a fall in the interest rates does not necessarily lead to more risk-taking. Yet, if interest rates are "too low" (lower than a benchmark), we find a significant evidence of more risk-taking by banks which is robust to different measures of bank-risk. This overall result also holds when Hong Kong, China and Singapore are excluded from the sample. Both these economies do not directly use interest rates as their main policy instrument.

The validity and consistency of the results is confirmed by the tests for the second-order serial correlation and instrument exogeneity (the Hansen test). The null hypothesis of no second-order serial correlation cannot be rejected in each of the bank risk specification. Similarly, the null of instrument exogeneity cannot be rejected implying that the instruments used are valid. Time and economy dummies are also jointly significant in most specifications.

As robustness checks, we also use an alternate measure of interest rate gap based on the natural real interest rates (Table 4). By and large, the results are consistent with the findings in Table 3. There is strong evidence to support the specification of a dynamic model—the lagged dependent variable is always statistically significant. "Too low" interest rates ($ig2$) contribute to greater risk-taking in all measures of bank risk, not lower interest rates per se (ir).[19] Bank profitability (pr) seems to be a more important bank specific variable that affects bank risk-taking compared to liquidity and size. Likewise, growth rate (gr) rather than slope of the yield curve (yc) is a more important determinant of economic activity or indirectly profitability of projects that affects credit risk of banks and hence bank risk-taking. Also exchange rate volatility and changes in stock market index are only significant for $br2$. Similarly, regulatory environment, particularly capital stringency appears to be an important determinant. However, supervisory power is also significant and appropriately signed for *br2*. One result that differs slightly between the two measures of interest rate gap, is the more mixed evidence of financial deepening in reducing bank risk using the natural gap measure. Finally, the specification tests on the absence of second-order serial correlation and instrument exogeneity are passed, implying that the parameter estimates are consistent and valid.

5.2 Quarterly Model

The effects of short-term interest rate on bank's risk tolerance can be very brisk, and hence the use of annual data to study the risk-taking channel has been contested by Altunbas et al. (2010). Furthermore, Jimenez et al. (2008) find interest rates could affect bank risk in two opposing ways. In the short term, low interest rates, by reducing the probability of default on existing loans, leads to a fall in the risk of bank's portfolio. Over time, however, banks start to undertake more risky operations and lending to projects with a higher probability of default. To further investigate this relationship and to distinguish between any likely short- and longer-term effects that might be missing in the annual specification, this paper also estimates a model with quarterly data. In the quarterly model, idiosyncratic risk is the bank risk used because of data availability.

Indeed, the quarterly model provides more nuanced results (Table 5, Column 1). The contemporaneous Taylor gap ($ig1$) is statistically significant and positive, meaning if interest rates are higher than benchmark, bank risk increases, or conversely, if interest rates are lower than benchmark, bank risk decreases. This runs contrary to what is expected of an operating risk-taking channel. That said, lagged $ig1$ has the a priori sign that supports the risk-taking channel (as in the annual model). In fact, the combined magnitude of the contemporaneous and lagged $ig1$ is still negative, implying overall the

[19] As in Table 3, changes in interest rates (ir) are only statistically significant when bank risk is measured as non-performing loans to total loans ($br2$).

risk-taking channel is still operating and the effects of "too low" interest rates is likely to dominate.

As in the annual model, the coefficient of exchange rate volatility, which captures market risk, is positive and significant, implying that countries with more volatility in the exchange rate tend to have a more risky banking sector. The other result that is statistically significant is the adverse impact of financial deepening on bank risk—the contemporaneous coefficient of credit to GDP is positive. Note, however, this result is not observed in the annual model when the bank risk is measured by the idiosyncratic risk. Again as a robustness check, the other measure of interest rate gap ($ig2$) is used (Column 2). The results are likewise similar to that of the Taylor gap.

6. Conclusion

Recent studies have found a significant negative relationship between interest rates and bank risk-taking in the US and the euro area. This paper explores the impact of low interest rates on bank risk-taking in selected Asian economies with a relatively developed banking sector. Using a recent line of empirical and theoretical literature, and a panel dataset of publicly listed banks, we find evidence of an operational bank risk-taking channel. In particular, we find that when interest rates are "too low"—lower than a benchmark—bank risk increases. This result is robust to other factors, which might have influenced banks' risk-taking behavior, namely, general economic conditions, bank specific characteristics, economy specific market risk, and the regulatory environment.

The results of this paper point to three main policy considerations. First, the conduct of monetary policy, in particular, the setting of interest rates does not seem neutral to the financial stability goal. It is therefore encouraging to see work done to incorporate financial stability considerations into macroeconomic models, especially in the context of monetary policy formulation (Agur and Demertzis 2010; Curdia and Woodford 2011). Second, more importantly, this suggests a greater role of macroprudential policy focusing on possible excesses in finance and its related areas, even during periods of benign inflation rate when interest rates are usually kept low. In particular, the capital stringency requirement seems to pose a limiting check on bank risk. Finally, as the Asian economies are not well insulated from the loose monetary policy of the advanced economies, it is important for policy makers to allow the exchange rates to move more flexibly, especially in level terms. There will be periods when policy makers—by allowing interest rates to fall too low—not only fuel the risk-taking channel, but may also interfere with the pursuit of domestic stabilization goals.

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Appendix. Data Description, Source, and Transformation

Variable	Data, Source and Period	Transformation/Remarks
Bank risk		
Idiosyncratic risk, $br1$	Daily total return index of bank *i*; index number. Source: Datastream Daily total market return index of economy *j*, index number. Source: Datastream, TOTMK...(RI). Period (annual model):* 2000 to 2011, except the People's Republic of China (PRC) from 2004; and India and Taipei,China from 2002.	Idiosyncratic risk is calculated as: $br1_i = \sum_{t=1}^{m} \varepsilon_{i,t}^2 / m,$ where m is the number of trading days in a year or a quarter depending on the model used, and $\varepsilon_{i,t}$ is the residual of the following estimated capital asset pricing model: $r_{i,j,t} - \overline{r_{i,J}} = \beta_{i,t}(r_{m,j,t} - \overline{r_{m,J}}) + \varepsilon_{i,t}$ where $r_{i,j,t}$ is the daily return of stock price index of bank *i* at time t, $\overline{r_{i,J}}$ is the average historical daily return of stock price index of bank *i*, $r_{m,j,t}$ is the daily return of stock market price index of economy *j*, and $\overline{r_{m,J}}$ is the average historical daily return of the stock market price index of economy *j*. Note, all daily returns are first transformed into natural log before estimation.
Non-performing loans to total loans, $br2$ (%)	Non-performing loans to total loans, %. Source: Consolidated bank balance sheet, universal bank model, Bankscope. Period: 2000 to 2011, except the PRC from 2004; the Republic of Korea from 2001; and India and Taipei,China from 2002.	
Z-score, $br3$	Equity capital to total assets of bank *i*, %. Source: Consolidated bank balance sheet, universal bank model, Bankscope. Return on assets of bank *i*, %. Source: Consolidated bank balance sheet, universal bank model, Bankscope.	The z-score is calculated as: $br3_{i,t} = z_{i,t} = \frac{ra_{i,t} + ek_{i,t}}{\sigma(ra)_{i,t}}$ where $ra_{i,t}$ is the return on asset and $ek_{i,t}$ the ratio of equity capital to total assets for bank *i*. $\sigma(ra)_{i,t}$ is the standard deviation of $ra_{i,t}$ computed using data for

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
	Period: 2000 to 2011, except the PRC and Taipei,China from 2004; and India from 2003.	period t, t-1 and t-2, that is, a three-year rolling window.
Volatility of return on assets, $br4$	Return on assets of bank i, %. Source: Consolidated bank balance sheet, universal bank model, Bankscope. Period: 2000 to 2011, except the PRC from 2004; Indonesia, Malaysia, the Philippines, Thailand from 2001; and India and Taipei,China from 2002.	Standard deviation of the return on assets, computed over a three year rolling window (over time period t, t-1 and t-2).
Interest rate variables Change in short-term interest rate, ir_t, (%)	3-month money market rate or 3-month interbank deposit rate; end of period, %. Source: IFS, 60B..ZF For India: Call money rate (%) Source: Reserve Bank of India For Taipei,China: Policy rate: discount rate (%). Source: CEIC, 45972101 (WMAD) Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Change in short-term interest rate is simply: $ir_t = i_t - i_{t-1}$, where i is the 3-month money market or interbank rate. For the annual model, i_t is an average of monthly rates.
Taylor rule gap, $ig1$ (%)	3-month money market rate/3-month interbank deposit rate; end of period, %. Source: IFS, 60B..ZF Annual CPI % change (quarterly frequency, %. Source: IFS, 64..XZF GDP volume index, 2005=100. Source: IFS, 99BVPZF For Taipei,China: Inflation: Consumer price index, year-on-year % change. Source: CEIC, 249101701 (WIGEBAAA) Gross domestic product, 2006p, national currency.	Quarterly Model: *ig*1 is computed as the difference between the actual nominal interest rate at end-period and that generated by a Taylor-rule as follows: $ti = c + 1.5(\pi - \pi^*) + 0.5y$, where π is the quarter-on-quarter inflation rate, and y is the measure of output gap created using Hodrick-Prescott filter (with a smoothing parameter $\lambda = 1600$). The constant c is defined as the sum of the average inflation and real GDP growth since 2000Q1. π^* is computed as the average level of the inflation rate since 2000Q1.

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
	Source: CEIC, 261788101 (WARKAA) GDP deflator, index number. Source: CEIC, 261820301 (WARRAA) GDP volume index = Nominal GDP/GDP deflator (adjusted to ensure that 2005 is base year). Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Annual Model: $ig1$ for the annual model is calculated as the average of quarterly $ig1$.
Natural rate gap, $ig2$ (%)	3-month money market rate/3 month interbank deposit rate; end of period, %. Source: IFS, 60B..ZF. Annual CPI % change, quarterly frequency, %. Source: IFS, 64..XZF. Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Quarterly Model: Real interest rate is computed using the Fisher equation: $r_t = i_t - \pi_t$, where r_t is the real interest rate, i_t the nominal interest rate and π_t is annual inflation rate (quarter–on-quarter). $ig2$ is computed as the difference between the above real interest rates and the natural rate calculated using the Hodrick-Prescott filter (with a smoothing parameter $\lambda = 1600$). Annual model: $ig2$ for the annual model is calculated as the average of quarterly $ig2$.
Macroeconomic variables		
Real GDP growth rate, gr (%)	Quarter: GDP volume index, quarter-on-quarter % change. (%) Source: IFS, 99BPXZF. Annual: GDP volume index, year-on-year % change. (%) Source: IFS, 99BPXZF For Taipei,China: Real GDP, y-o-y % change, quarterly series. Source: CEIC, 261981801 (WARKAB). Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
Yield curve, yc (%)	Malaysia, the Philippines, Thailand, Singapore: 3 month T-bill rate, end-period, % Source: IFS, 60C..ZF The People's Republic of China: Central Bank Bil, middle-rate, end-period, %. Source: Datastream, CHBNK3M. Hong Kong, China: Exchange fund bills (3 months), end-period, %. Source: Datastream, HKEFB3M. India: 91-day T-bill rate, end-period, %. Source: Datastream, INTB91D. Indonesia: SBI 90-day middle rate, end-period, %. Source: Datastream, IDSB90. The Republic of Korea: Yield on CD-91-day, end-period, %. Source: Datastream, KOCD91D. Taipei,China: T-bill rate 91-day, end-period, %. Source: CEIC, 45984701 (WMPGA). India, the Republic of Korea, Malaysia, the Philippines, Singapore, Thailand: 10-year government bond yield, end-period, %. Source: IFS, 61…ZF. The People's Republic of China: 10-year government bond yield, end-period, %. Source: Bloomberg, GCNY10YR. Hong Kong, China: HK Exchange Fund note, 10-year, end-period, %. Source: Datastream, HKEFN10. Indonesia: 10-year government bond yield, end-period, %. Source: Bloomberg, GIDN10YR. Taipei,China: Government bond yield, 10-year, end-period, %.	Quarterly Model: yc is the difference between the 10 year government bond yield and the 3-month T-bill rate. Annual Model: The average of quarterly yield curve is used as a measure of the steepness of yield curve for the annual model.

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
	Source: CEIC, 45985701 (WMUAE). Period (annual model): From 2000 to 2011, except the PRC from 2005; India and Taipei,China from 2002; and Indonesia from 2003.	
Bank credit to GDP ratio, cg (%)	For all countries: Bank's claim on private sector, national currency, billion. Source: IFS, 22D..ZF. GDP, national currency, billion. Source: IFS, 99B..ZF The PRC: GDP, national currency, billion. Source: Datastream, CHGDP...A. Taipei,China: Bank Credit: Loans and investments of financial institutions, national currency, billion. Source: Datastream, TWBANKLPA. GDP, national currency, billion. Source: Datastream, TWGDP...B. Period (annual model): 2000 to 2011, except the PRC from 2004; India and Taipei,China from 2002; and Indonesia, Malaysia, Philippines and Thailand from 2001.	Ratio of bank credit to GDP using quarterly credit and quarterly GDP, and annual credit and annual GDP for the quarterly and annual model, respectively.
Exchange rate volatility, er	Daily nominal exchange rate, daily average (USD/national currency). Source: Bloomberg Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	er is calculated as the standard deviation of the first difference in the natural log of the daily exchange rate: $er = \ln e_t - \ln e_{t-1}$, where e is the daily exchange rate. Quarterly exchange rate volatility is therefore calculated based on the daily rate in each quarter; and annual volatility, daily rate in each year.
Change in broad stock market index, *sm*	Share price: end period, index. Source: IFS, 62.EPZF	Calculated as (annual/quarterly) changes in the natural log of the broad stock market index.

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
	Taipei,China: Equity Market Index: TAIEX Capitalization Weighted, end-month, index number. Source: CEIC, 46107601 (WZJA). Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	
Bank specific variables		
Total assets (log), *sz* (Million USD)	Annual: Total Assets, USD million. Source: Consolidated bank balance sheets, universal bank model, Bankscope. Quarter: Total Assets, USD million. Source: Consolidated bank balance sheets, Bloomberg. Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	In cases where accounting standard had changed from local Generally Accepted Accounting Principles (GAAP) to International Financial Reporting Standards (IFRS), information from both C* (local GAAP) and C2 (IFRS) accounts was used to obtain historical series.
Profitability (return on equity), *pr* (%)	Annual: Return on Average Equity (ROAE), %. Source: Consolidated bank balance sheets, universal bank model, Bankscope. Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	As above.
Liquidity (% of total assets), *lq* (%)	Annual: Liquid assets/short-term funding, % Source: Consolidated bank balance sheets, universal bank model, Bankscope. Quarter, USD million: Cash and bank balance. Interbank assets. Short-term investment. Total Assets. Source: Bloomberg	For annual data, when accounting standards had changed from local GAAP to IFRS, information from both C* (local GAAP) and C2 (IFRS) accounts was used to obtain historical series. For quarterly model: Liquidity = (Cash and bank balance + interbank assets + short term investments)/Total Assets

Appendix. *Continued*

Variable	Data, Source and Period	Transformation/Remarks
	Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	
Capitalization (% of total assets), *cp* (%)	Equity capital as a percentage of total assets Annual: Equity/total assets, %. Source: Consolidated bank balance sheets, universal bank model, Bankscope. Quarter: Total capital ratio. (%) Source: Bloomberg Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Capitalization is the ratio of equity capital to total assets. For annual data, when accounting standards had changed from local GAAP to IFRS, information from both C* (local GAAP) and C2 (IFRS) accounts was used to obtain historical series. For quarterly data, total capital ratio is the ratio of total capital to total assets.
Regulatory Indexes		
Supervisory Power, *sp*	Source: Barth et al. (2013) Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Supervisory power, reflects the powers invested with the supervisory agencies to take specific actions against bank management and directors, shareholders, and bank auditors. The supervisory power index can take values between 0 and 14, with higher values denoting higher supervisory power. This variable is determined by the answers to14 survey questions. This index like the other two regulatory indexes is an annual series. To obtain the quarterly series, the value for each year is used as the value of each quarter in that particular year.
Market Discipline, *md*	Source: Barth et al. (2013) Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Market discipline reflects the degree of transparency and disclosure of accurate information to the public that the banks are forced to undertake. This index can take values between 1 and 7 (depending on answers to 7 survey questions),

Appendix. ***Continued***

Variable	Data, Source and Period	Transformation/Remarks
		again with higher values denoting higher market discipline.
Capital Stringency, *cs*	Source: Barth et. al. (-2013) Period (annual model): 2000 to 2011, except the PRC from 2004; and India and Taipei,China from 2002.	Capital stringency shows the extent of both initial and overall capital stringency. Initial capital stringency refers to the constraints on the sources of funds counted as regulatory capital, as well as whether the regulatory or supervisory authorities verify these sources. Overall capital stringency indicates whether or not provisions are made for market risk and value losses while calculating the regulatory capital. Theoretically, the capital stringency index can take values between 0 and 8 (depending on answers to 8 survey questions), with higher values indicating more stringent capital requirements.

CPI = consumer price index; GDP = gross domestic product.

Note: * All quarterly data for the People's Republic of China, Indonesia, Malaysia, the Philippines, the Republic of Korea, and Singapore are from 2004:1 to 2011:4, except the yield curve of the People's Republic of China from 2005:1. All quarterly data from Thailand and Taipei,China are from 2003:1 to 2011:4.

Table 1. Summary Statistics of the Variables used in Annual Regression, 2000–2011

Variable	No. of obs.	Mean	Std. Deviation	Min	Max
Idiosyncratic risk, *br1*	824	0.1240	0.7240	0.0000	12.3000
Non-performing loans to total loans, *br2*	778	0.0578	0.0704	0.0009	0.5781
Z-score, *br3*	734	3.7790	1.2860	-2.0380	7.8180
Volatility of returns on asset, *br4*	739	0.6315	2.7340	0.0047	43.2400
Changes in short-term interest rate, *ir*	826	-0.2245	1.8048	-13.2600	7.4900
Taylor gap, *ig1*	826	-5.7420	4.8520	-23.5900	10.5600
Natural gap, *ig2*	826	0.1140	2.3180	-7.9590	7.6720
Growth rate, *gr*	813	5.7600	3.2580	-7.2370	14.7600
Yield curve, *yc*	805	1.8119	1.2049	-0.6431	6.7590
Credit to GDP, *cg*	800	0.7519	0.3989	0.1856	2.0210
Exchange rate volatility, *er*	826	0.0014	0.0010	0.0000	0.0074
Change in stock market index, *sm*	826	0.0350	0.1239	-0.3915	0.4770
Bank size, *sz*	824	10.0900	1.7020	-0.3790	14.7100
Profitability, *pr*	824	12.0600	17.5500	-277.4000	109.2000
Liquidity, *lq*	824	22.5100	11.3600	2.1370	80.7400
Bank capitalization, *cp*	790	8.1470	3.1570	0.1600	23.7900
Supervisor index, *sp*	826	11.5387	1.3326	7.0000	14.0000
Market discipline index, *md*	820	6.8535	0.8408	5.0000	9.0000
Capital stringency index, *cs*	826	5.2142	1.5386	3.0000	8.0000

Notes: See the appendix for details of each variable. The variables in index are index numbers, while idiosyncratic risk, z-score, volatility of returns on asset, and exchange rate volatility are unit-free. All the other variables are in percent, except bank size which is the natural log of US million.

Source: Authors' calculations.

Table 2. Descriptive Statistics by Economy, 2000–2011 (mean values)

Variable	PRC	HK	IND	INO	KOR	MAL	PHI	SIN	TAP	THA
*br*1	0.0043	0.0065	0.0088	0.2230	0.0413	0.0179	0.0628	0.0100	0.0592	0.7340
*br*2	0.0150	0.0126	0.0313	0.0616	0.0164	0.0852	0.1250	0.0409	0.0124	0.1125
*br*3	4.3090	4.2500	4.2620	2.9950	3.0650	4.0860	4.1530	4.2020	3.4790	2.8390
*br*4	0.1104	0.2009	0.1420	2.7140	0.4187	0.3811	0.2858	0.1872	0.2982	1.0170
ir	0.0192	-.42998	0.1253	-1.3360	-0.1550	-0.0311	-0.4430	-0.1431	-.09774	0.0583
*ig*1	-11.650	-4.0300	-8.7800	-5.7880	-4.1940	-4.5030	-2.4540	-6.9160	-3.0480	-4.3430
*ig*2	-0.1010	-0.1710	0.7400	-0.6120	0.0874	0.0458	0.3680	0.0186	-0.0615	0.1700
gr	10.9100	4.5150	7.7560	5.4170	4.2670	5.0120	4.7130	5.9410	4.2110	3.9490
yc	1.5116	2.2253	1.3069	1.9677	1.1235	1.4977	3.5071	1.7385	0.8974	2.2588
cg	1.1850	1.5314	0.4452	0.2440	0.9406	1.1073	0.3097	1.0010	0.5378	0.9857
er	0.0004	0.0001	0.0015	0.0027	0.0028	0.0009	0.0017	0.0014	0.0012	0.0014
sm	0.0355	0.0199	0.0009	0.0775	0.0411	0.0282	0.0744	0.0153	0.0203	0.0335
sz	12.1000	10.7500	10.1500	9.2570	11.6300	9.8640	7.8210	11.5300	6.3100	9.6430
pr	18.4500	16.4800	17.2200	17.8200	10.8800	11.8700	9.9990	10.4800	6.5570	-1.7050
lq	27.3900	29.8200	10.2000	28.6100	13.8700	29.7400	29.9300	29.9500	14.9900	16.4100
cp	5.5870	8.6300	6.4590	10.5500	6.0610	8.7750	11.4900	9.6670	6.5570	7.7840
sp	10.3376	9.8261	12.2110	12.5652	10.3654	11.3448	11.3636	12.5000	13.1233	10.7273
md	6.4545	7.0000	6.7891	6.3913	7.6154	7.3362	7.0000	7.8333	6.8767	6.0454
cs	3.4415	4.6521	7.0000	5.8913	4.3461	4.0345	5.15151	5.8333	5.2192	5.2500
Number of banks	14	4	16	9	5	10	9	3	8	8
Weight of economy *i*	16.28	4.65	18.60	10.46	5.81	11.63	10.46	3.49	9.30	9.30

Notes: PRC =the People's Republic of China; HKG =Hong Kong, China; IND =India; INO =Indonesia; KOR =the Republic of Korea; MAL =Malaysia; PHI =the Philippines; SIN =Singapore; TAP =Taipei,China; and THA =Thailand. *br*1 =idiosyncratic risk, *br*2 =non-performing loans to total loans, *br*3 =z-score, *br*4 =volatility of returns on asset, *ir* =changes in short-term interest rate, *ig*1 =Taylor gap, *ig*2 =natural gap, *gr* =growth rate, *yc* =yield curve, *cg* =credit to GDP, *er* =exchange rate volatility, *sm* =change in stock market index, *sz* =bank size, *pr* =profitability, *lq* =liquidity, *cp* =bank capitalization, *sp* =supervisor index, *md* =market discipline index, and *cs* =capital stringency index. Number of banks =number of banks included from each economy. Weight of Economy *i* =number of banks (economy *i*)/total number of banks.

Source: Authors' calculations.

Table 3 Results. Annual Model with Taylor Interest Rate Gap (*ig*1) and Different Bank Risk Measures

Variable	Idiosyncratic risk, *br*1	Non-performing loans, *br*2	Z-score, *br*3	Volatility of return on assets, *br*4
L.*br1*	0.4168***			
	(0.0301)			
L.*br2*		0.7844***		
		(0.1170)		
L.*br3*			0.5588***	
			(0.0520)	
L.*br4*				0.5837***
				(0.1098)
ir	0.0217	0.0017**	0.0127	-0.0155
	(0.0180)	(0.0007)	(0.0267)	(0.0164)
ig1	-0.0122*	-0.0015***	0.0189*	-0.0123*
	(0.0070)	(0.0004)	(0.0110)	(0.0068)
gr	-0.0196**	-0.0008***	0.0223*	-0.0086
	(0.0098)	(0.0003)	(0.0131)	(0.0070)
yc	-0.0616*	-0.0029	0.0320	0.00462
	(0.0334)	(0.0025)	(0.0623)	(0.0283)
cg	0.4654	0.0315	1.3628***	-0.5137**
	(0.3168)	(0.0197)	(0.4421)	(0.2092)
er	-69.1473	2.4107*	-60.4324	-22.2689
	(41.6670)	(1.2842)	(78.6819)	(34.4077)
sm	0.0274	-0.0297*	-0.2113	-0.2938
	(0.2005)	(0.0162)	(0.4042)	(0.1989)
sz	-0.4946**	-0.0046	-0.1529	-0.3284
	(0.2343)	(0.0058)	(0.2722)	(0.2276)
L.*pr*	-0.0305***	-0.0002	0.0031	-0.0112***
	(0.0038)	(0.0001)	(0.0065)	(0.0039)
L.*lq*	0.0125	-0.0004*	-0.0092	0.0002
	(0.0123)	(0.0002)	(0.0095)	(0.0037)
L.*cp*	-0.0379	-0.0008	0.0001	-0.0112
	(0.0257)	(0.0012)	(0.0424)	(0.0228)
sp	-0.0773	-0.0023	0.0631	-0.0076
	(0.0482)	(0.0016)	(0.0542)	(0.0241)
md	-0.0903	0.0021	-0.0824	0.0248
	(0.0705)	(0.0021)	(0.0642)	(0.0479)
cs	-0.0431**	-0.0025**	0.0317	0.0020
	(0.0204)	(0.0012)	(0.0599)	(0.0290)
Constant	6.9982**	0.0529	1.8187	4.0521*
	(2.9138)	(0.0561)	(3.1848)	(2.1335)
Observations	684	660	627	632
F-statistics	85.74***	289.96***	25.88***	17.14***
AR(2)	0.478	0.214	0.703	0.144
Hansen	0.211	0.304	0.616	0.187
Wald test for economy and time effects	1.46	3.07***	2.98***	1.93**

Notes: *br*1 =idiosyncratic risk, *br*2 =non-performing loans to total loans, *br*3 =z-score, *br*4 =volatility of returns on asset, *ir* =changes in short-term interest rate, *ig*1 =Taylor gap, *ig*2 =natural gap, *gr* =growth rate, *yc* =yield curve, *cg* =credit to GDP, *er* =exchange rate volatility, *sm* =change in stock market index, *sz* =bank size, *pr* =profitability, *lq* =liquidity, *cp* =bank capitalization, *sp* =supervisor index, *md* =market discipline index, and *cs* =capital stringency index. L refers to one-period lag. F-stat and its p-value is the goodness of fit of the regression, AR(2) is the test for second-order serial correlation and Hansen is the test for over-identifying restrictions. Wald test is the test for joint significance of economy and time dummies. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Source: Authors' estimations.

Table 4 Results. Annual Model with Natural Interest Rate Gap ($ig2$) and Different Bank Risk Measures

Variable	Idiosyncratic risk, $br1$	Non-performing loans, $br2$	Z-score, $br3$	Volatility of return on assets, $br4$
L.$br1$	0.4136***			
	(.0290)			
L.$br2$		0.7840***		
		(0.1158)		
L.$br3$			0.5502***	
			(0.0569)	
L.$br4$				0.5911***
				(0.1168)
ir	0.0326**	0.0010*	0.0041	-0.0059
	(0.0152)	(0.0005)	(0.0282)	(0.0119)
$ig2$	-0.0271**	-0.0015**	0.0373*	-0.0143*
	(0.0110)	(0.0007)	(0.0193)	(0.0084)
gr	-0.0220**	-0.0007**	0.0252*	-0.0095
	(0.0106)	(0.0003)	(0.0134)	(0.0075)
yc	-0.0708*	-0.0016	0.0369	0.0146
	(0.0357)	(0.0024)	(0.0670)	(0.0233)
cg	0.5885	0.0419**	1.3108***	-0.4569**
	(0.3629)	(0.0202)	(0.4617)	(0.2075)
er	-96.4726	2.4649*	-60.0872	-20.4845
	(58.1322)	(1.2473)	(79.7011)	(31.1661)
sm	-0.0234	-0.0312*	-0.1832	-0.2849
	(0.1897)	(0.0171)	(0.4202)	(0.2009)
sz	-0.4758**	-0.0064	-0.2243	-0.3480
	(0.2224)	(0.0067)	(0.3259)	(0.2603)
L.pr	-0.0300***	-0.0001	0.0046	-0.0108***
	(0.0042)	(0.0001)	(0.0060)	(0.0038)
L.lq	0.0133	-0.0005*	-0.0108	-0.0004
	(0.0127)	(0.0002)	(0.0101)	(0.0040)
L.cp	-0.0351	-0.0009	0.0011	-0.0108
	(0.0253)	(0.0012)	(0.0482)	(0.0218)
sp	-0.0818	-0.0028*	0.0625	-0.0104
	(0.0493)	(0.0015)	(0.0539)	(0.0239)
md	-0.1024	0.0031	-0.0756	0.0208
	(0.0725)	(0.0021)	(0.0680)	(0.0463)
cs	-0.0484**	-0.0031**	0.0293	-0.0031
	(0.0236)	(0.0013)	(0.0619)	(0.0326)
Constant	6.9679**	0.0707	2.4713	4.3406*
	(2.8898)	(0.0639)	(3.6909)	(2.3629)
Observations	684	660	627	632
F-statistics	77.54***	231.39***	18.55***	14.82***
AR(2)	0.390	0.246	0.674	0.139
Hansen	0.252	0.300	0.218	0.195
Wald test for economy and time effects	1.69*	3.55***	2.88***	1.61*

Notes: $br1$ =idiosyncratic risk, $br2$ =non-performing loans to total loans, $br3$ =z-score, $br4$ =volatility of returns on asset, ir =changes in short-term interest rate, $ig1$ =Taylor gap, $ig2$ =natural gap, gr =growth rate, yc =yield curve, cg =credit to GDP, er =exchange rate volatility, sm =change in stock market index, sz =bank size, pr =profitability, lq =liquidity, cp =bank capitalization, sp =supervisor index, md =market discipline index, and cs =capital stringency index. L refers to one-period lag. F-stat and its p-value is the goodness of fit of the regression, AR(2) is the test for second-order serial correlation and Hansen is the test for over-identifying restrictions. Wald test is the test for joint significance of economy and time dummies. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Source: Authors' estimations.

Table 5 Results. Quarterly Model with Idiosyncratic Bank Risk ($br1$) as Dependent Variable and Taylor Gap ($ig1$) and Natural Gap ($ig2$)

Variable	(1)	(2)
L.br	0.9072***	0.8955***
	(0.1435)	(0.1416)
ir	-0.0473	-0.0705
	(0.0750)	(0.0888)
L.ir	-0.0160	-0.0145
	(0.0527)	(0.0535)
$ig1$	0.0158*	
	(0.0090)	
L.$ig1$	-0.0209**	
	(0.0095)	
$ig2$		0.0233*
		(0.0138)
L.$ig2$		-0.0367*
		(0.0185)
gr	0.0240	0.0245
	(0.0210)	(0.0215)
L.gr	-0.0290	-0.0288
	(0.0193)	(0.0191)
yc	-0.2126	-0.2112
	(0.1745)	(0.1698)
L.yc	0.1840	0.1845
	(0.1198)	(0.1188)
cg	0.0771*	0.0779*
	(0.0410)	(0.0423)
L.cg	-0.0641	-0.0651
	(0.0469)	(0.0436)
er	47.9185***	46.7615**
	(17.6981)	(17.9569)
L.er	-14.8894	-16.7828
	(24.4068)	(22.4340)
sm	-0.3309	-0.3119
	(0.2911)	(0.2708)
L.sm	0.0414	0.0615
	(0.1569)	(0.1456)
sz	-0.0476	-0.0339
	(0.0641)	(0.0564)
L.cp	0.0022	0.0016
	(0.0025)	(0.0026)
L.lq	0.0035	0.0039
	(0.0049)	(0.0049)
sp	-0.0303	-0.0316
	(0.0220)	(0.0227)
md	0.0304	0.0271
	(0.0311)	(0.0299)
cs	-0.0623	-0.0643
	(0.0497)	(0.0510)
Constant	0.8242	0.7471
	(0.9859)	(0.8607)
Observations	1,615	1,616
F-statistics	349.51***	293.62***

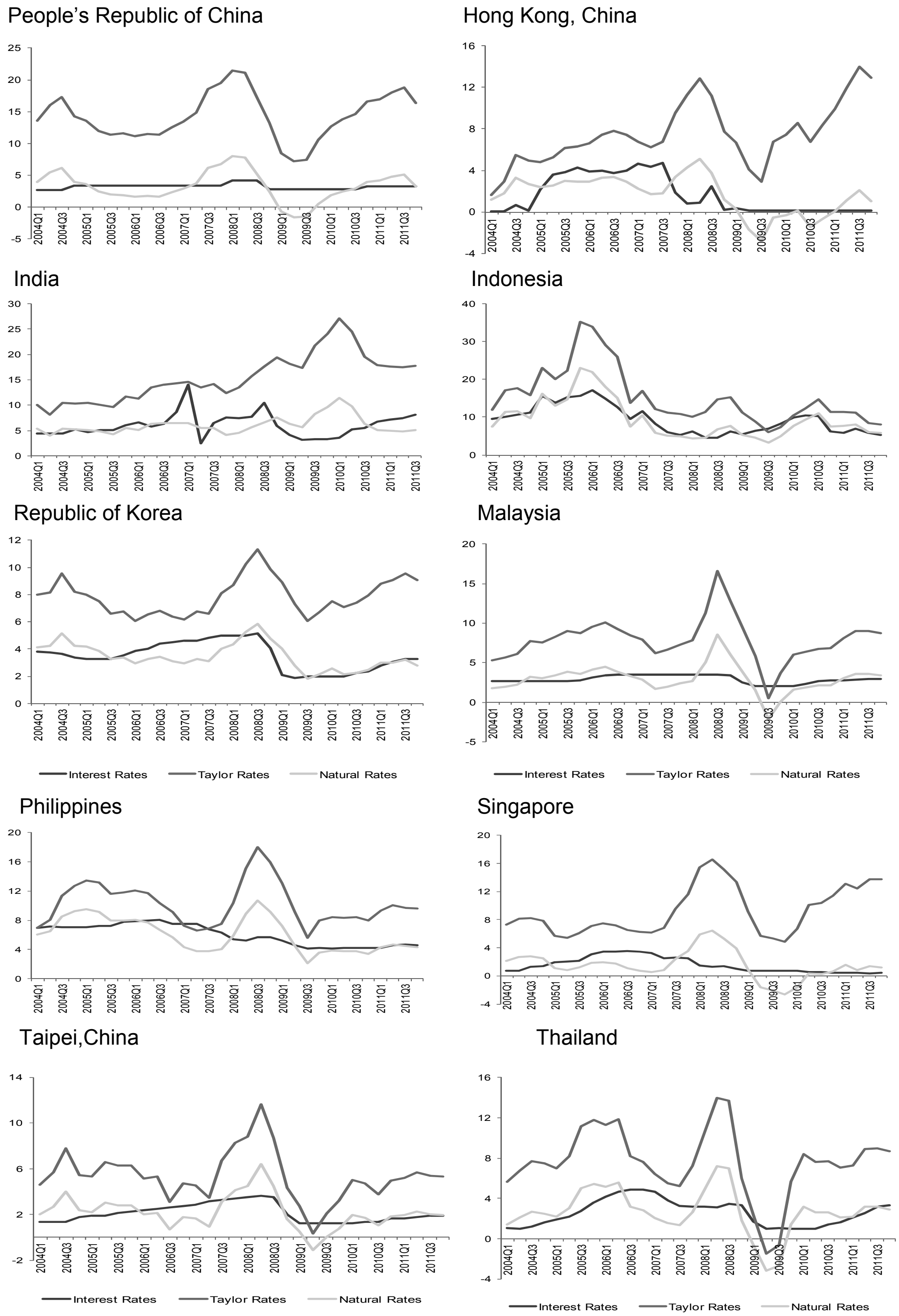
Table 5. *Continued*

Variable	**(1)**	**(2)**
AR(2)	0.276	0.276
Hansen Wald test for economy and seasonal effects	0.360 1.81*	0.457 1.79*

Notes: *br*1 =idiosyncratic risk, *ir* =changes in short-term interest rate, *ig*1 =Taylor gap, *ig*2 =natural gap, *gr* =growth rate, *yc* =yield curve, *cg* =credit to GDP, *er* =exchange rate volatility, *sm* =change in stock market index, *sz* =bank size, *lq* =liquidity, *cp* =bank capitalization, *sp* =supervisor index, *md* =market discipline index, and *cs* =capital stringency index. L refers to one-period lag. F-stat and its p-value is the goodness of fit of the regression, AR(2) is the test for second-order serial correlation and Hansen is the test for over-identifying restrictions. Wald test is the test for joint significance of economy and seasonal dummies. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, and * p<0.1.

Source: Authors' estimations.

Figure 1. Interest Rates, Taylor Rates, and Natural Rates by Economy (%)



Note: Definition and derivation of the different interest rates can be found in the appendix.

Source: Authors' calculations.

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Can Low Interest Rates be Harmful
An Assessment of the Bank Risk-Taking Channel in Asia

This paper finds that low interest rates particularly interest rates that are "too low" can be harmful to the economy. Using public listed data of Asian banks, the paper finds banks take on more risk when interest rates are kept too low–an evidence that supports the presence of the bank risk-taking channel.

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