Derivative Activities and Chinese banks' Exposures to Exchange Rate and Interest Rate Movements

Abstract

This study investigates the impact of Chinese banks' derivative activities on their exposure to exchange rate and interest rate changes. The standard Jorion (1990) model provides a weak evidence of Chinese banks' exposure to these risks. However, the exposure increases substantially when time varying exposure regressions with orthogonalised market returns are used. We also show that Chinese banks exhibit linear and nonlinear exposure to the exchange rate and interest rate fluctuations. Further analysis indicates that the use of derivatives reduces banks' foreign exchange risk, but does not affect their interest rate exposure. Thus, derivative products are more likely to be used as an integrated part of the Chinese banks' risk management systems, which could thus help to stabilise the banking system.

JEL Classification: G21; G32

Keywords: Chinese banks; Foreign exchange exposure; Interest rate exposure; Derivative activities

1. Introduction

Derivative securities have been commonly described as a double-edged sword. They can be extremely useful for risk management purposes, but they may also create additional risks, which may expose firms or even the whole economy to potential financial market disasters (see, for example, Berry 2003; Au Yong *et al.* 2009). The risk consequences of the misuse of derivatives is more pronounced in the banking industry, as large derivative related losses might cause the failure of large banks and threaten the stability of the whole banking system.

The effectiveness of derivative securities in risk management is likely to depend on the level of financial system development. Specifically, derivative products may reduce exposure in countries with sophisticated regulatory frameworks and risk management systems that deal adequately with all relevant aspects of risk. However, derivative trading may lead to excessive risk taking in countries with a weaker regulatory environment (Furman and Stiglitz 1998). Existing studies on the impact of derivative activities on the risk exposure of banks focus mainly on well-developed banking markets, such as the US (see, for example, Choi and Elyasiani 1997; Chaudhry *et al.* 2000; Hentschel and Kothari 2001), Europe and Japan (Reichert and Shyu 2003). Empirical evidence of this type is scarce in less developed banking markets[1].

Our study helps to fill this gap in the literature by investigating the impact of derivative activities on Chinese banks' exposure to exchange rate and interest rate risks. We believe that this issue is of clear interest to regulators and investors in China and around the globe, particularly following the recent changes in China's exchange rate regime. The Chinese government decided to abandon its fixed exchange rate policy and move to a managed floating exchange regime, with respect to a currency basket, in July 2005. The official currency of China, the RMB, was initially allowed to float within a narrow band of ±0.3% against the US dollar. The band was enlarged to 0.5% in 2007 and then to 1% in April 2012 (PBOC 2012). Chinese banks have responded to the regime changes by engaging more aggressively in derivative activities. In 2005, Chinese banks were alerted to the potential risks associated with the use of derivative securities and were required by the China Banking Regulatory Commission (CBRC) to enhance the risk management inherent in derivative activities (CBRC 2005). In January 2011, the CBRC introduced new derivative regulations in the revised Provisional Administrative Rules Governing Derivatives Activities of Financial

[1] The one exception is Au Yong *et al.* (2009), who examine the impact of derivative activities on the interest rate and exchange rate exposures on banks from 10 Asia-Pacific countries: Australia, Hong Kong, Japan, Malaysia, New Zealand, the Philippines, Singapore, South Korea, Taiwan and Thailand.

Institutions, adding new requirements on the scope of derivative transactions, risk management control, derivative product sale and post-sale service, etc. (CBRC 2011).

In addition to being the first to address concerns regarding the risk effect of derivative usage by Chinese banks, this study makes a number of other important contributions to the literature. First, existing studies on the risk consequences of derivative activities assume that banks' exposures to foreign exchange and interest rate risks are constant over time. However, it is commonly documented that these exposures depend on firm-specific characteristics, such as size, liquidity, growth opportunities and hedging activities (see, for example, Smith and Stulz 1985; Allayannis and Weston 2001; Dunne *et al.* 2004), which may vary considerably over time. The changes in regulatory regimes may also have a direct impact on banks' exposure. We use a GARCH-based multifactor model with time varying parameters to allow banks' exchange rate and interest rate exposures to vary over time[2]. Secondly, we argue that the capital market approach used by past empirical studies, such as Choi *et al.* (1992), Wetmore and Brick (1994) and Choi and Elyasiani (1997), only measures the bank's foreign exchange and interest rate risks over and above that of the market portfolio. To estimate the bank's total exposure to the foreign exchange rate and interest rate movements, we use orthogonalised, rather than actual, market returns to measure the time varying exposure of Chinese banks[3]. Thirdly, existing studies on banks' exposure have examined almost exclusively the linear relationship between foreign exchange rate changes and bank returns[4]. This study relaxes the linearity assumption and investigates exposure component that may be caused by the nonlinear relationships between exchange rate movements and firm's cash flows. Fourthly, we are the first to control for combined effects of the time-varying adjustments, nonlinear exposure and the market return orthogonalisation on the foreign exchange and interest rate exposure of individual banks. Finally, the time varying exposure coefficients allow us to use panel regressions to examine the determinants of banks' exposure to interest rate and foreign exchange fluctuations. In addition to their ability to overcome the small-sample size problem, panel regressions deal with the potential biases associated with ignoring the temporal dimension of the dependent and explanatory variables in the cross-sectional regressions.

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[2] A similar approach was adopted by Patro *et al.* (2002) and Agyei-Ampomah *et al.* (2013) to study the foreign exchange exposure of non-financial firms and stock indexes, respectively.

[3] Priestley and Odegaard (2007) also uses orthogonalised market returns to estimate the total exposure of non-financial firms to foreign exchange movements. However, the authors do not account for the time varying nature of the exposure nor do they allow the residuals for the model to vary over time.

[4] A few recent studies, including Bartram (2004), Muller and Verschoor (2006) and Priestley and Odegaard (2007), investigate the nonlinear foreign exchange rate exposure of nonfinancial firms.

The results suggest that Chinese banks' exposure to exchange rate and interest rate fluctuations are not constant over time. We find that the inclusion of the market portfolio returns in the standard exposure models masks a large part of banks' exposure to the exchange rate and interest rate fluctuations. Specifically, the standard Jorion (1990) model indicates that none of the sample banks is exposed to the US$/RMB or Euro/RMB exchange rate fluctuations. However, we find that by relaxing the linearity assumptions and including orthogonalised market returns in the GARCH-based multivariate model with time varying parameters all the sample banks have at least one significant yearly exposure to foreign exchange and interest rate changes. We also show that the use of derivatives reduces banks' exposure to foreign exchange risk, but does not affect their exposure to the interest rate risk. Our evidence implies that derivative products are more likely to be used as an integrated part of the banks' risk management systems, which could thus help to stabilise the banking system.

The remainder of the paper is organised as follows. Section 2 provides a brief review of the literature. Section 3 describes the Chinese banking sector, exchange rate regime and derivatives activities by financial institutions and regulations. Section 4 presents our methodology. Section 5 describes our dataset. Section 6 reports the empirical findings and Section 7 concludes.

2. Brief review of the literature

The liberalisation of financial markets has helped banks to expand their customer base to take advantage of profit opportunities in foreign markets. Yet, the continued globalisation of capital flows has increased banks' exposure to financial risks. Several analytical studies suggest that banks should exhibit exposure to both exchange rate and interest rate movements. Banks should exhibit a significant exposure to the exchange rate risk as the value of their future cash flows is affected directly or indirectly by the exchange rate movements (see, for example, Chamberlain *et al.* 1997; Martin and Mauer 2003). The direct exposure involves the impact of foreign exchange movements on the banks' foreign currency-dominated assets or liabilities structure, off-balance-sheet exposure and non-asset-based foreign activities. The indirect exposure arises from the impact of foreign exchange movements on the banks' competitiveness. Even a pure domestic bank may be exposed to currency fluctuations through the exposures of its customers, suppliers, and investors (see, for example, Hodder 1982; Choi 1986; Madura 2000). Interest rate risk refers to the effect of interest rate changes on the rate-earning assets and rate-paying liabilities (see, for example, Saha *et al.* 1999). It is, therefore, an inherent part of the asset transformation function and should have a significant influence on banks' stock returns.

Prior evidence on the exchange rate sensitivity of banks' stock returns is largely mixed. Choi *et al.* (1992) and Chamberlain *et al.* (1997) fail to find a strong association between banks' stock returns and foreign exchange fluctuations, while Choi and Elyasiani (1997) and Martin (2000) find that the majority of their sample banks are exposed to foreign exchange risk. Studies on the interest rate exposure of banks are also inconclusive. Several studies, including Chance and Lane (1980), Lloyd and Shick (1977), English (2002), Maes (2004), show that the movement of banks' stock returns are weakly influenced by interest rate changes. Others, however, observe a strong negative association between bank equity returns and changes in interest rate (see, for instance, Lynge and Zumwalt 1980; Flannery and James 1984; Schott and Peterson 1986; Bae 1990; Staikouras 2003).

A number of explanations have been advanced to account for the mixed evidence on the relationship between banks' stock returns and their foreign exchange and interest rate exposures. Bartram (2004) argues that one reason for the weak relationship in previous studies may be related to the use of foreign exchange rate indices as exposure estimates. He claims that currencies indices may result in a biased exposure, as the weighting of the different currencies in these indices is not representative of individual firms. He also argues that the diversification effects associated with aggregating currencies into indices may lead to lower exposure estimates relative to those produced using individual currencies. Fraser and Pantzaliz (2004) provide evidence that the exposure of US multinationals to foreign exchange risk is sensitive to the foreign exchange index used in the exposure regression. Specifically, they show that 5.5%, 8.7% and 12.6% of their 310 sample firms exhibit significant exposure to the Major Currency (MAJCUR) index, firm-specific exchange rate index and the Federal Reserve Board's currency risk index, respectively.

Priestley and Odegaard (2007) argue that since the market portfolio is also exposed to the foreign exchange fluctuations, the inclusion of market returns in the exposure regression may cause spurious relationship between industry returns and currency movements. They show that the US industry exposure to the Japanese Yen (JP¥) increases from 10.34% to 27.58% when orthogonalised rather than actual market returns are used in the exposure regressions. Agyei-Ampomah *et al.* (2013) show that the overall number of UK non-financial firms exposed to at least one of the three major currencies (US$, Euro or JP¥) increases from 30.50% to 52.8% following the orthogonalisation of market returns.

Despite the widely held view that the firms' exposure to foreign exchange fluctuations may be nonlinear (see, for example, Ware and Winter 1988; Sercu and Uppal 1995), most of the existing empirical literature assumes a linear relationship between cash flows and foreign exchange rates (Bartram 2004). The linear exposure rises from firms' standard foreign currency payables and receivables, whereas nonlinearities are related to the firms' reactions and adjustments to exchange rate changes. Specifically, profits are likely to be a nonlinear function of exchange rate when production, imports and exports decisions are flexible (Ware and Winter 1988). For example, while the appreciation of a home currency increases the cost of exports, the nonlinearities arising from sourcing inputs from abroad may slow down the effect of a unit appreciation on the cash flows (Priestley and Odegaard 2007). It has been suggested that while existing risk management strategies may reduce some of the linear exposure, the nonlinearity issues are rarely considered by corporations when designing their hedging strategies (Bodnar and Gebhardt 1999; Bodnar *et al.* 1998; Bartram 2004). This implies that the nonlinear exposure may be more pronounced empirically than the linear exposure. Consistent with this view, many recent studies show that the exposure of nonfinancial firms to foreign exchange risk increases significantly when the linearity assumption is relaxed (see, for example, Bartram 2004; Muller and Verschoor 2006; Priestley and Odegaard 2007).

It has also been widely suggested that banks' exposure to foreign exchange and interest rate fluctuations may depend on whether they use derivatives for hedging or speculation purposes (Au Yong *et al.* 2009). Hirtle (1997) shows that the use of derivatives plays a significant role in reducing banks' exposure to the interest rate risk. Choi and Elyasiani (1997), however, find that the use of derivatives increases banks' exposure to foreign exchange fluctuations beyond the level reflected in their traditional financial statement exposures. Chaudhry *et al.* (2000) find that options increase US banks' exposure, but swaps reduce it. Similar results are reported by Reichert and Shyu (2003) in the case of Japanese banks. Finally, several studies, including, Dumas and Solnik (1995), De Santis and Gerard (1998) and Patro *et al.* (2002), show that the exchange rate exposure of equity indices is not constant over time and that exposure is likely to be price only when time-variation is allowed.

In addition to being the first to investigate the impact of derivative uses on the Chinese banks' exposure to foreign exchange and interest rate risks, this study introduces a number of important methodological innovations. It accounts for the individual and combined effects of the time-varying adjustments, nonlinear exposure and the market return orthogonalisation on the foreign exchange and interest rate exposure of individual banks. It also uses panel regressions to overcome the small-sample problem and capture the temporal dimension of the dependent and explanatory variables when investigating the determinants of banks' risk exposures.

3. Chinese banks and their derivative activities

This section provides a brief overview of the Chinese banking sector, foreign exchange policy and derivatives markets.

3.1. The Chinese banking sector

China began its market reform and opening up policy in the late 1970s. Prior to the introduction of financial reforms in 1979, Chinese banks were centralised, government-owned and largely isolated from the rest of the world. Driven by market-oriented economic and financial reforms, the Chinese banking system has been transformed into an increasingly competitive market, with different types of banks offering a huge variety of financial services. According to the CBRC 2011 annual report, China's banking sector comprises of two policy banks, five large commercial banks, 12 joint-stock commercial banks, 144 city commercial banks, 212 rural commercial banks, 190 rural cooperative banks and 2,265 rural credit cooperatives. The number of banking institutions reached 3,800, with 3.198 million employees and total assets of RMB113.3 trillion, which is about US$ 19 trillion (CBRC 2011).

The Chinese banking regulatory system consists of four key entities: i) the People's Bank of China (PBOC), which currently operates as the central bank and is responsible for formulating and implementing monetary policy; ii) the China Banking Regulatory Commission (CBRC), which acts as the main regulatory authority for Chinese banks; (iii) the Ministry of Finance, which formulates fiscal policies and the central government's budget; ~~and~~ (iv) the State Administration of Foreign Exchange (SAFE), which is responsible for the supervision and monitoring of foreign exchange transactions and the management of China's foreign exchange reserve.

3.2. Chinese foreign exchange policy

China is one of the fastest growing economies in the world. It has had an average annual GDP growth rate of 10% in the past thirty years. Since the beginning of market-oriented economic reform in 1978, the PBOC has adopted either a pegged or managed exchange rate regime, with the exchange rate to the US$ being artificially fixed at just under 2.5RMB. During the period 1979 to 1994, a dual RMB exchange rate regime was adopted and the official rate was claimed to be pegged to a basket of currencies, but in fact it depreciated dramatically. The official rate for the US$ was adjusted to 1.56 RMB, 2.94 RMB, 5.76 RMB and 8.62 RMB in 1979, 1985, 1993 and 1994, respectively.

In 1994, the Chinese authority changed the dual exchange rate regime to single US$ pegged exchange regime. The RMB had been steady between 8.62 per US$~~dollar~~ in 1994 to 8.29 per US$~~dollar~~ in 1997. The RMB was then pegged to the US$ at the level of 8.28 per US$ during the period October 1997 to July 2005. On July 21, 2005, the ~~People's Bank of China~~PBOC~~,~~ made the announcement to switch the RMB to a new exchange rate regime in which the RMB was pegged to a basket of foreign currencies, which includes the Yen, US Dollar, Euro and many other Asian currencies. The RMB appreciated by 2.1% immediately and a cumulative 21% against the US$ by July 2008. To help its exports during the global financial crisis, China pegged the RMB at 6.83 per US$ until June 2010. However, during this period, tensions between the US and China on the value of the RMB escalated again. Under such pressure, the RMB exchange rate reforms to improve the flexibility in exchange rate fluctuations were re-launched on June 19, 2010. By the end of February 2013, the ~~Chinese~~ RMB rose to a new record of 6.28 per US$. Although the RMB exchange rate regime is still heavily managed at present, it tends to be much more volatile than before.

3.3. Derivative activities by financial institutions and regulations in China

China's derivatives market is still relatively small by global standards, but it has developed rapidly over the past few years. In 2009, the total size of the derivatives market in China was US$ 1.42 trillion, which formed only 0.33% of the global derivatives market. The trading volume of interest rate and exchange rate derivatives has increased from US$1.017 trillion in 2009 to US$1.465 trillion in 2010 (Yan 2010).

~~The RMB exchange rate has attracted increasing attention due to the growing importance of China in the global economy.~~ Although the Chinese government has long maintained its control over banks' lending and deposit rates, the booming property market and the increased demand for both fixed and floating mortgages in China has ~~lead~~ led the PBOC to remove the floor restrictions on the lending rate. This, in turn, has increased banks' exposure to interest rate risk and their use of interest rate derivatives.

Several derivative instruments have been introduced to help market participants to manage their exposure to foreign exchange and interest rate fluctuations. For example, in 1994, a spot foreign exchange trading system for financial institutions was introduced by the China Foreign Exchange Trade System (CFETS). In April 1997, the Bank of China, as the first authorised bank, launched its RMB forward exchange settlement and sales business. In February 2006, China Development Bank and China Everbright Bank completed the first RMB interest rate swap transaction. In April 2006, RMB exchange swaps were introduced in the Chinese interbank foreign exchange market. Outside China, the Chicago Mercantile Exchange (CME) launched futures and option contracts on the RMB against the US dollar, euro and Japanese yen.

While formal derivative trading is relatively new to the Chinese market, informal derivatives transactions, such as equity warrants issued by domestic firms and synthetic versions of vanilla derivatives contracts, have been taking place for a very long time. Chinese banks and foreign banks could do back-to-back business using "synthetic" versions of vanilla derivatives contracts. A domestic bank with good client base could write the deal and then hedge the deal with a foreign bank (Neftci and Xu 2006). In the 1990's, the lack of formal legal foundation on ~~the~~ indirect derivative trading had led some leading Chinese financial institutions to bankruptcy. For example, the International Trust and Investment Corporation (GITIC), a major player in structured products and derivatives, declared bankruptcy in 1998. Chinese courts voided all GITIC's derivatives contracts, arguing that these products were not approved by the appropriate regulatory authorities.

A much more focused regulatory body, the CBRC, ~~in~~ was established in 2003. To deal with the complicated problems associated with derivative products, in March 2004, the CBRC introduced the first formal regulations governing derivative activities by financial institutions, which provide clear definition of derivative products, state the criteria for qualifying financial institutions and specify the internal risk management requirements that institutions must satisfy. Such criteria include a complete and sound policy and procedures for risk management and internal controls of derivatives activities; a sound processing transaction system that links front, middle and back offices; necessary premises and facilities for derivatives activities; an experienced personnel with good record in charge of the derivatives activities; relevant staff dealing with trading, research and development in risk assessment and so on.[5] According to the provisions, financial institutions refer to "banks,

[5] Please refer to the details via http://www.cbrc.gov.cn/EngdocView.do?docID=556.

trust and investment companies, finance companies, financial leasing companies, auto financing companies, and branches opened by foreign banks in China". They can qualify as a broker/market maker, or an end user who uses derivatives for hedging purposes, or both. These rules and further changes made by the CBRC have widened the scope of the permissible derivative trading and allowed the Chinese financial institutions to trade derivatives for risk management, customer service, market-making and self-trading purposes. However, despite the wide use of derivatives, the Chinese regulatory authorities require banks to establish their own independent and comprehensive framework to ensure that the use of derivative activities does not lead to excessive risk taking.

4. Methodology

This section outlines the procedures employed to estimate the foreign exchange and interest rate exposures of individual banks and the approach used to investigate the impact of derivatives use on bank's exposure.

4.1. Standard exposure estimates

Banks' exposure to foreign exchange and interest rate fluctuations is commonly estimated using an asset-pricing model of the following form (see, for example, Choi *et al.* 1992; Choi and Elyasiani 1997; Wong *et al.* 2009)

$$R_{i,t} = \alpha_i + \beta_i^m R_{m,t} + \beta_i^{FX} FX_t + \beta_i^I I_t + \varepsilon_{i,t}, \quad (1)$$

where $R_{i,t}$ and $R_{m,t}$ are the returns on a stock *i* and a market portfolio *m*, respectively; FX_t is the percentage change in the value of the currency; I_t is the yield on 5-year government bond, converted into holding period returns; α_i is a constant that varies across banks, β_i^m, β_i^{FX}, and β_i^I are the coefficients of bank *i*'s market-wide exposure, exchange rate exposure and interest rate exposure, respectively.[6]

4.2. The effect of orthogonalisation

[6] The returns of dual-listed banks may be affected by the returns of domestic and the foreign market portfolios. Our sample contains banks that are listed in both China and Hong Kong. Following Wong *et al.* (2009), we use a dual-listed asset pricing model to investigate the exposures of these banks. Further details on modelling the returns of dual-listed banks can be found in Appendix A.

Since $R_{m,t}$ is the aggregation of the individual stocks traded in a given market, the market portfolio is also exposed to foreign exchange and interest rate fluctuations (Priestley and Odegaard 2007). Thus, the coefficients β_i^{FX} , and β_i^{I} in Equation (1) do not measure the bank *i*'s total exposure to the foreign exchange and interest rate movements, but they rather capture the exposure over and above that of the market portfolio. To address this issue, we first estimate orthogonalised market returns using the regression

$$R_{m,t} = \vartheta_m^{FX} FX_t + \lambda_m^I I_t + \tau_{m,t}, \qquad (2)$$

where $\tau_{m,t}$ is the orthogonalised market returns, which capture the part of market return that is not correlated with the foreign exchange and interest rate fluctuations. The OLS ~~estimator of~~ estimates $\tau_{m,t}$, denoted $\hat{\tau}_{m,t}$ is then used in Equation (1) which is modified as follows

$$R_{i,t} = \theta_i^0 + \theta_i^m \hat{\tau}_{m,t} + \theta_i^{FX} FX_t + \theta_i^I I_t + \eta_{i,t} \ . \qquad (3)$$

Here, the parameters θ_i^{FX} and θ_i^I are interpreted as the coefficients of total exposure of bank *i* to foreign exchange and interest rate risks, respectively.

4.3. Non-linear exposures

The nature of the nonlinearity may depend on firm-specific characteristics, such as its imports and exports, its competitive environment and pricing as well as risk management strategies. Thus, various nonlinear functions can be used to model the nonlinear exposure (Bartram 2004). However, Priestley and Odegaard (2007) argue that the inclusion of the squared values of FX_t in the exposure regression should capture the simple nonlinearities related to the possible convex structure of the foreign exchange risk (see, for example, Sercu and Uppal 1995 ~~and~~ ; Priestley and Odegaard 2007). In line with Priestley and Odegaard, we model a nonlinear relationship between a bank's exposure and its stock returns by adding the squared values of FX_t and I_t to the specification in Equations (3)

$$R_{i,t} = \varpi_i^0 + \varpi_i^m \hat{\tau}_{m,t} + \varpi_i^{FX} FX_t + \varpi_i^I I_t + \varpi_i^{FX,n} FX_t^2 + \varpi_i^{I,n} I_t^2 + \psi_{i,t} \ , \qquad (4)$$

where the coefficients $\varpi_i^{FX,n}$ and $\varpi_i^{I,n}$ are used to capture the bank *i*'s nonlinear exposure to foreign exchange and interest rate risks, respectively.

4.4. Time-varying exposures

So far, the approach specified above assumes that the foreign exchange and interest rate exposures of Chinese banks ~~is~~ are constant over time. However, several studies show risk exposure is time-varying (see, for example, Patro *et al.* 2002; Agyei-Ampomah *et al.* 2013). The following models are used to estimate the time-varying exposure parameters

$$R_{i,t} = \sum_{n=1}^{N} \alpha_{i,n} D_n + \sum_{n=1}^{N} \beta_{i,n}^{m} D_n R_{m,t} + \sum_{n=1}^{N} \beta_{i,n}^{FX} D_n FX_t + \sum_{n=1}^{N} \beta_{i,n}^{I} D_n I_t + \sum_{n=1}^{N} \beta_{i,n}^{FX,n} D_n FX_t^2 + \sum_{n=1}^{N} \beta_{i,n}^{I,n} D_n I_t^2 + \upsilon_{i,t} \ , \quad (5)$$

$$R_{m,t} = \sum_{n=1}^{N} \vartheta_{m,n}^{FX} D_n FX_t + \sum_{n=1}^{N} \lambda_{m,n}^{I} D_n I_t + \pi_{m,t} \ , \quad (6)$$

$$R_{i,t} = \sum_{n=1}^{N} \theta_{i,n}^{0} D_n + \sum_{n=1}^{N} \theta_{i,n}^{m} D_n \hat{\pi}_{m,t} + \sum_{n=1}^{N} \theta_{i,n}^{FX} D_n FX_t + \sum_{n=1}^{N} \theta_{i,n}^{I} D_n I_t + \sum_{n=1}^{N} \theta_{i,n}^{FX,n} D_n FX_t^2 + \sum_{n=1}^{N} \theta_{i,n}^{I,n} D_n I_t^2 + \nu_{i,t} , \quad (7)$$

where D_n is a dummy variable with a value of 1 if t $\in$ year n, where n = 1, 2,..., 8, and zero otherwise[7]. The parameters of Equations (5) through (7) are thus allowed to vary yearly. To account for the heteroskedastic nature of stock returns, the variances of the residual terms of these equations are assumed to follow a GARCH (1, 1) process (see, for example, Mandelbrot 1963; Fama 1965; Bollerslev *et al.* 1992). The time varying nature of stock volatility is mainly attributed to changes in firm's leverage, investment opportunities and other characteristics (Black 1976; Christie 1982) and controlling for the GARCH effect in the residuals leads to more efficient parameter estimates (see, for example, Corhay and Rad 1996; Hahn and Reyes 2004). The coefficients on $\beta_{i,n}^{FX}$ and $\beta_{i,n}^{FX,n}$ ($\beta_{i,n}^{I}$ and $\beta_{i,n}^{I,n}$) in Equation (5) capture a bank *i*'s yearly linear and nonlinear exposure to foreign exchange rate (interest rate) fluctuations over and above that of the market portfolio, respectively. The parameters $\theta_{i,n}^{FX}$ and $\theta_{i,n}^{FX,n}$ ($\theta_{i,n}^{I}$ and $\theta_{i,n}^{I,n}$) in Equation (7) capture the bank *i*'s total yearly linear and nonlinear exposures to the currency (interest rate) movements.

[7] The n = 1, 2, …., 8 represent the years 2005, 2006, …,2012, respectively.

4.5. Banks derivatives and its exposure

The following panel regressions are used to examine the impact of derivatives use on banks' exposure to exchange rate and interest rate fluctuations, respectively

$$FX_{i,n} = \gamma_0 + \gamma_1 FXD_{i,n-1} + \gamma_2 SIZE_{i,n-1} + \gamma_3 LIQ_{i,n-1} + \gamma_4 CAP_{i,n-1} + \mu_{i,n}, \quad (8)$$

$$\begin{aligned} IR_{i,n} = \varphi_0 + \varphi_1 IRD_{i,n-1} + \varphi_2 SIZE_{i,n-1} + \varphi_3 LIQ_{i,n-1} + \varphi_4 CAP_{i,n-1} + \varphi_5 RES_{i,n-1} \\ + \varphi_6 NIM_{i,n-1} + \varphi_7 NONINT_{i,n-1} + \varphi_8 LOANS_{i,n-1} + \mu_{i,n} \end{aligned}, \quad (9)$$

where $FX_{i,n}$ and $IR_{i,n}$ are the exchange rate and interest rate exposures of bank *i* in year *n*. Similar to Hutson and Stevenson (2010), the exposure variables are measured as the square root of the absolute value of the estimated values of the parameters $\theta_{i,n}^{FX}$, $\theta_{i,n}^{FX,n}$, $\theta_{i,n}^{I}$ and $\theta_{i,n}^{I,n}$ of Equation (7). We use a similar set of explanatory variables as Au Yong *et al.* (2009). FXD and IRD are the ratios of exchange rate derivatives/total assets and interest rate derivatives/total assets, respectively. Non-interest income/total assets ($NONINT$), loans/total assets ($LOANS$) and net interest income/total assets (NIM) are used to proxy for on-balance sheet interest rate risk and loan reserves/total assets (RES) as a proxy for credit risk. We also use additional control variables that may explain the variation in banks' exposure to interest and exchange rate fluctuations. These variables include the cash and cash equivalents scaled by bank size as a liquidity proxy (LIQ), the ratio of book value of equity/total assets as a proxy for banks capital (CAP) and the natural logarithm of total assets as a measure of bank size ($SIZE$).

A significantly negative coefficient on $FXD(IRD)$ in Equation (8) (Equation (9)) would suggest that the use of derivatives reduces banks' exposure to the foreign exchange rate (interest rate) movements, and vice versa. Fraser *et al.* (2002) predict a negative coefficient on $NONINT$. They argue that because of the negative association between interest rate and economic growth, banks that rely more heavily on non-interest income should exhibit higher exposure to interest rate changes. A positive association between interest rate risk exposure and banks' net interest margin is also widely documented in the literature (see, for example, English 2002). The coefficient on the variable $LOANS$ is expected to be positive, as banks with high concentration of loans should exhibit more exposure to interest rate fluctuations. Since liquidity and capital can be viewed as substitutes for hedging, banks with high levels of liquidity and capital are more likely to be exposed exchange rate and interest rate risks. Given the ambiguous sign of bank size in the previous studies, we do not make any prediction on the relationship between *SIZE* and banks' exposure to exchange rate and interest rate risks.

5. Data and descriptive statistics

We study the foreign exchange and interest rate exposures for sixteen listed Chinese banks over the period of January 2005 to December 2012. Panel A of Table 1 presents the distribution of our sample over time (see also Appendix B for further details). The starting date of our study period coincides with the regulatory change in the RMB exchange rate regime. We argue that extending the sample period to earlier years is not desirable, as the RMB was almost fixed against the US$ and few banks were listed on the stock exchange. Our sample includes all exchange-listed Chinese banks, which consist of the large five commercial banks, eight joint-stock commercial banks and three city commercial banks. According to the CBRC's 2011 Annual Report, the total assets of Chinese banking institutions reached RMB 113.3 trillion, of which the five large commercial banks and twelve joint-stock commercial banks accounted for 47.3% and 16.2%, respectively. Thus, the exchange-listed banks form a large part of the overall Chinese banking industry.

The daily closing price of the sample banks, the daily return on market indices, namely Shanghai Stock Exchange A ~~share~~ Share Index (SHASHR) and Shenzhen Stock Exchange Component Index (SICOM) and HANG SENG Index (HIS), the daily exchange rate series, which include the US$/RMB and the Euro/RMB, and the yield on five-year government bond are obtained from DataStream[8]. The choice between market indices is determined by the bank's listing locations. Specifically, we use SHARHR (SICOM) as a proxy for the market portfolio to estimate the exposure of banks listed on the Shanghai (Shenzhen) Stock Exchange and HIS is added to the exposure regressions for dual-listed banks (see Appendix A). The year-end values of a bank's total assets, the book value of equity, asset liquidity, net interest income, net non-interest income, loans, loan loss reserves, foreign exchange derivatives and interest rate derivatives are manually collected from banks' annual reports sourced from Thomson.

[8] Our choice of the daily frequencies is justified by Morse's (1984) finding that daily returns tend to produce less biased and more efficient parameter estimates of the mean abnormal returns caused by an information event than the monthly (and weekly) return series. Similar findings are reported by Brown and Warner (1980, 1985) and Dyckman *et al.* (~~1982~~1984). We repeat our analysis using weekly return series and our conclusions remain largely unchanged. The details of these results are available upon request.

Panel B of Table 1 presents the descriptive statistics of the daily returns on the market index and the daily changes in exchange rate and interest rate for the period 2005-2012. The mean values of the exchange rate changes is -0.015% for the US$/RMB and -0.008% for the Euro/RMB, respectively. The average return on the market index is 0.061% with the highest standard deviation of 1.787%. The average yield on the five-year government bond, converted into holding period returns, is 0.024% with a standard deviation 1.743%.

Panel C of Table 1 reports summary yearly statistics of the remaining variables included our analysis. As of year 2012, the Chinese banks use more currency derivatives (mean of RMB 364.98 Billion) than interest rate derivatives (mean of RMB 173.21 Billion). The exchange rate derivatives to total assets and interest rate derivatives to total assets are 0.08 and 0.04, respectively. These figures are much smaller than the 1.50 and 1.89 reported by Choi and Elyasiani (1997) for US banks and the 0.20 and 0.38 reported by Au Yong *et al.* (2009) for the ten Asia-pacific countries, respectively. All the variables vary significantly over the sample period. Thus, if these variables are the determinants of a bank's exchange rate and interest rate exposure, such variations imply that a bank's foreign exchange and interest rate risks may also not be constant over time.

Panel D of Table 1 presents ~~the~~ a correlation matrix of the variables in Equations (8) and (9). The absolute values of the correlation coefficients range from a high of 0.97 between *NIM* and *LOANS* and a low of 0.001 between *FXD* and *NONINT*.

[**Insert Table 1 about here**]

6. Empirical results

The empirical results are presented in three subsections. The first subsection presents the interest rate and foreign exchange exposure estimates from the standard multifactor asset-pricing model with constant coefficients. The second one reports the results from the conditional market model with time varying residuals. Finally, we discuss the panel regression results on the determinants of Chinese banks' exposure to interest rate and exchange rate fluctuations.

6.1.Unconditional exposure

Table 2 presents the exposure estimates from Equations (1) through (4). Panel A of Table 2 shows that the exchange rate and interest rate coefficients in the standard Jorion (1990) model (Equation (1)) are not significantly different from zero, suggesting that none of the sample banks is exposed to the fluctuations in exchange rate or interest rate over the period 2005-2012. This finding is consistent with the large body of the literature, which reports only weak evidence of systematic foreign exchange exposure (see, for example, Griffin and Stulz 2001; Doidge *et al.* 2003). However, we argue that the results in Panel A may be biased, as Equation (1) ignores the fact that the market index may also be exposed to foreign exchange and interest rate movements. More specifically, if the market portfolio is exposed to interest rate and/or exchange rate changes, the standard Jorion (1990) model would captures only the banks' exposure over and above that of the market portfolio. Following Priestley and Odegaard (2007), we use orthogonalised, rather than actual, market returns as the explanatory variable in the exposure equation to capture banks' total exposure to exchange rate and interest rate fluctuations.

Panel B of Table 2 shows that the market index is significantly associated with the movements in the US$ and the Euro, but not significantly related to changes in the interest rate. Specifically, it shows that the market portfolio is negatively correlated with the US$/RMB exchange rate changes, but positively associated with the Euro/RMB exchange rate movements. These results suggest that Chinese firms tend to have more (less) US$-denominated (euro-denominated) revenues than costs. The dominance of dollar revenues due to dollar-denominated invoicing by Chinese firms, which may, in turn, have resulted from the historical practices based a stable dollar-Yuan link (Bernard 2008)[9]. The insignificant exposure of the Chinese market index to the interest rate fluctuations may reflect heavy involvement of the Chinese government in the interest rate markets.

As presented in Panel C of Table 2, the number of banks with significant exposure to the movements in individual currencies increases with the use of orthogonalised market returns. Specifically, 11 and 16 of the total 16 banks included in our sample exhibit statistically significant exposure to the US$ and the Euro movements, respectively. The average US$/RMB exposure is negative (-1.1588) and statistically significant (t-value of -3.506), implying that the depreciation of RMB leads to an increase in the value of Chinese banks. It also indicates that the Chinese banks may have more dollar-denominated revenues than costs. We also find that the sample banks have a significant exposure to the Euro with an significantly positive average exposure coefficient of 0.3612, indicating that a depreciation of RMB against the Euro results in a decline in the value of Chinese banks. The positive

[9] In a survey of Chinese textile firms, Bernard (2008, p.7) shows that "while most sales are denominated in dollars, average sales to the EU in the surveyed firms are greater than those to the US, 30.6 and 24.4 percent of export sales respectively."

coefficient on Euro/RMB exchange rate changes also indicates that Chinese banks may have more euro denominated costs than revenues. Consistent with this view, Bernard (2008) argues that the large positive dollar revenues earned by most Chinese firms are, in many cases, a result of dollar pricing than a disproportionately large role of the US as a destination market.

Panel D of Table 2 reports the estimation results of Equation (4). It shows that a large number of sample banks exhibit both linear and nonlinear exposure to the US$/RMB and Euro/RMB exchange rate fluctuations. It also suggests that the linear exposure profiles are more pronounced than the nonlinear exposure specifications. Specifically, the results suggest that all (87.5%) of the sample banks experience a significant linearly exposure to the Euro (US$) movements. Similarly, a statistically significant nonlinear exposure to the Euro (US$) is detected in 43.75% (12.5%) of the cases. Overall, the results in Panel D suggest that foreign exchange exposure forms a significant part of the returns of individual Chinese banks.

The results in Panels C and D of Table 2 indicate that the use of orthogonalised market returns and relaxing the nonlinearity assumption does not alter banks' interest rate exposure. Specially, the coefficients on I_t in Equations (3) and (4) indicate that none of the sample bank is exposed to interest rate changes. The lack of interest exposure could be attributed to the exposure measurement bias, which will be addressed in the next section.

[**Insert Table 2 about here**]

6.2. Conditional exposure

So far, our analysis is based on the assumption that the exchange rate and interest rate exposures of the market portfolio and individual banks are constant over time. In this study, we use Equations (5) through (7) to allow the exchange rate and interest rate exposure parameters to vary over time. Table 3 reports the results of the yearly exchange rate and interest rate coefficients in Equation (5).[10] The results indicate that the exposure parameters are not constant over time, with the highest yearly exposure variation is observed in the case of the US$ coefficients. Specifically, Chinese banks' exposure to the US$/RMB varies yearly from a low of -0.9833 in 2007 to a high of 4.6761 in 2009. Table 3 also shows that three sample banks exhibit at least one significant yearly exposure to the movement of the

[10] We also find significant time varying market betas. Since the main purpose of this paper is to examine the interest rate and foreign exchange exposures, we choose not to report the time varying market betas in order to save space.

US$/RMB fluctuations, while six are exposed to the movement in the Euro/RMB. Table 3 indicates nonlinearity is more pronounced when the exposure is allowed to vary over time. Specifically, we detect a significant nonlinear exposures to Euro (US$) movements in 8 (4) of our sample banks. We also show that 10 (6) of the banks are exposed, either linearly or nonlinearly, to the Euro/RMB (US$/RMB) exchange rate changes.

Table 3 also reports the conditional exposure of Chinese banks to the interest rate changes. It shows that when the movements in the US$/RMB is used to estimate foreign exchange risk, two of the sample banks have at least one significant yearly interest rate exposure. We also show that four of the sample banks exhibit at least one significant yearly exposure (either linear or nonlinear) to the interest changes.

[**Insert Table 3 and 4 about here**]

Table 4 shows the results of the conditional exposure of the market index to the changes in the US$/RMB and the Euro/RMB over the period 2005-2012 (Equation (6)). The results suggest that the foreign exchange exposure of the market portfolio varies considerably over time. Consistent with the results in Panel B of Table 2, we show that the market portfolio is negatively exposed to the changes in US$/RMB, but positively related to the Euro/RMB exchange rate fluctuations. It is also notable that statistically significant exposure to interest rates only occurs in 2007 and 2012 for both the US$ and the Euro. By contrast there is significant exposure to both exchange rates from 2009 to 2011. Interestingly, the table suggests a difference in the timing of significant dependence. There is significant positive dependence on the RMB/Euro exchange rate from 2008 to 2011, where for the RMB/US$ the period of negative significance is from 2009 until at least 2012. Again, we attribute this to the dominance of dollar-denominated invoicing amongst the Chinese firms.

Table 5 reports the orthogonalised conditional exposure coefficients of Equation (7). The number of banks with significant exposure to exchange rate and interest rate fluctuations increases considerably following the orthogonalisation process. The increase is particular more pronounced over the last 3 years of the sample period. Specifically, the results show that 13, 15 and 9 banks exhibit significant exposure to the US$ in the years 2010, 2011 and 2012, respectively. We also show that all banks are exposed to the Euro movements in the years 2010 and 2011 and that 13 of the 16 sample banks experience significant exposures to Euro/RMB fluctuations in the year 2012. Consistent with the results in Panel C of Table 2, the majority of the sample banks have negative (positive) exposure to the US$ (Euro) movements. The number of banks with nonlinear foreign exchange and interest exposures in Table 5 is almost identical to that reported in Table 3.

Overall, the results in Table 5 show each bank experiences at least one yearly linear or nonlinear exposure to the exchange rate and interest rate movements. Thus, our approach generates a much stronger association between banks' stock returns and exchange rate changes than previous studies in the literature (see, for example, Choi and Elyasiani 1997; Au Yong *et al.* 2009; Wong *et al*. 2009). Furthermore, we show that Chinese banks are exposed linearly and nonlinearly to the interest rate movement and these exposures are more pronounced following the orthogonalisation of market returns. Finally, the Chinese banks' exposure to interest rate changes remains largely time varying, with the weakest exposure reported in year 2007 and the strongest reported in year 2012. The lack of interest rate risk exposure in the earlier sample period coincides with the period of a heavy involvement of the Chinese central bank in controlling lending and borrowing interest rates. We attribute the recently increase in the interest rate exposure of Chinese banks to the increased demand for mortgages in China, which has led the PBOC to remove the floor restrictions on lending rate.

[**Insert Table 5 about here**]

6.3. Derivatives and banks' exposures

This section investigates the determinants of Chinese banks' exposure to exchange rate and interest rate movements. We are particularly interested in examining the impact of derivatives trading on the risk profile of Chinese banks. Previous studies, including Choi and Elyasiani (1997), Chaudhry *et al.* (2000) and Reichert and Shyu (2003), apply the cross-sectional regressions to estimate the association between banks' foreign exchange exposure and derivative instruments. Nguyen *et al.* (2007) and Au Yong *et al.* (2009), among others, also use cross-sectional regressions to investigate the determinants of interest rate exposure.

In this study, we argue that the cross-sectional analysis is likely to generate biased estimates, as it ignores the temporal dimension of both dependent and explanatory variables. By using the linear and nonlinear foreign exchange and interest rate coefficients as dependent variables in the time varying exposure regressions, we are able to use panel data regressions to account for the time-varying nature of banks' characteristics. We use the results of the correlation matrix in Panel D of Table 1 to avoid multicollinearity problems that may result from including highly correlated variables in the same regression. We also use panel regressions with random effects, as the Hausman test tends not to reject the null hypothesis that the preferred model is the random effects[11].

Table 6 presents the regression results on the determinants of banks' linear and nonlinear foreign exchange exposure obtained in estimating Equation (8). The coefficient on *FXD* is significantly negative regardless of whether $\theta_{i,n}^{FX}$ or $\theta_{i,n}^{FX,n}$ is used as the dependent variable. This finding implies that the use of foreign exchange derivatives reduce the Chinese banks' exposure to both linear and nonlinear foreign exchange risks. This finding is consistent with Choi and Elyasiani (1997) who show that derivative trading reduces the foreign exchange risk of the US banks, but differs from Au Yong *et al.* (2009), who find that the use derivative does not influence the foreign exchange exposure of Asia-pacific banks. The coefficient on *CAP* is in some cases positive and statistically significant, implying that banks may take more foreign exchange risk when they have sufficient capital to absorb foreign exchange shocks.

[**Insert Table 6 about here**]

Tables 7 and 8 reports the regression results on the determinants of banks' interest rate exposure obtained from estimating Equation (9) with respect to the exchange rate exposures of US$ and Euro measured in Equation (7), respectively. The coefficients on *IRD* are not significant, regardless of whether $\theta_{i,n}^{I}$ or $\theta_{i,n}^{I,n}$ are used as the dependent variable, implying that the use of interest rate derivatives does not lead to excessive risk taking by Chinese banks. –The significant negative coefficient on *SIZE* indicates that large banks are less exposed to the interest rate movements. The sign and the statistical significance of the remaining variables seem to depend largely on the model specification.

[**Insert Table 7 and 8 about here**]

7. Conclusion

This study investigates the role of derivative activities in determining Chinese banks' exposure to exchange rate and interest rate risks. Our results suggest that banks' exposure is model dependent. The standard Jorion (1990) model indicates that Chinese banks are not

[11] Whilst the results of this test are not tabulated, more details are available upon request. We also repeat all the analysis using panel regressions with fixed effects and our conclusions remain unchanged. Further details are available upon request.

exposed to exchange rate or interest rate fluctuations. We argue that the results estimated from this model may be biased due to its explicit assumption that banks' exposure is constant over time. Since banks' circumstances, including the extent of international operations and risk management activities, change over time, their exposures to exchange rate and interest rate movements are also expected to vary over time. Another important source of bias stems from the fact that the market portfolio may also be exposed to the exchange rate and interest rate changes. Thus, the exposure parameters of the standard Jorion (1990) model may not capture the banks' total exchange rate and interest rate risks. Instead, they only measure the banks' exposures over and above those of the market portfolio. Furthermore, most empirical studies investigate the linear relationship between stock returns and foreign exchange movements. However, many studies suggest that the exposure of firms to foreign exchange fluctuations may be nonlinear (see, for example, Ware and Winter 1988; Sercu and Uppal 1995; Bartram 2004; Muller and Verschoor 2006; Priestley and Odegaard 2007). To address the above biases, we model the linear and nonlinear exposure of Chinese banks using a GARCH-based-multifactor-model with time varying parameters and orthogonalised market returns. Our results suggest that all the sample banks experience at least one significant (at the 5% level) yearly exposure to foreign exchange changes and interest rate movements.

We then use the estimated linear and nonlinear time-varying exposure parameters to investigate the impact of derivative trading on exposure profiles of Chinese banks. We show that banks' derivative activities reduce their linear and nonlinear exposure to exchange rate changes, but not affect their interest risk profile. Overall, our results suggest the regulatory bodies can stabilise the banking system by encouraging banks to use more derivative products for risk management purposes.

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Appendix A: The return estimates of the dual-listed banks

We model the returns of Chinese banks that are dual-listed on the Hong Kong Stock Exchange as follows

$$R_{id,t} = \alpha_i + \beta_i^{md} R_{md,t} + \beta_i^{mf} R_{mf,t} + \beta_i^{FX,d} FX_t + \beta_i^{I,d} I_t + \varepsilon_{i,t}, \quad \text{(A.1)}$$

where $R_{id,t}$ is the return of a dual-listed bank *i*; $R_{md,t}$ and $R_{mf,t}$ are the SHASHR (SICOM) and HIS index returns; FX_t is the percentage change in the value of a single currency; I_t is the yield on 5-year government bond, converted into holding period returns; α_i is a constant that varies across banks; the parameters β_i^{md}, β_i^{mf}, $\beta_i^{FX,d}$ and $\beta_i^{I,d}$ represent the dual-listed bank's exposure to the SHASHR(SICOM), HIS, foreign exchange and interest rate movements, respectively; $\varepsilon_{i,t}$ is the error term.

We argue that Eq.(A.1) ignores the fact that market index returns are also exposed to currency fluctuations and exchange rate movement and $\beta_i^{FX,d}$ and $\beta_i^{I,d}$ may, therefore, only capture the foreign exchange and interest rate exposures over and above that of the market portfolio. To estimate the total exposure of dual listed banks, we define the orthogonalised market index returns, or $\tau_{md,t}$ and $\tau_{mf,t}$, respectively, as the residual term of following equations

$$R_{md,t} = \theta_{md}^{FX} FX_t + \theta_{md}^{I} I_t + \tau_{md,t}, \quad \text{(A.2)}$$

$$R_{mf,t} = \theta_{mf}^{FX} FX_t + \theta_{mf}^{I} I_t + \tau_{mf,t}, \quad \text{(A.3)}$$

and then modify Eq.(A.1) as follows

$$R_{i,dt} = \theta_i^0 + \theta_i^{md} \hat{\tau}_{md,t} + \theta_i^{mf} \hat{\tau}_{mf,t} + \theta_i^{FX,d} FX_t + \theta_i^{I,d} I_t + v_{i,t},$$

(A.4)

where $\theta_i^{FX,d}$ and $\theta_i^{I,d}$ are the total exposure of a dual-listed bank *i* to foreign exchange and interest rate movements, respectively, and $\hat{\tau}_{md,t}$, $\hat{\tau}_{mf,t}$ are the OLS estimators of the corresponding parameters in (A.2) and (A.3) Similarly, to account for the nonlinearity issue, we include the squared values of FX_t and I_t in Equation (A.4). Finally, we propose the following models to account for the nonlinearity and the time-varying exposure of the dual-listed banks

$$R_{i,t} = \sum_{n=1}^{N} \alpha_{i,n} D_n + \sum_{n=1}^{N} \beta_{i,n}^{md} D_n R_{md,t} + \sum_{n=1}^{N} \beta_{i,n}^{mf} D_n R_{mf,t} + \sum_{n=1}^{N} \beta_{i,n}^{FX,d} D_n FX_t + \sum_{n=1}^{N} \beta_{i,n}^{I,d} D_n I_t + \sum_{n=1}^{N} \beta_{i,n}^{FX,d,n} D_n FX_t^2 + \sum_{n=1}^{N} \beta_{i,n}^{I,d,n} D_n I_t^2 + \upsilon_{i,t} , \quad \text{(A.5)}$$

$$R_{md,t} = \sum_{n=1}^{N} \vartheta_{md,n}^{FX} D_n FX_t + \sum_{n=1}^{N} \lambda_{md,n}^{I} D_n I_t + \pi_{md,t} , \quad \text{(A.6)}$$

$$R_{mf,t} = \sum_{n=1}^{N} \vartheta_{mf,n}^{FX} D_n FX_t + \sum_{n=1}^{N} \lambda_{mf,n}^{I} D_n I_t + \pi_{mf,t} , \quad \text{(A.7)}$$

$$R_{i,dt} = \sum_{n=1}^{N} \theta_{i,n}^{0} D_n + \sum_{n=1}^{N} \theta_{i,n}^{md} D_n \hat{\pi}_{md,t} + \sum_{n=1}^{N} \theta_{i,n}^{mf} D_n \hat{\pi}_{mf,t} + \sum_{n=1}^{N} \theta_{i,n}^{FX,d} D_n FX_t + \sum_{n=1}^{N} \theta_{i,n}^{I,d} D_n I_t + \sum_{n=1}^{N} \theta_{i,n}^{FX,d,n} D_n FX_t^2 + \sum_{n=1}^{N} \theta_{i,n}^{I,d,n} D_n I_t^2 + \nu_{i,t} , \quad \text{(A.8)}$$

where D_n is a dummy variable with a value of 1 if t $\in$ year n, where n = 1, 2,...,N, and zero otherwise. The coefficients on $\beta_{i,n}^{FX,d}$ and $\beta_{i,n}^{FX,d,n}$ ($\beta_{i,n}^{I,d}$ and $\beta_{i,n}^{I,d,n}$) in Equation (A.5) capture a dual-listed bank *i*'s yearly linear and nonlinear exposures to foreign exchange rate (interest rate) fluctuations over and above that of the market portfolio, respectively. The parameters $\theta_{i,n}^{FX,d}$ and $\theta_{i,n}^{FX,d,n}$ ($\theta_{i,n}^{I,d}$ and $\theta_{i,n}^{I,d,n}$) in Equation (A.8) capture a dual-listed bank *i*'s total yearly linear and nonlinear exposures to the currency (interest rate) movements.

Appendix B: The listing information of our sample banks

Name of the Bank	Listing Date	Listing Location
Agricultural Bank of China	2010-07-15	Shanghai
Agricultural Bank of China	2010-07-16	Hong Kong
Bank of Beijing	2007-09-19	Shanghai
Bank of China	2006-07-05	Shanghai
Bank of China	2006-06-01	Hong Kong
Bank of Communication	2007-05-15	Shanghai
Bank of Communication	2005-06-23	Hong Kong
Bank of Nanjing	2007-07-19	Shanghai
Bank of Ningbo	2007-07-19	Shenzhen
China Citic Bank	2007-04-27	Shanghai
China Citic Bank	2007-04-27	Hong Kong
China Construction Bank	2007-09-25	Shanghai
China Construction Bank	2005-10-27	Hong Kong
China Everbright Bank	2010-08-18	Shanghai
China Merchants Bank	2002-04-09	Shanghai
China Merchants Bank	2006-09-22	Hong Kong
China Minsheng Banking Corp	2000-12-19	Shanghai
China Minsheng Banking Corp	2009-11-26	Hong Kong
Hua Xia Bank	2003-09-12	Shanghai
Industrial Bank	2007-02-05	Shanghai
Industrial and Commercial Bank of China	2006-10-27	Shanghai
Industrial and Commercial Bank of China	2006-10-27	Hong Kong
Ping An Bank	1991-04-03	Shenzhen
Shanghai Pudong Development Bank	1999-11-10	Shanghai

Table 1: Summary statistics for currency measures, market index and bank characteristics

Panel A: No. of listed banks in our sample at the end of the year

2005	7	2006	9
2007	13	2008	13
2009	14	2010	16
2011	16	2012	16

Panel B: Summary statistics for daily returns on the market index, daily exchange rate and interest rate changes

	Mean	Median	Max	Min	SD
MKT	0.061%	0.123%	9.454%	-8.845%	1.787%
US$/RMB	-0.015%	-0.004%	0.364%	-2.012%	0.096%
Euro/RMB	-0.008%	0.011%	3.393%	-6.694%	0.666%
IR	0.024%	0.000%	8.696%	-9.933%	1.743%

Panel C: Summary statistics for bank-specific yearly factors (RMB Billion)

Year	Total Assets	Book Value of Equity	Liquid Assets	Loan to Customers	Net Interest Income	Net Non-interest Income	Loan Reserves	Exchange Rate Derivatives	Interest Rate Derivatives
2005*	1514.66	82.03	152.99	927.72	31.52	3.64	59.58	70.76	66.10
2006	1645.38	81.25	202.89	922.94	35.08	4.87	25.06	116.95	74.83
2007	1916.50	97.68	241.18	1021.09	40.88	4.12	27.34	174.92	72.17
2008	2241.54	124.73	363.37	1107.55	60.35	3.26	78.71	246.29	90.86
2009	2680.35	155.36	500.58	1288.42	72.32	10.71	36.01	220.51	108.60
2010	3376.63	178.93	573.57	1729.25	68.77	15.70	41.95	262.90	110.01
2011	3988.24	235.71	758.84	2051.48	87.74	18.90	47.73	374.43	144.85
2012	4654.74	282.69	1018.20	2347.48	109.42	26.37	58.99	364.98	173.21

Panel D: Correlations

	SIZE	CAP	LIQ	LOANS	NIM	NONINT	RES	FXD	IRD
SIZE	1.00								
CAP	0.03	1.00							
LIQ	0.11	0.92	1.00						
LOANS	0.02	0.92	0.92	1.00					
NIM	0.02	0.96	0.93	0.97	1.00				
NONINT	-0.09	0.03	-0.03	0.04	0.01	1.00			
RES	-0.05	0.61	0.60	0.68	0.68	0.05	1.00		
FXD	-0.28	0.21	0.17	0.17	0.22	0.00	0.06	1.00	
IRD	-0.13	0.31	0.28	0.24	0.29	0.04	0.07	0.74	1.00

Note: MKT is the return on the market index; US$/RMB~~&Euro~~ is the change in US dollar to RMB exchange rate; Euro/RMB is the change in Euro to RMB exchange rate; IR is the yield on 5-year government bond, converted into holding period returns; $SIZE$ is the natural logarithm of total assets; CAP is the ratio of book value of equity/total assets; LIQ is the cash and cash equivalents scaled by total assets; $LOANS$ is the loans to customers/total assets; NIM is the net interest income/total assets; $NONINT$ is the non-interest income/total assets; RES is the loan reserves/total assets; FXD and IRD are the ratios of exchange rate derivatives/total assets and interest rate derivatives/total assets, respectively.

* The statistics are reported for the five banks listed prior to 2005.

Table 2: The unconditional exposure of the Chinese banks and the market index (Equations (1) through (4)).

Panel A: The exchange rate and interest rate coefficient of the standard Jorion (1990) model (Equation (1))					
	Mean	No. of Banks Sig at 5%		Mean	No. of Banks Sig at 5%
US$	0.1784	0	IR	0.0123	0
Euro	-0.0147	0	IR	0.0117	0
Panel B: The market index exposure to currency risk and interest rate risk (Equation (2))					
	Coef.	t-stat		Coef.	t-stat
US$	-1.3785	-3.5066	IR	-0.0065	-0.2610
Euro	0.3873	5.5846	IR	0.0012	0.0480
Panel C: The exchange rate and interest rate coefficient of orthogonalised Jorion (1990) model (Equation (3))					
	Mean	No. of Banks Sig at 5%		Mean	No. of Banks Sig at 5%
US$	-1.1588	11	IR	0.0053	0
Euro	0.3612	16	IR	0.0129	0
Panel D: The exchange rate and interest rate coefficient of orthogonalised Jorion (1990) model (Equation (4))					
	Mean	No. of Banks Sig at 5%		Mean	No. of Banks Sig at 5%
US$	-1.2921	14	IR	0.0060	0
$US\$^2$	-209.1542	2	IR^2	0.0465	0
US or US^2	NA	14	IR or IR^2	NA	0
Euro	0.3504	16	IR	0.0103	0
$Euro^2$	-5.4965	7	IR^2	0.1026	0
Euro or $Euro^2$	NA	16	IR or IR^2	NA	0

Note: US$ is the change in US dollar to RMB exchange rate; Euro is the change in Euro to RMB exchange rate; IR is the yield on 5-year government bond, converted into holding period returns.

Table 3: The conditional exposure of the Chinese banks (Equation (5))

Year	US$ Mean	No. of Banks Sig at 5%	$US\$^2$ Mean	No. of Banks Sig at 5%	US$ or $US\$^2$ No. of Banks at 5%	IR Mean	No. of Banks Sig at 5%	IR^2 Mean	No. of Banks Sig at 5%	IR or IR^2 No. of Banks at 5%
2005	3.1786	1	172.8455	0	1	0.0197	0	0.5153	0	0
2006	1.8817	0	-363.6195	0	0	0.0519	0	2.8717	0	0
2007	-0.9833	1	-547.7569	0	1	0.0713	0	-6.4147	0	0
2008	-0.2431	0	-663.1384	3	3	0.0827	1	0.4121	1	2
2009	4.6761	1	16568.7238	3	3	-0.0053	0	1.3656	0	0
2010	-0.6368	2	32.2444	0	2	-0.0459	1	0.9436	1	2
2011	-0.5280	2	-546.5581	0	2	-0.0135	0	0.0270	0	0
2012	-0.0874	0	-249.5348	1	1	0.0306	0	-0.0632	0	0
Sig. One-year exposure		3		4	6		2		2	4
Year	**Euro Mean**	**No. of Banks Sig at 5%**	**$Euro^2$ Mean**	**No. of Banks Sig at 5%**	**Euro or $Euro^2$ No. of Banks at 5%**	**IR Mean**	**No. of Banks Sig at 5%**	**IR^2 Mean**	**No. of Banks Sig at 5%**	**IR or IR^2 No. of Banks at 5%**
2005	0.1465	0	7.1255	0	0	0.0400	1	0.4849	0	1
2006	-0.0928	0	-19.4447	0	0	0.0435	0	1.3153	0	0
2007	0.0113	0	-23.1338	0	0	0.0983	0	-6.3784	0	0
2008	-0.0533	0	-2.6577	1	1	0.0634	1	0.6383	0	1
2009	-0.0703	0	1.6562	0	0	-0.0013	0	1.3378	0	0
2010	0.0343	0	-9.7367	3	3	-0.0712	2	1.7460	2	3
2011	-0.0077	1	-6.1117	1	1	-0.0136	0	-0.0306	0	0
2012	0.1596	6	-21.8234	6	9	0.0297	1	-0.0090	0	1
Sig. One-year exposure		6		8	10		5		2	6

Note: US$ is the change in US dollar to RMB exchange rate; Euro is the change in Euro to RMB exchange rate; IR is the yield on 5-year government bond, converted into holding period returns; Sig. One-year Exposure refers to the number of banks with at least one significant yearly currency (interest rate) exposure.

Table 4: The conditional exposure of the market index (Equation (6))

Currency			IR	
US$	Coef.	t-stat	Coef.	t-stat
2005	-1.8882	-5.6992	-0.0322	-0.5188
2006	-2.2051	-1.9544	-0.0385	-0.4639
2007	-1.4602	-1.0010	-0.3591	-2.6410
2008	-2.1212	-1.2529	-0.0429	-0.4355
2009	-10.4484	-1.9784	-0.0010	-0.0126
2010	-2.1213	-1.7303	-0.0358	-0.5339
2011	-1.9585	-2.5717	0.0308	0.9598
2012	-1.4411	-1.9697	0.0691	2.4213
Euro	Coef.	t-stat	Coef.	t-stat
2005	0.0891	0.4673	-0.0349	-0.5919
2006	0.1098	0.8880	-0.0328	-0.3772
2007	0.4920	1.1179	-0.3352	-2.4654
2008	0.4643	2.2934	-0.0108	-0.1065
2009	0.3000	1.9874	0.0087	0.1151
2010	0.5119	3.8666	-0.0280	-0.4096
2011	0.4154	3.9683	0.0326	0.9983
2012	0.1792	1.3942	0.0712	2.4960

Note: US$ is the change in US dollar to RMB exchange rate; Euro is the change in Euro to RMB exchange rate; IR is the yield on 5-year government bond, converted into holding period returns.

Table 5: The orthogonalised conditional exposure of the Chinese banks (Equation (7))

Year	US$ Mean	No. of Banks Sig at 5%	US$^{2} Mean	No. of Banks Sig at 5%	US$ or US$^{2} No. of Banks at 5%	IR Mean	No. of Banks Sig at 5%	IR^2 Mean	No. of Banks Sig at 5%	IR or IR^2 No. of Banks at 5%
2005	1.3787	0	173.0079	1	1	-0.0086	0	0.5325	0	0
2006	-0.3787	0	-360.0788	0	0	0.0147	1	2.8632	0	1
2007	-2.2915	4	-547.5720	0	4	-0.2488	3	-6.4353	0	3
2008	-2.9416	6	793.4500	3	6	0.0262	0	0.5247	1	1
2009	-5.7549	2	16575.5481	3	5	-0.0061	0	1.3659	0	0
2010	-2.6400	13	-19.5143	0	13	-0.0758	3	0.8847	1	4
2011	-2.2271	15	-547.0490	0	15	0.0131	1	0.0254	0	0
2012	-1.2392	9	-247.7224	1	10	0.0858	16	-0.0633	0	16
Sig. one-year exposure		16		5	16		16		2	16

Year	Euro Mean	No. of Banks Sig at 5%	Euro^2 Mean	No. of Banks Sig at 5%	Euro or Euro^2 No. of Banks at 5%	IR Mean	No. of Banks Sig at 5%	IR^2 Mean	No. of Banks Sig at 5%	IR or IR^2 No. of Banks at 5%
2005	0.1980	0	-1.6192	0	0	-0.0168	1	0.4407	0	1
2006	0.0211	0	-19.4425	0	0	0.0092	1	1.3150	0	1
2007	0.4099	2	-18.5411	0	2	-0.1933	1	-6.8365	1	2
2008	0.4483	14	-2.6595	1	14	0.0517	1	0.6382	0	1
2009	0.2292	4	1.6587	0	4	0.0072	0	1.3382	0	0
2010	0.5396	16	-9.5267	3	16	-0.0991	5	1.7484	2	6
2011	0.3453	16	-7.2207	1	16	0.0170	2	0.0337	0	2
2012	0.3012	13	-21.8197	6	13	0.0860	16	-0.0091	0	16
Sig. one-year exposure		16		8	16		16		3	16

Note: US$ is the change in US dollar to RMB exchange rate; Euro is the change in Euro to RMB exchange rate; IR is the yield on 5-year government bond, converted into holding period returns; Sig. One-year Exposure refers to the number of banks with at least one significant yearly currency (interest rate) exposure.

Table 6: Panel regressions on the determinants of the foreign exchange exposure (Equation (8))

	US$ Linear		US$ Non-Linear	
	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)
FXD	-0.472***	-0.614***	-12.740***	-13.670***
	(-4.43)	(-7.69)	(-3.06)	(-4.12)
SIZE	-0.060	-0.061	0.642	0.626
	(-1.65)	(-1.85)	(0.38)	(0.39)
LIQ	0.158		0.365	
	(1.00)		(0.06)	
CAP		1.435**		7.932
		(2.36)		(0.55)
CONS	2.413***	2.377***	28.350	28.170
	(5.01)	(5.46)	(1.30)	(1.30)
N	102	102	102	102
Wald chi2	20.84	63.96	15.02	24.23
Prob > chi2	0.0001	0.0000	0.0018	0.0000
	Euro Linear		Euro Non-Linear	
FXD	-0.093***	-0.113***	-1.186***	-1.194***
	(-3.03)	(-4.33)	(-2.84)	(-2.87)
SIZE	-0.007	-0.007	-0.223	-0.224
	(-0.73)	(-0.77)	(-1.37)	(-1.42)
LIQ	0.042		-0.029	
	(1.14)		(-0.04)	
CAP		0.245***		-0.002
		(3.14)		(-0.00)
CONS	0.689***	0.682***	6.796***	6.797***
	(5.06)	(5.24)	(2.94)	(2.95)
N	102	102	102	102
Wald chi^2	20.86	37.02	12.92	8.436
Prob > chi^2	0.0001	0.0000	0.0048	0.0378

Notes: This table presents the regression results on the determinants of the foreign exchange exposure (Equation (8)). The square root of the absolute value of the currency coefficient in Equation (7) is used as the dependent variable. The independent variables include: $SIZE$ is the natural logarithm of total assets; CAP is the ratio of book value of equity/total assets; LIQ is the cash and cash equivalents scaled by total assets; $FXD\ is$ the ratios of exchange rate derivatives/total assets.
**indicates the 5% significance level.
***indicates the 1% significance level.

Table 7: Panel regressions on the determinants of the interest rate exposure with the US$ modelled in Equation (7)

	US$ Linear					US$ Non-Linear				
	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)
IRD	0.095	0.107	0.0623	0.0716	0.0440	-1.391	-1.812	-2.043	-2.102	-2.085
	(0.69)	(0.69)	(0.41)	(0.48)	(0.31)	(-0.95)	(-1.47)	(-1.49)	(-1.59)	(-1.61)
SIZE	-0.022***	-0.022***	-0.021***	-0.021***	-0.024***	-0.112**	-0.108**	-0.101	-0.103**	-0.108
	(-3.00)	(-2.90)	(-2.76)	(-2.82)	(-3.26)	(-2.24)	(-2.10)	(-1.91)	(-1.97)	(-1.87)
NONINT	-2.221**	-1.748	-3.395***	-2.796***		-6.473	-15.760	-25.970***	-24.73***	
	(-2.38)	(-1.29)	(-3.58)	(-2.76)		(-0.93)	(-1.47)	(-2.58)	(-2.59)	
LIQ	0.074					-0.078				
	(1.45)					(-0.14)				
CAP		0.113					1.203			
		(0.56)					(0.92)			
LOANS			0.045***					0.344***		
			(5.43)					(3.71)		
NIM				0.673***					6.350***	
				(3.22)					(3.79)	
RES					0.680					6.568**
					(1.49)					(2.47)
CONS	0.562***	0.560***	0.533***	0.546***	0.589***	2.818***	2.713***	2.534***	2.588***	2.635***
	(5.52)	(5.31)	(5.20)	(5.24)	(5.70)	(3.83)	(3.52)	(3.28)	(3.39)	(3.02)
N	102	102	102	102	100	102	102	102	102	100
Wald chi2	19.34	16.91	44.40	26.14	12.74	8.864	11.65	19.94	23.18	8.705
Prob >	0.0007	0.0020	0.0000	0.0000	0.0052	0.0646	0.0201	0.0005	0.0001	0.0335

Notes: This table presents the regression results on the determinants of the interest rate exposure (Equation (9)). The square root of the absolute value of interest rate coefficient in Equation (7) is used as the dependent variable. The independent variables include: $SIZE$ is the natural logarithm of total assets; CAP is the ratio of book value of equity/total assets; LIQ is the cash and cash equivalents scaled by total assets; $LOANS$ is the loans to customers/total assets; NIM is the net interest income/total assets; $NONINT$ is the non-interest income/total assets; RES is the loan reserves/total assets; IRD is the ratio of interest rate derivatives/total assets. Standard errors are adjusted for heteroskedasticity.

**indicates the 5% significance level.
***indicates the 1% significance level.

Table 8: Panel regressions on the determinants of the interest rate exposure with the Euro modelled in Equation (7)

	Euro Linear					Euro Non-Linear				
	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)	Coef. (t-stat.)
IRD	0.029	0.084	-0.0164	0.023	-0.009	-1.531	-1.744	-2.164	-2.110	-2.232**
	(0.16)	(0.42)	(-0.09)	(0.12)	(-0.04)	(-1.19)	(-1.65)	(-1.96)	(-1.94)	(-2.11)
SIZE	-0.030***	-0.031***	-0.030***	-0.030***	-0.031***	-0.163***	-0.161***	-0.152***	-0.155***	-0.166***
	(-4.06)	(-4.36)	(-4.10)	(-4.11)	(-3.93)	(-3.45)	(-3.36)	(-3.21)	(-3.25)	(-3.18)
NONINT	-0.719	0.250	-1.840	-0.911		-2.087	-6.720	-21.160	-16.960	
	(-0.55)	(0.17)	(-1.54)	(-0.70)		(-0.25)	(-0.55)	(-1.62)	(-1.46)	
LIQ	-0.044					-0.019				
	(-0.81)					(-0.04)				
CAP		-0.263					0.648			
		(-1.41)					(0.41)			
LOANS			0.009					0.354***		
			(0.61)					(3.12)		
NIM				-0.200					5.444**	
				(-0.71)					(2.55)	
RES					-0.293					7.441***
					(-0.54)					(3.35)
CONS	0.701***	0.718***	0.692***	0.705***	0.712***	3.537***	3.483***	3.251***	3.345***	3.479***
	(6.42)	(6.82)	(6.53)	(6.47)	(6.12)	(4.92)	(4.70)	(4.56)	(4.63)	(4.33)
N	102	102	102	102	100	102	102	102	102	100
Wald chi2	20.63	21.05	29.81	24.68	19.78	12.58	12.51	40.80	29.45	22.21
Prob >	0.0004	0.0003	0.0000	0.0001	0.0002	0.0135	0.0139	0.0000	0.0000	0.0001

Notes: This table presents the regression results on the determinants of the interest rate exposure (Equation (9)). The square root of the absolute value of interest rate coefficient in Equation (7) is used as the dependent variable. The independent variables include: $SIZE$ is the natural logarithm of total assets; CAP is the ratio of book value of equity/total assets; LIQ is the cash and cash equivalents scaled by total assets; $LOANS$ is the loans to customers/total assets; NIM is the net interest income/total assets; $NONINT$ is the non-interest income/total assets; RES is the loan reserves/total assets; IRD is the ratio of interest rate derivatives/total assets. Standard errors are adjusted for heteroskedasticity.

**indicates the 5% significance level.
***indicates the 1% significance level.