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Monetary policy transmission through the bank lending channel in Thailand

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ABSTRACT

This paper investigates the strength of the bank lending channel in the transmission of monetary policy in Thailand. Bank behavior is captured by quarterly balance sheet data for ten commercial banks of diverse size for the period 2007-2016. Based on a flexible form profit function, bank supply and demand equations are estimated that capture lending and funding choices. The estimation results are used to derive time-dependent supply and demand elasticities which are then combined with estimates of pass-through from the policy rate to retail rates to simulate the dynamic impact of a monetary tightening on bank portfolio allocations. Due to pass-through differentials among retail interest rates, an increase in the policy rate is shown to raise the cost of loan-production relative to the return on loans, thereby motivating banks to contract their lending. Small banks show a greater degree of loan contraction than large banks because large banks are better able to fund continued lending through debt issuance. Because the Thai economy relies heavily on bank loans, these findings suggest that the bank lending channel is an important conduit for the transmission of monetary policy in Thailand.

1. Introduction

Since the Asian Financial Crisis of 1997, Thailand has undergone significant structural reforms in its monetary policy framework. Under direction of the International Monetary Fund, the pegged exchange rate regime was replaced by a managed floating exchange rate system under a monetary targeting regime. Upon the exit from the IMF program in May 2000, an inflation-targeting regime was introduced under which the Bank of Thailand gained autonomy to adjust the policy rate to control aggregate demand and maintain the inflation rate within a targeted range. Under this framework, the effect of monetary policy is expected to transmit to the real economy through various channels,[2] namely the credit channel, the asset price channel, the exchange rate channel, and the expectation channel, in addition to the direct interest rate channel. The bank lending channel is viewed as a component of the credit channel. In particular, it operates through changes in bank reserves caused by a tightening or loosing of monetary policy which restricts or expands the ability of banks to provide loans. Hossain and Arwatchanakarn (2017) noted that the Bank of Thailand's implementation of inflation targeting, despite

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[2] Bank of Thailand, https://www.bot.or.th/English/MonetaryPolicy/MonetPolicyKnowledge/Pages/TransmissionMechanism.aspx.

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uncertainties in the transmission mechanism, might result in excessive volatility of the inflation rate as well as the real interest rate and exchange rate, which may be detrimental to economic growth.

The role of the bank lending channel as the major conduit of monetary policy transmission in Thailand is very important. It has been scrutinized in a number of studies, including Disyatat and Vongsinsirikul (2003), Charoenseang and Manakit (2007), and Kubo (2008). Their results suggest the importance of the bank lending channel, coupled with the traditional interest rate and other indirect channels to influence the economy. These studies employed vector autoregression analysis (VAR) with aggregate data on bank loans to examine bank loan movement in conjunction with temporary shocks to key macroeconomic indicators such as GDP, investment, and consumption. Nonetheless, the evidence from these studies is marred by the identification problem, as pointed out by Kashyap, Stein and Wilcox (1996). A decline in bank loans observed after a tightening of monetary policy might alternatively be interpreted as the result of a slowdown in economic activity caused by the effect of the traditional interest rate or cost of capital channel alone, leading to a downward shift in the demand for loans rather than the postulated contraction in bank supply of loans. Kashyap and Stein (1995) proposed a direct and more robust empirical strategy to investigate the bank lending channel using disaggregate data on bank balance sheets from which they directly examined whether monetary contraction is able to induce banks to alter their loan supply along with other assets and liabilities. According to their theoretical model, unless banks can completely insulate themselves against deposit and reserve drainage by borrowing from other external sources or liquidating some asset holdings, they must curtail lending during contractionary monetary periods.

Thailand's financial sector, including commercial banks, has experienced ongoing change and development. The abolition of the interest rate ceiling and the relaxation of exchange rate and capital account controls were implemented in the 1990s (Chantapong, 2005). During the Asian Financial Crisis, the restriction on foreign ownership of commercial banks was removed to attract foreign investors to recapitalize distressed banks (Mahathanaseth and Tauer, 2014). In addition, after the crisis period, the financial sector Master Plan I & II, covering the period from 2004 to 2014, was introduced by the Bank of Thailand.[3] The substantial part of this plan included measures to improve the efficiency of the financial sector by enhancing market mechanisms. These included granting new banking licenses and easing entry into the banking sector, broadening the scope of commercial bank business, relaxing regulations on new branch establishment, and reducing restrictions on the scope of business of foreign financial institutions. As a result, the number of domestically registered commercial banks rose from 13 in 2002 to 19 in 2016, six of which have majority foreign ownership. The total number of bank branches almost doubled to 7016 in 2016 from 3668 in 2002. However, conventional wisdom that these financial deregulations weakens the importance of the bank lending channel in executing monetary policy is debatable (Gopalan and Rajan, 2017). On the one hand, an expansion in access to cross-border funding sources may reduce the role of banks as intermediaries in monetary transmission. On the other hand, intensified competition in the banking sector could facilitate interest rate pass-through and strengthen the impact of the policy rate on banking sector interest rates and the impact of monetary policy through the bank lending channel.

Moreover, despite the many advances, Thailand's banking sector remains concentrated and far from conditions of perfect competition. The five largest banks still account for more than 60% of total assets and 75% of the total number of branches in the banking system.[4] One of the banks is a state enterprise[5] which actively executes government policy toward meeting the credit needs of small and medium enterprises (SMEs). The presence of such a big state bank could hinder the market mechanism in the banking sector. In addition, Thai capital and bond markets remain immature. Access to primary funding sources is still limited to large firms.[6] As a result, banks are a major source of credit, especially for SMEs. Ananchotikul and Limjaroenrat, (2017) found that nearly 80% of Thai SMEs in their panel sample[7] borrowed from a single bank, which might be attributed to severe imperfect information and switching cost problems. Furthermore, in spite of a tendency toward deregulation in bank business activities, the Bank of Thailand has put forth various measures intended to improve governance, such as limiting bank lending to related companies and prescribing procedures for granting credit, investing in securities, undertaking contingent liabilities, and selling assets (Watanagase, 2001). Other prudential measures have also been enacted including a maximum 80% loan-to-value ratio for real estate, a maximum 270-day term-to-maturity of promissory notes issued by banks, and a limit on investment in share equities of a single company. All of these measures could cause sluggish and costly adjustment in bank balance sheets in response to monetary shocks. These market imperfections, financial frictions, and effective controls, might lead to credit rationing and maintaining the importance of the bank lending channel in the monetary policy transmission mechanism of Thailand.

The question of whether the bank lending channel exists is not only still open, but if it exists, it is essential to know the strength of its impact for reliable and accurate monetary policy implementation in Thailand. Hence, the main objective of this study is to reinvestigate the existence and strength of the bank lending channel in Thailand using disaggregated data on bank balance sheets. Unlike previous studies which typically regressed bank loans on monetary policy indicators and idiosyncratic bank characteristics such as size, ownership, and financial strength, our empirical strategy involves estimation of both the supply of loans and the demand for funding from different sources, namely deposits, borrowing, and the interbank market as determined by own- and cross-price elasticities.

[3] Bank of Thailand, https://www.bot.or.th/English/FinancialInstitutions/Highlights/FSMP3/FinancialSectorMasterPlanIII.pdf.
[4] Bank of Thailand, https://www.bot.or.th/English/Statistics/FinancialInstitutions/CommercialBank/Pages/default.aspx.
[5] As of 2016, the Thai government owns 55.05% of Krung Thai bank's share through the Financial Institution Development Fund.
[6] According to the Thai Bond Market Association, only 205 companies issued bonds in 2015.
[7] Their panel data set covers the period of 2004 – 2014 and contains 145,823 observations.

In conjunction with our focus on the bank lending channel, we also investigate interest rate pass-through from the policy rate to bank retail rates, i.e. the direct interest rate channel, because it is often regarded as the main channel in monetary policy transmission. While there is extensive literature on both the interest rate pass-through and the bank lending channels, they have typically been examined separately despite their inter-dependency given that interest rate pass-through to money market rates and retail bank rates influences the marginal cost for banks to attract deposits and grant loans (De Bondt, 2005). A contribution of this study is to conduct an analysis of both mechanisms. This provides a more complete picture of monetary policy transmission through the banking sector in Thailand amid rapid transformation of the financial landscape.

This study on Thailand can be viewed as a case study of monetary policy transmission in an emerging economy that has pursued significant financial deregulation and liberalization. Gopalan and Rajan (2017) point out that domestic monetary policy transmission has become a subject of importance for emerging and developing economies (EMDEs) as many countries have gravitated toward more market determined exchange rate regimes and consequent use of interest rates as the primary instrument for macroeconomic management. A change in the policy rate is expected to pass through to retail market rates and thereby be transmitted through various channels, including the bank lending channel, unless the intermediary role of banks is muted due to financial underdevelopment.

Our empirical method offers three advantages. First, we use data on individual bank balance sheets rather than aggregate banking data to estimate the system of supply of loans and demand for loanable funds to address the identification problem. Second, our estimates of own- and cross-price elasticities of bank supply of loans and demand for loanable funds enable us to directly measure and statistically test not only the responsiveness of bank loan supply in response to a change in bank retail rates as influenced by the policy rate, but also the degree of substitutability between bank funding sources, which is the key to assessing the bank lending channel. Lastly, our system of bank demand and supply equations is modified to incorporate a dynamic element to distinguish between the immediate and long run impacts of monetary policy through the banking system.

The rest of the paper proceeds as follows. Section 2 provides a review of the bank lending channel literature. Section 3 focuses on a description of the methodology, empirical specification, and data. Section 4 begins with estimation of the pass-through from the policy rate to bank retail rates, then proceeds with estimation of bank demand and supply equations involving own- and cross-price elasticities. The estimation results of interest rate pass-through and associated elasticities are then used to simulate the dynamic impacts of a change in the policy rate on bank loan supply and portfolio structure. Finally, Section 5 summarizes and offers concluding remarks.

2. Literature review

Mishkin (1996) provides a thorough overview of the transmission mechanisms of monetary policy. Of interest for our purposes are the traditional interest rate channel and the bank lending channel. In the Keynesian IS-LM view of the monetary transmission mechanism, often referred to as the traditional interest rate channel, a contractionary monetary policy leads to a rise in the real interest rate, which in turn increases the cost of capital, causing a decrease in investment spending, thereby resulting in a decline in aggregate demand and output. However, the supposition that there are two assets, money and bonds, and a single interest rate, implying perfect substitutions between bonds and other debt instruments, including bank loans, is the central feature in this transmission mechanism, which is obviously simplistic. It is generally acknowledged that bank loans and market bonds are not perfect substitutes, especially for small and medium firms which often have limited access to bond markets and must primarily resort to bank loans. Much research on asymmetric information in credit markets, such as Stiglitz and Weiss (1992), suggests a special role for banks in screening and monitoring borrowers due to their expertise in gathering information and developing relationships with customers. This enables banks to overcome the information problem, providing them an advantage over other lenders in the primary debt markets.

The role of banks as a conduit of monetary policy transmission, or the so-called credit channel, has arisen from the problem of asymmetric information in financial markets. The credit channel is broken into two separate channels, called the balance sheet channel and the bank lending channel (Bernanke and Gertler, 1995). The balance sheet channel, sometimes referred to as the broad credit channel or the financial accelerator, operates through the credit worthiness of bank-dependent borrowers. A monetary contraction affects borrower balance sheets in several ways, including a fall in their equity prices, impairing their liquidity and increasing their debt burdens. A deterioration in borrower net worth worsens the information problem, increases the risks to lenders, and raises borrowers' external finance premium, resulting in a decrease in lending and hence in investment spending. On the other hand, the bank lending channel stresses the supply of loans offered by depository institutions like banks. This transmission mechanism is interpreted as a monetary contraction, which reduces bank deposits and reserves and curtails banks' ability to sell loans, thereby decreasing funding for bank-dependent borrowers and causing aggregate spending and output to fall. Summarily, both the balance sheet channel and the bank lending channel act as amplifiers to the impact of monetary policy through the interest rate channel.

Empirical research on the bank lending channel falls into two categories. Early works, such as Bernanke and Blinder (1992), Gertler and Gilchrist (1993), and Bernanke and Gertler (1995), rely on aggregate data to establish its existence by using VAR impulse responses to look for the co-movement between the monetary shock, bank lending, and aggregate expenditures. However, this line of research suffers from a major shortcoming referred to as the identification problem, i.e. it fails to specify whether a decline in bank lending after monetary tightening is the result of a shift in the supply of bank loans or a fall in the demand for loans caused by the effect of the direct interest rate channel. Research led by Kashyap and Stein

(1995) makes use of disaggregated data on bank balance sheets to address the identification problem by arguing that banks' ability to supply loans is closely tied with their balance sheet characteristics, such as liquidity and capital strength, which are independent of loan demand shocks. Undercapitalized and illiquid banks, because of their higher external finance premium, should be more vulnerable to deposit leakage, and thus to reductions in loan supply, than large and healthy banks. In other words, the bank lending channel, if it exists, should be transmitted mainly through small and weak banks. In these studies, banks are typically sorted according to asset size, liquidity, and capital strength, to test for the existence of the bank lending channel by examining differential responses in loan supply. A reduction in loan supply by small and weak banks to a negative monetary shock is regarded as evidence of the existence of the bank lending channel.

Beyond testing its existence, several recent studies attempted to examine the impact of changes in the banking sector landscape on the effectiveness of monetary policy transmission through the bank lending channel using cross-country data. For example, Olivero et al. (2011a, 2011b) suggested that more consolidation and competition in the banking sector undermines the effectiveness of the bank lending channel in emerging economies. Wu et al. (2011) found that the bank lending channel in emerging economies was weakened by greater foreign bank penetration. Sanfilippo-Azofra et al. (2018) studied the relationship between financial development and effectiveness of the bank lending channel using data on 31 developing countries, and found that the negative effect of tightening monetary policy through the bank lending channel is stronger when financial development increases. However, the cross-country data in those studies might produce biased results owing to different economic and financial structures.

Studies of the bank lending channel in Thailand, such as Disyatat and Vongsinsirikul (2003), found that the bank lending channel plays an important role in the transmission mechanism, although the role of this channel was undermined by problems in the corporate and banking sector during the post-crisis period 2000 – 2003. Charoenseang and Manakit (2007) not only reaffirmed the validity of the bank lending channel in Thailand, but also noted that a decrease in the degree of disintermediation, as well as an increase in the roles of other funding sources, lessened its importance in monetary policy transmission. Lastly, Kubo (2008) found a significant movement between credit and private expenditures using a structural VAR, and inferred that the results may be consistent with the theoretical prediction of the bank lending channel. Even though all of these studies pointed to the existence of the bank lending channel in Thailand, their results are still questionable due to their reliance on aggregate data and the associated identification problem.

Moreover, in recent years, Thailand's banking sector, like that of many emerging economies, has experienced significant deregulation and a wave of mergers and acquisitions. These structural changes might dilute the effectiveness of monetary policy on bank lending as suggested by Phiromswad (2015), who found that the bank lending channel became much weaker after the subprime crisis as a result of an increase in uncertainty around the world. However, Hossain and Arwatchanakarn (2017) argued that Thailand's money and capital markets remained relatively underdeveloped so that monetary policy may still have significant impacts on banks' loan supply. Banks have traditionally been the most important depository institutions and credit sources in Thailand. Access to stock and corporate bond markets as alternative sources of funding is still limited to very large firms. The limited role of non-bank financing in Thailand was empirically supported by Mahathanaseth and Tauer (2012) who found that the Thai banking sector was highly concentrated and the elasticity of substitution between corporate bonds and bank loans was very low. Also, the presence of market imperfections such as asymmetric information, credit rationing, and switching costs might sustain the importance of banks in the monetary policy transmission mechanism despite the ongoing development of Thailand's financial sector.

There are three reasons why the existence and strength of the bank lending channel in Thailand should be reinvestigated. First, no previous research on the bank lending channel in Thailand employed disaggregated data from bank balance sheets. All previous research relied on macro-data on aggregate bank credit thus raising concern about the identification problem. Second, as a consequence of deregulation and financial development in Thailand, the importance of transmission through the bank lending channel may have been undermined. Third, a refashioning of the monetary policy framework was carried out in 2007. This involved a change in the policy rate from the 14-day repurchase (RP) rate to the 1-day RP rate in the belief that the liquidity condition in the money market is best reflected in the 1-day rate and that using this rate will reduce distortions in the term structure of short-term money market interest rates.

This article has two distinctions from the existing literature on the bank lending channel in Thailand. First, the use of disaggregated bank balance sheet data to estimate a system of supply and demand functions derived from a flexible form profit function is adopted to overcome the identification problem, enabling us to coherently reinvestigate the importance of the bank lending channel. Second, an alternative view of the transmission mechanism of the bank lending channel is highlighted. The propositions that the central bank is capable of efficiently manipulating bank reserves and deposits and thus that banks are unable to insulate their loans against a decline in deposits are increasingly challenged in Thailand as well as many other countries as a consequence of financial liberalization and shifts in the intermediate targets of monetary policy from money supply to short-term interest rates (Disyatat, 2011). In our mechanism, similar that of to Kishan and Opiela (2000), the impact of monetary policy is channeled mainly through disparate adjustments in short-term market interest rates, possibly associated with market frictions,[8] which in turn affect banks' profitability and thereby motivate banks to

[8] Disyatat and Vongsinsirikul (2003) empirically found that bank retail rates in Thailand are rather sticky in comparison with most developed countries. They attributed this finding to high adjustment costs and a less competitive banking system.

reallocate their portfolios including their loan supply. The results are expected to provide a more lucid understanding of the transmission mechanism of the bank lending channel in Thailand.

3. Methodology and data

This section begins with a description of our estimation strategy involving a system of bank output supplies and input demands. Estimation challenges are presented and an appropriate estimation technique is specified. Next, we discuss how our panel data set is formed, and how variables used in the estimation are constructed. Finally, descriptive statistics on bank balance sheet data are presented.

3.1. Methodology

A system of bank demand and supply equations is to be simultaneously estimated. Our approach is similar to that of Altunbaş et al. (2002) who estimate a set of four equations involving loans, security holdings, deposits, and interbank borrowing using a random effects panel data approach. However, instead of a reduced-form estimation, we apply the theory of the firm to banking (Klein, 1971) and use the duality principle (McFadden, 1978) to specify a profit maximization problem which gives rise to a system of demand and supply equations from which time-dependent elasticities of substitution are explicitly derived. These elasticities allow us to identify the bank lending channel transmission mechanism by simulating dynamic responses of bank portfolio choices, including loan supply, following a change in the policy rate.

Consistent with the intermediation approach commonly used in bank profit estimates (Berger and Humphrey, 1997), bank inputs are defined as liabilities on their balance sheets, including deposits, debts issued, and interbank borrowings, all of which are used to finance the loans and investments regarded as outputs. We focus on financial inputs, while real resource inputs like physical capital and labor are omitted due to data limitations. We assume there is no substitutability between these real resources and financial inputs, so that banks are required to use the real resources in fixed proportion with the level of financial resources and outputs. Banks are then viewed as maximizing their financial profit, defined as the difference between their revenues from loans and investments and their financial costs, subject to the balance-sheet constraint. Formally,

$$\pi_{it}(\mathbf{p}) = \max_{\substack{x_{1it},x_{2it},\\ x_{3it},x_{4it},x_{5it}}} \quad p_{1it}x_{1it} + p_{2it}x_{2it} - C(\mathbf{p}; x_{1it}, x_{2it}, x_{3it}, x_{4it}, x_{5it}) \tag{1}$$

$$\text{s.t.} \quad x_{1it} + x_{2it} + R_{it} \leq x_{3it} + x_{4it} + x_{5it} \tag{2}$$

$$\text{and} \quad R_{it} \geq k \cdot x_{3it} \tag{3}$$

where $\pi(\cdot)$ and $C(\cdot)$ are profit and (financial) cost functions, respectively; $\mathbf{p} = (p_1, p_2, p_3, p_4, p_5)$ is a vector of prices wherein p_1 is the loan rate, p_2 the rate of return on investment, p_3 the deposit rate, p_4 the borrowing rate, and p_5 the interbank rate; correspondingly, x_1 is loans, x_2 investments, x_3 deposits, x_4 bonds, and x_5 interbank borrowings; R is bank reserves; and k is the required reserved ratio.

Eq. (1) states that each bank chooses quantities of outputs and inputs to maximize financial profit. The cost function, $C(\cdot)$, represents not only funding and management costs, but also contains information on substitutability between funding sources. One of our main objectives is to extract these elasticities, which show the responsiveness of bank portfolio choices, including loan supply, when the bank is impacted by a monetary shock. Eq. (2) is the balance sheet constraint. A bank is required to maintain its assets, consisting of loans, investments, and reserves, at less than its total liabilities defined as the sum of deposits, debt instruments issued, and interbank borrowings. Eq. (3) is the reserve requirement constraint. Bank reserves in Thailand consist of current account and term deposits at the Bank of Thailand, cash at the central cash centers of commercial banks, and unencumbered eligible public securities. Some interest is paid on term deposits and public securities, but none on cash and current deposits. Banks might hold excess reserve for liquidity in the short run, but the amount of excess reserve holdings should be relatively stable and not very sensitive to market interest rates. As a result, the demand for reserves is omitted from our estimation

The specific form of $\pi(\cdot)$ is unknown because the functional form of $C(\cdot)$ is unknown, so our strategy is to adopt a generalized Leontief function which in the bank profit estimation literature is a frequently used functional form. The function is specified as:

$$\begin{aligned}\pi_{it}(p_{1it}, p_{2it}, p_{3it}, p_{4it}, p_{5it}) = {} & \beta_{11}p_{1it} + 2\beta_{12}\sqrt{p_{1it}p_{2it}} + 2\beta_{13}\sqrt{p_{1it}p_{3it}} + 2\beta_{14}\sqrt{p_{1it}p_{4it}} + 2\beta_{15}\sqrt{p_{1it}p_{5it}} + \beta_{22}p_{2it} \\ & + 2\beta_{23}\sqrt{p_{2it}p_{3it}} + 2\beta_{24}\sqrt{p_{2it}p_{4it}} + 2\beta_{25}\sqrt{p_{2it}p_{5it}} + \beta_{33}p_{3it} + 2\beta_{34}\sqrt{p_{3it}p_{4it}} + \beta_{44}p_{4it} \\ & + 2\beta_{45}\sqrt{p_{4it}p_{5it}} + \beta_{55}p_{5it} + \xi_{it}\end{aligned} \tag{4}$$

where $\pi(\cdot)$ is the maximum profit and ξ the random error term. Note that the required reserve ratio, k, is absent from Eq. (4) because it is set by the Bank of Thailand and was maintained at 0.06 throughout our period of study, so should have no impact

on bank demands and supplies. Note also that Eq. (4) satisfies the linear homogeneity condition of the profit function; that is, if all interest rates (prices) double, so too does the maximum profit.

Applying Hotelling's lemma[9] yields the system of demand and supply equations. A partial-adjustment structure of bank assets and debt is incorporated in order to capture the effect of adjustment costs, as described by Disyatat and Vongsinsirikul (2003), which might prevent instantaneous adjustment. This will influence the dynamics of monetary policy transmission through bank portfolio structures. First-order differencing is performed on these demand and supply equations to avoid the spurious regression problem caused by use of non-stationary variables and to remove bank time-invariant unobserved heterogeneity. The resulting model consists of the supply and demand equations to be estimated:

$$\Delta x_{1it} = \alpha_{12}\Delta\sqrt{\frac{p_{2it}}{p_{1it}}} + \alpha_{13}\Delta\sqrt{\frac{p_{3it}}{p_{1it}}} + \alpha_{14}\Delta\sqrt{\frac{p_{4it}}{p_{1it}}} + \alpha_{15}\Delta\sqrt{\frac{p_{5it}}{p_{1it}}} + (1-\lambda_1)\Delta x_{1it-1} + \varepsilon_{1it} \tag{5}$$

$$\Delta x_{2it} = \alpha_{12}\Delta\sqrt{\frac{p_{1it}}{p_{2it}}} + \alpha_{23}\Delta\sqrt{\frac{p_{3it}}{p_{2it}}} + \alpha_{24}\Delta\sqrt{\frac{p_{4it}}{p_{2it}}} + \alpha_{25}\Delta\sqrt{\frac{p_{5it}}{p_{2it}}} + (1-\lambda_2)\Delta x_{2it-1} + \varepsilon_{2it} \tag{6}$$

$$-\Delta x_{3it} = \alpha_{13}\Delta\sqrt{\frac{p_{1it}}{p_{3it}}} + \alpha_{23}\Delta\sqrt{\frac{p_{2it}}{p_{3it}}} + \alpha_{34}\Delta\sqrt{\frac{p_{4it}}{p_{3it}}} + \alpha_{35}\Delta\sqrt{\frac{p_{5it}}{p_{3it}}} - (1-\lambda_3)\Delta x_{3it-1} + \varepsilon_{3it} \tag{7}$$

$$-\Delta x_{4it} = \alpha_{14}\Delta\sqrt{\frac{p_{1it}}{p_{4it}}} + \alpha_{24}\Delta\sqrt{\frac{p_{2it}}{p_{4it}}} + \alpha_{34}\Delta\sqrt{\frac{p_{3it}}{p_{4it}}} + \alpha_{45}\Delta\sqrt{\frac{p_{5it}}{p_{4it}}} - (1-\lambda_4)\Delta x_{4it-1} + \varepsilon_{4it} \tag{8}$$

$$-\Delta x_{5it} = \alpha_{15}\Delta\sqrt{\frac{p_{1it}}{p_{5it}}} + \alpha_{25}\Delta\sqrt{\frac{p_{2it}}{p_{5it}}} + \alpha_{35}\Delta\sqrt{\frac{p_{3it}}{p_{5it}}} + \alpha_{45}\Delta\sqrt{\frac{p_{4it}}{p_{5it}}} - (1-\lambda_5)\Delta x_{5it-1} + \varepsilon_{5it} \tag{9}$$

where Δ denotes the first-order difference operator.

The variable λ_j for $j = 1,2,3,4,5$ measures the speed of adjustment toward long-run desired levels of supply and demand, and is expected to lie between 0 and 1 such that the closer it is to 1, the faster the speed of adjustment; ε_j for $j = 1,2,3,4,5$ is the random shock; the coefficient $\alpha_{jk} = \beta_{jk}\lambda_j$ measures the immediate impact of a change in the interest rate on bank demands and supplies. Based on these coefficient estimates, we can compute the time dependent impact as $\alpha_{jk}\left[1-(1-\lambda_j)^t\right]/\lambda_j$. Since $0 < \lambda_j < 1$, the long run impact can be measured by α_{jk}/λ_j.

These coefficients are not very meaningful, however. Of more interest are the own- and cross-price elasticities of demand and supply which reflect banks' adjustment in their portfolios in response to changes in market interest rates, and therefore captures their ability to sustain lending against monetary policy. The time-dependent elasticities of bank loan supply and investment in financial assets with respect to retail interest rates can be calculated using the following formulas:

$$e_{jj} = \frac{-1/2\sum_{\substack{k=1\\k\neq j}} \alpha_{jk}\left(p_k/p_j\right)^{1/2}}{x_j} \cdot \frac{\left[1-(1-\lambda_j)^t\right]}{\lambda_j} \quad \text{for } j = 1,2 \tag{10}$$

$$e_{jk} = \frac{1/2\alpha_{jk}\left(p_k/p_j\right)^{1/2}}{x_j} \cdot \frac{\left[1-(1-\lambda_j)^t\right]}{\lambda_j} \quad \text{for } j = 1,2 \text{ and } k = 1,2,3,4,5 \tag{11}$$

The own- and cross-price elasticities of bank demands for deposits, bond borrowings, and interbank borrowings are computed as follows:

$$e_{jj} = \frac{1/2\sum_{\substack{k=1\\k\neq j}} \alpha_{jk}\left(p_k/p_j\right)^{1/2}}{x_j} \cdot \frac{\left[1-(1-\lambda_j)^t\right]}{\lambda_j} \text{for } j = 3,4,5 \tag{12}$$

$$e_{jk} = \frac{-1/2\alpha_{jk}\left(p_k/p_j\right)^{1/2}}{x_j} \cdot \frac{\left[1-(1-\lambda_j)^t\right]}{\lambda_j} \quad \text{for } j = 3,4,5 \text{ and } k = 1,2,3,4,5 \tag{13}$$

[9] $\partial\pi(\cdot)/\partial p_i = x_i^*$ where $x_i^* = x_i(p_1,p_2,p_3,p_4,p_5)$ is the output supply or input demand function.

We can calculate the short-run or immediate elasticity from Eqs. (10)–(13) by letting $t = 1$, whereas the long-run elasticity is obtained by taking the limit as $t \to \infty$.

Two remaining issues need to be considered. First, the problem of serially correlated error terms might arise because of the nature of time-series data in our panel sample. Second, the presence of lagged dependent variables, or $\Delta x_{j,i,t-1}$ as regressors, might create the problem of correlation between the explanatory variables and the error terms, called the endogeneity problem, especially when the error terms are serially correlated. These problems could result in bias and inconsistent estimates. Hence, the generalized method of moments (GMM) estimation technique is utilized to achieve consistent and asymptotically efficient estimates. Our estimation technique resembles the dynamic panel data approach proposed by Arellano and Bond (1991), where the first-order lagged dependent variables on the right hand side of Eqs. (5)–(9) are instrumented using the deeper lags of the dependent variables and the predetermined variables. In addition, the heteroskedasticity and autocorrelation consistent (HAC) weighting matrix is used, and is iterated until the estimated coefficients converge. Finally, the Sargan statistic is employed for a test of the validity of our specified instruments.

3.2. Data

As of 2016, 30 banks were operating in Thailand of which 19 were domestically registered commercial banks and the rest were foreign bank branches whose business is heavily restricted by law. Our panel data set consists of 10 commercial banks which are registered in Thailand for the period 2007–2016 at quarterly frequency. Two considerations were involved in sample selection. First, we focus on the period from 2007 onward because significant refashioning of the monetary policy framework was carried out early in this era: the policy rate was switched from the 14-day RP rate to the 1-day RP rate in January 2007; and the Bank of Thailand Act was amended in 2008 to prioritize price stability and emphasize cooperation between the monetary policy board and the government in determining the targets of monetary policy. Second, we consider only domestically registered commercial banks because the core business of foreign branch banks in Thailand is not lending but transaction services. Only 10 out of 19 domestic commercial banks are selected because they operated continuously throughout our sample period, while the 9 remaining banks were newly established or emerged from mergers and acquisitions during the period. Therefore, our panel data set is balanced and consists of 400 observations obtained from 10 banks over 40 quarters. Data on these banks' balance sheets were acquired from their quarterly financial statements reported to the stock exchange of Thailand.

To estimate the system of supplies and demands given by Eqs. (5)–(9), the following variables were extracted from the bank balance sheets. Loans (x_1) is composed of loans to customers and net accrued interest receivables. Investment (x_2) consists of both debt and equity securities held. Deposits (x_3) covers all types of deposit accounts offered to customers. Debt issued and borrowing (x_4) comprises both bonds and borrowed money. Interbank borrowing (x_5) includes all interbank and money market items. Interest rates accruing on bank assets and liabilities were constructed by dividing average yields and interest paid by the quantities.[10] These implicit rates were used rather than the official rates[11] declared by banks, since banks usually charge (or are charged) rates below or above these reported rates depending on negotiations. Loan rate (p_1) and yield rate on investment (p_2) are then defined as interest income on loans and interest income on investment divided by total loans and investments, respectively. Similarly, deposit rate (p_3), borrowing rate (p_4) and interbank rate (p_5) are calculated by dividing interest expense on deposits, debt issued, and interbank borrowings by their respective total quantities.

Following Kashyap and Stein (1995), we divided the 10 banks in our sample into two equal groups of large banks and medium-and-small banks (simply called small banks onward), based on their assets, in order to test for differential responses their supplies and demands to monetary policy. The large bank sample consists of Bangkok Bank (BBL), Kasikorn Bank (KBANK), Siam Commercial Bank (SCB), Krung Thai Bank (KTB), and Bank of Ayudhya (BAY). The small bank sample consists of Thai Military Bank (TMB), Thanachart Bank (TBANK), Kiatnakin Bank (KKB), TISCO Bank (TISCO), and Land and House Bank (LH BANK). Our size categories resemble the Bank of Thailand's peer groups: large banks are those with asset shares in total assets of the banking system above 10%, whereas the medium and small banks are those with asset share of 3–10% and less than 3%, respectively.

Table 1 shows average data on balance sheets of all banks, large banks, and small banks. As seen in the table, the large banks are on average almost 5-times larger than the small banks in term of assets. Further, the large banks on average have a substantially higher liquidity ratio, slightly lower debt-to-equity ratio, and considerably lower loan-to-deposit ratio than the small banks. These ratios indicate that the small banks are more financially constrained than the large banks.

We conducted Hadri Lagrange multiplier (LM) tests for panel unit roots of each variable against the null hypothesis that the data are stationary, whereas the alternative is that at least one panel contains a unit root. Table 2 shows the p-value tests for each variable from which we conclude that all but one variable are non-stationary in levels at a significance level of 0.10, while all are I(1), i.e. they become stationary after first differencing, at a confidence level of 95%. This validates the specification in our model of first-order differencing.

Means and standard deviations of the variables used in estimating Eqs. (5)–(9), are summarized in Table 3.

[10] This approximation is similar to the calculation of the bank interest rate spread.

[11] Minimum deposit rates and minimum loan rates of commercial banks are reported daily.

Table 1
Composition of bank balance sheets (million baht).

	All Banks	Big Banks	Small Banks
Assets	1,089,938	1,792,346	387,531
Cash	18,661	32,454	4,868
Interbank and money market items	125,955	215,559	36,352
Investments in securities, net	158,612	262,084	55,141
Loans and accrued interest receivables	732,394	1,195,567	269,220
Premises and equipment, net	16,607	28,937	4,277
Other assets	37,709	57,745	17,673
Liabilities	980,613	1,609,816	351,410
Deposits	778,310	1,301,360	255,261
Interbank and money market items	61,369	99,817	22,921
Debt issued and borrowings	89,301	123,777	54,826
Other liabilities	51,632	84,863	18,402
Equity	109,325	182,530	36,121
Total liabilities and equity	1,089,938	1,792,346	387,531
Liquidity ratio	27.82%	28.46%	24.87%
Debt to equity ratio	89.97%	89.82%	90.68%
Loan to deposit ratio	110.28%	108.43%	119.71%

Note: Figures represent averages over 40 quarters, 2007-2016. Liquidity ratio is calculated as the sum of cash, interbank and money market items, and investment in securities divided by total assets.Source: Authors' calculation.

4. Estimation results

We begin this section with estimation of the degree of pass-through from the policy rate to various short-term retail rates. This will show whether these rates react differentially to the policy rate, which is the premise for the bank lending channel to exist. That is, if interest rates in the banking system adjust differentially in response to a change in the policy rate, then banks should reallocate their portfolios, including loans, accordingly to restore profit maximization. Two estimation approaches are commonly adopted in the literature, the autoregressive distributed lag (ARDL) model and the vector error correction (VEC) model (de Bondt, 2005). Each of these has its advantages, so we employ both. After testing for the degree of pass-through, we estimate the system of bank supply and demand equations, then use the estimated coefficients to compute the time-dependent elasticities of supply and demand. Lastly, we use the pass-through results together with the estimated time-dependent elasticities to simulate the dynamic impacts of changes in the policy rate on bank loan quantities as well as the magnitudes of other assets and liabilities in bank portfolios.

4.1. Interest rate pass-through

In our specification of the transmission mechanism of the bank lending channel, the short-term retail rates of interest include the loan rate, the deposit rate, and the interbank rate. The loan rate is viewed as an output price, while the deposit rate and the interbank rate represent the marginal cost of funding to finance bank loans and investments. Because Eqs. (5)–(9) representing bank demands and supplies are homogeneous of degree zero in all interest rates, banks will not alter their portfolio allocations unless a change in the policy rate causes non-proportional changes in these interest rates resulting from incomplete pass-through. Hence, it is vital to first examine the pass-through degree from the policy rate to these interest rates.

The 1-day bilateral repurchase rate (RP) is the official policy rate employed by the Bank of Thailand. The minimum loan rate (MLR),[12] the 3-month deposit rate, and the interbank rate are used to represent the money market rates facing banks. Monthly data on these rates are reported by the Bank of Thailand.

We first analyze the degree of interest rate pass-through using an ARDL model. This method involves estimation of a single regression equation for each retail interest rate in which the lagged dependent variable and the policy rate are used as regressors. The approach offers three advantages. First, the ARDL model allows us to estimate not only the dynamics of the pass-through impacts, but also to test for cointegration and for long-run impacts, as with the traditional Error Correction Model (ECM). Second, as shown by Pesaran and Shin (1999), and unlike the traditional ECM model which requires all variables to be I(1), the ARDL can be used to estimate the cointegration relationship regardless of whether the variables are I(0) or I(1), and with no need to pre-specify which variables are I(0) or I(1). Third, unlike other methods of estimating cointegration relationships, the ARDL representation does not require symmetry of lag lengths, that is, the number of lag terms of each variable can differ (Pesaran and Shin, 1999). The ARDL model can be written as:

$$y_t = \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=1}^{q} \delta_j z_{t-j} + \upsilon_t \tag{14}$$

[12] MLR is the minimum loan rate that Thai banks charge customers. It is comparable with the prime rate in the US.

Table 2
p-Values for the Hardi LM test for panel unit roots.

Variable	All Banks		Big Banks		Small Banks	
	Level	Δ	Level	Δ	Level	Δ
x_1	0.0000	0.0752	0.0000	0.2215	0.0000	0.2003
x_2	0.0000	0.9770	0.0000	0.9222	0.0000	0.8910
x_3	0.0000	0.4199	0.0000	0.3962	0.0000	0.5756
x_4	0.0000	0.5159	0.0000	0.5981	0.0000	0.3024
x_5	0.0000	0.8655	0.0000	0.7687	0.0000	0.8988
$\sqrt{p_2/p_1}$	0.0000	0.9537	0.0000	0.9893	0.0000	0.6927
$\sqrt{p_3/p_1}$	0.0000	0.9406	0.0000	0.3977	0.0000	0.9007
$\sqrt{p_4/p_1}$	0.0000	0.9976	0.0573	0.9734	0.0000	0.9788
$\sqrt{p_5/p_1}$	0.0000	0.9983	0.0000	0.9697	0.0000	0.9842
$\sqrt{p_1/p_2}$	0.0000	0.9994	0.0645	0.9898	0.0000	0.6029
$\sqrt{p_3/p_2}$	0.0000	0.9992	0.0882	0.9894	0.0000	0.6614
$\sqrt{p_4/p_2}$	0.0001	0.9993	0.1030	0.9892	0.0000	0.9493
$\sqrt{p_5/p_2}$	0.0000	0.9992	0.0408	0.9887	0.0000	0.9563
$\sqrt{p_1/p_3}$	0.0000	0.6535	0.0000	0.5502	0.0000	0.7306
$\sqrt{p_2/p_3}$	0.0000	0.9962	0.0000	0.9849	0.0000	0.8036
$\sqrt{p_4/p_3}$	0.0000	0.9977	0.0003	0.9720	0.0000	0.9830
$\sqrt{p_5/p_3}$	0.0000	0.9937	0.0000	0.9370	0.0000	0.9836
$\sqrt{p_1/p_4}$	0.0000	0.9979	0.0198	0.9706	0.0000	0.9805
$\sqrt{p_2/p_4}$	0.0000	0.9966	0.0000	0.9844	0.0000	0.9634
$\sqrt{p_3/p_4}$	0.0000	0.9990	0.0000	0.9623	0.0000	0.9869
$\sqrt{p_5/p_4}$	0.0000	0.9978	0.0000	0.9645	0.0000	0.9839
$\sqrt{p_1/p_5}$	0.0000	0.9975	0.0000	0.9774	0.0000	0.9751
$\sqrt{p_2/p_5}$	0.0000	0.9981	0.0000	0.9850	0.0000	0.9701
$\sqrt{p_3/p_5}$	0.0000	0.9982	0.0000	0.9686	0.0000	0.9850
$\sqrt{p_4/p_5}$	0.0000	0.9983	0.0000	0.9793	0.0000	0.9828

Note: x_1, x_2, x_3, x_4 and x_5 are quantity of loans, investments, deposits, bonds, and interbank borrowings, respectively; p_1, p_2, p_3, p_4 and p_5 are loan rate, rate of return on investment; deposit rate, borrowing rate, and interbank rate.

Eq. (14) is generally labeled as ARDL(p,q) where p and q are the numbers of lags of the dependent variable (y) and the independent variable (z), respectively, and the variable υ is the error term. The dependent variables in our analysis include the loan rate (MLR), the 3-month deposit rate, and the interbank rate, whereas the independent variable is the 1-day repurchase rate (RP) as the policy rate. The numbers of lag lengths are selected based on a set of post-estimation diagnostic tests, including the Breusch Pagan Lagrange Multiplier test (BP LM test) for autocorrelation in the residual term, the autoregressive conditional heteroscedasticity test (ARCH test), the augmented Dickey-Fuller test (ADF test) for stationary residuals, and the Ramsey test for functional-form misspecification (RESET test). In addition, the standard F-test for joint significance of coefficients is utilized.

ARDL estimation results for pass-through of the policy rate to the loan rate, the deposit rate, and the interbank rate along with post-estimation diagnostic tests are shown in Table 4. The null hypothesizes of the BP LM and ARCH tests are accepted at a 10% significance level, indicating no serial correlation and no heteroscedasticity in the residual terms. We reject the null hypothesis of the ADF test on residuals at the 1% significance level, meaning that the residual term is I(0). The RESET test detects no functional form misspecification. The standard F-test concludes that the coefficients are jointly significant at a 1% significance level. The dynamic impacts are calculated and tested for statistical significance using a WALD test, and the Bound test is used to test for cointegration and the statistical significance of the long-run impacts. The Bound test validates a cointegration relationship between the policy rate and bank retail interest rates at a 90% confidence level or above.

From Table 4, we can infer differential adjustments among interest rates in response to a permanent increase in the policy rate. A permanent increase in the policy rate of 100 basis points leads to immediate increases in the loan rate, deposit rate, and interbank rate of 40.79, 58.13, and 66.58 basis points, respectively. All of these estimated impacts, including the 3-month and 6-month impacts, are statistically different from zero at a significance level of 0.01. The dynamic evolution of these rates over a time horizon of 24 months is illustrated in Fig. 1. The loan rate and the deposit rate move along with each other, so that a nearly constant spread between them is maintained. All three rates appear to overshoot in the short run. The loan rate and the deposit rate reach their peaks in the sixth month, after which they slowly descend toward their long-run levels of 43.44 and 58.11 basis points. Our results of the incomplete and sluggish pass-through of the loan and deposit rate evince the kind of financial market imperfections described in Sections 1 and 2. The low impact of the policy rate on the deposit rate indicates the low degree of substitutability between deposits and central bank loans as sources of funds for commercial banks (Agénor and Montiel, 1996). On the other hand, the interbank rate adjusts more quickly as it takes only three month to reach the peak, and within 10 months converges to its long-run level of 97.48 basis points. It should be noted that the long-run relationship

Table 3
Summary statistics.

Variable		All Banks		Big Banks		Small Banks	
		Level	First Difference	Level	First Difference	Level	First Difference
x_1	Mean	732,394	14,255	1,195,567	24,159	269,220	4,350
	S.D.	28,063	1,569	27,974	2,515	14,813	1,594
x_2	Mean	158,612	3,366	262,084	6,075	55,141	657
	S.D.	7,581	1,808	10,462	3,526	3,660	775
x_3	Mean	778,310	14,098	1,301,360	23,859	255,261	4,337
	S.D.	32,212	2,030	34,027	3,379	15,921	2,034
x_4	Mean	89,301	1,143	123,777	1,994	54,826	293
	S.D.	2,655	992	3,453	1,674	3,008	1,064
x_5	Mean	61,369	2,066	99,817	3,633	22,921	498
	S.D.	3,183	992	4,799	1,891	1,652	581
$\sqrt{p_2/p_1}$	Mean	0.9153	−0.0046	0.7005	−0.0057	1.1300	−0.0034
	S.D.	0.0207	0.0096	0.0101	0.0119	0.0339	0.0151
$\sqrt{p_3/p_1}$	Mean	0.6991	−0.0088	0.5080	−0.0049	0.8903	−0.0126
	S.D.	0.0150	0.0033	0.0057	0.0023	0.0225	0.0063
$\sqrt{p_4/p_1}$	Mean	0.9632	−0.0006	0.8650	−0.0055	1.0613	−0.0064
	S.D.	0.0139	0.0106	0.0112	0.0133	0.0235	0.0167
$\sqrt{p_5/p_1}$	Mean	0.7069	−0.0074	0.5852	−0.0031	0.8287	−0.0116
	S.D.	0.0155	0.0087	0.0121	0.0096	0.0258	0.0146
$\sqrt{p_1/p_2}$	Mean	1.2765	0.0092	1.5351	0.0130	1.0179	0.0055
	S.D.	0.0347	0.0410	0.0594	0.0857	0.0248	0.0078
$\sqrt{p_3/p_2}$	Mean	0.7955	−0.0055	0.7727	−0.0008	0.8183	−0.0102
	S.D.	0.0172	0.0232	0.0317	0.0455	0.0131	0.0097
$\sqrt{p_4/p_2}$	Mean	1.1720	0.0016	1.3281	0.0046	1.0157	−0.0014
	S.D.	0.0305	0.0398	0.0542	0.0773	0.0235	0.0194
$\sqrt{p_5/p_2}$	Mean	0.8167	0.0016	0.8825	0.0020	0.7509	−0.0092
	S.D.	0.0189	0.0398	0.0339	0.0460	0.0155	0.0144
$\sqrt{p_1/p_3}$	Mean	1.6456	0.0186	2.0214	0.0188	1.2697	0.0185
	S.D.	0.2740	0.0060	0.0242	0.0100	0.0317	0.0068
$\sqrt{p_2/p_3}$	Mean	1.3442	0.0059	1.4039	0.0012	1.2844	0.0106
	S.D.	0.1655	0.0162	0.0242	0.0277	0.0218	0.0145
$\sqrt{p_4/p_3}$	Mean	1.4945	0.0100	1.7404	0.0076	1.2487	0.0124
	S.D.	0.0221	0.0163	0.0274	0.0246	0.0247	0.0214
$\sqrt{p_5/p_3}$	Mean	1.0548	0.0019	1.1782	0.0036	0.9315	0.0003
	S.D.	0.1744	0.0127	0.0285	0.0199	0.0160	0.0158
$\sqrt{p_1/p_4}$	Mean	1.1148	0.0060	1.1805	0.0048	1.0490	0.0054
	S.D.	0.0152	0.0122	0.0104	0.0114	0.0278	0.0217
$\sqrt{p_2/p_4}$	Mean	0.9655	−0.0005	0.8279	−0.0027	1.1030	0.0017
	S.D.	0.0178	0.0147	0.0145	0.0169	0.0294	0.0240
$\sqrt{p_3/p_4}$	Mean	0.7291	−0.0045	0.5978	−0.0027	0.8605	−0.0063
	S.D.	0.0118	0.0097	0.0081	0.0061	0.0178	0.0184
$\sqrt{p_5/p_4}$	Mean	0.7434	−0.0032	0.6922	−0.0004	0.7946	−0.0060
	S.D.	0.0126	0.0113	0.0162	0.0136	0.0187	0.0180
$\sqrt{p_1/p_5}$	Mean	1.6406	0.0160	1.8402	0.0121	1.4410	0.0199
	S.D.	0.0299	0.0197	0.0347	0.0296	0.0444	0.0261
$\sqrt{p_2/p_5}$	Mean	1.3567	0.0045	1.2766	−0.0032	1.4367	0.0122
	S.D.	0.0209	0.0202	0.0291	0.0302	0.0289	0.0268
$\sqrt{p_3/p_5}$	Mean	1.0337	−0.0015	0.9291	−0.0034	1.1382	0.0004
	S.D.	0.0149	0.0133	0.0189	0.0160	0.0205	0.0212
$\sqrt{p_4/p_5}$	Mean	1.5068	0.0079	1.5943	0.0026	1.4193	0.0132
	S.D.	0.0278	0.0266	0.0377	0.0396	0.0400	0.0357

Notes: x_1, x_2, x_3, x_4 and x_5 are quantity of loans, investments, deposits, bonds, and interbank borrowings, respectively in million baht; p_1, p_2, p_3, p_4 and p_5 are loan rate, rate of return on investment; deposit rate, borrowing rate, and interbank rate.Source: Authors' calculation.

between the policy rate and the interbank rate is almost one-to-one, reflecting near perfect substitutability between the interbank market and repurchase transactions with the central bank as funding sources for banks.

Next, we reexamine interest rate pass-through using a VEC model in order to affirm and compare with the ARDL results. The VEC model differs from the ARDL model in three aspects. First, when all variables are I(1), the VEC model provides useful information on both the long-run relationship through the cointegration vector and the short-run relationship through the error correction mechanism. Second, the VEC model allows for the possibility of more than one cointegration vector. Third, with the VEC model, all variables, i.e. bank retail interest rates and the policy rate, are treated as endogenous and allowed to

Table 4
ARDL estimation results for interest rate pass-through.

	Loan rate	Deposit rate	Interbank rate
Immediate impact	0.4079***	0.5813***	0.6658***
3-month impact	0.5085***	0.7377***	1.0271***
6-month impact	0.6448***	0.7582***	0.9442***
Long-run impact	0.4344***	0.5811***	0.9748***
ARDL(p, q)[a]	(1,6)	(1, 6)	(4, 1)
Adjusted R^2	0.97	0.98	0.63
Diagnostic tests			
Bound test	9.78***	5.06**	3.49*
F-test	117255***	6286***	12,104***
ADF test for residual	−11.62***	−11.09***	−12.04***
B-P LM test[b]	1.18 (p-value = 0.32)	0.42 (p-value = 0.89)	2.48 (p-value = 0.05)
ARCH test[c]	0.58 (p-value = 0.99)	6.97 (p-value = 0.43)	0.21 (p-value = 0.99)
RESET test	2.65 (p-value = 0.11)	2.08 (p-value = 0.15)	0.01 (p-value = 0.95)

Note:
[a]Lag-lengths of (2,7), (1,2), and (4,2) are suggested for MLR, deposit rate, and interbank rate, respectively, by HQ, SIC, and adjusted R^2. However, the lag-lengths are slightly adjusted so that the estimation results can pass all tests.
[b,c]The numbers of lagged residuals used equal the number of the highest order lag in the estimation so are the degrees of freedom of the test statistics which are distributed as Chi-squared. They are 6, 6, and 4 for MLR, deposit rate, and interbank rate, respectively.
*, **, and *** indicate significance at 0.10, 0.05, and 0.01, respectively.

interact with each other. Dynamic adjustment in the policy rate in response to changes in bank retail rates can be viewed as the monetary policy authority's discretionary reaction to the market.

The VEC model of the interest rest rate pass through is specified in Eq. (15).

$$\Delta \mathbf{y}_t = \mathbf{v} + \prod \mathbf{y}_{t-1} \sum_{i=1}^{p-1} \Gamma_i \Delta \mathbf{y}_{t-i} + \boldsymbol{\upsilon}_t \tag{15}$$

where $\mathbf{y}_t$ is a 4×1 vector of variables consisting of retail bank rates, namely the loan rate (MLR), the deposit rate (DEPOSIT), the interbank rate (INTERBANK), and the policy rate (RP); $\mathbf{v}$ is a 4×1 vector of constants; $\boldsymbol{\upsilon}$ is a 4×1 vector of disturbances; Γ_i is a 4×4 matrix of parameters; $\prod$ is a 4×4 matrix whose rank, r, determines the number of cointegration vectors. $\prod$ can be decomposed into $\prod = \boldsymbol{\alpha}\boldsymbol{\beta}'$, where $\boldsymbol{\alpha}$ is the 4xr adjustment vector representing the speed of adjustments of the variables toward long-run equilibrium, and $\boldsymbol{\beta}$ is the 4xr cointegration vector, reflecting the linear relationships among the variables in long-run equilibrium.

Before VEC estimation, it is crucial to determine that all variables are I(1). Results of the ADF test are given in Table 5. For the level data the null hypothesis is not rejected, while for the first-differenced data it can be rejected at the 1% significance level. Hence, the ADF test gives a conclusion that all series are I(1) at the 1% significance level.

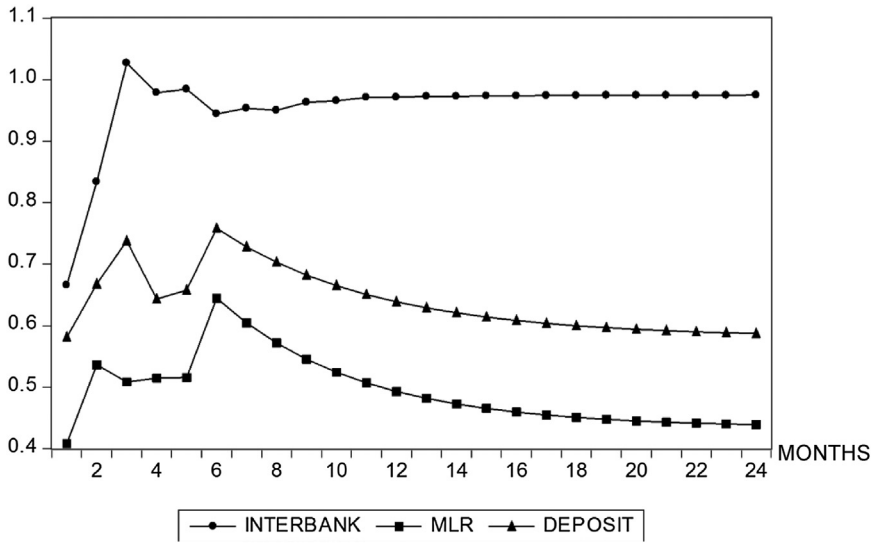

Fig. 1. Pass-through in response to a 100 basis point increase in the policy rate (in %).

Table 5
ADF test results for unit roots.

	Level	First difference
Loan rate (MLR)	−2.4277	−7.9169***
3-month deposit rate (DEPOSIT)	−1.0513	−7.1972***
Interbank rate (INTERBANK)	−1.2286	−5.0576***
Policy rate (RP)	−1.1706	−5.9978***

Note:
1. *, **, and *** indicate significance at 0.10, 0.05, and 0.01, respectively.
2. Lag length specification in the test is suggested by SIC.
3. The test equation includes an intercept but no trend.

Having shown that all variables are I(1), we need to determine whether there is at least one linear combination of these variables which is I(0), i.e. they are cointegrated. The Johansen cointegration test is conducted to determine the number of cointegrating vectors. The cointegration relationship is normalized on the interbank rate. The number of lags in the test equation is 6 which is suggested by the likelihood ratio (LR) and the Akaike information criterion (AIC). The trace test indicates one cointegrating equation at a 0.05 significance level. The estimates of the cointegrating vector and the adjustment coefficients are presented in Table 6.

The estimated cointegration vector of Table 6 can be written as

$$\text{INTERBANK}_t + 1.1085 - 0.1940\text{MLR}_t - 0.9123\text{DEPOSIT}_t - 0.3528\text{RP}_t = 0 \quad (16)$$

The long-run impact of the policy rate on the interbank rate can be computed by taking the derivative of the interbank rate in Eq. (16) with respect to the policy rate (RP), i.e. ∂INTERBANK/∂RP. The result indicates that given a 100 basis point increase in the policy rate, the interbank rate will increase by 35.28 basis points in the long run. The estimated cointegration vector also enables us to calculate the long-run impact of a 100 basis point change in the policy rate on the loan rate and the deposit rate, i.e., ∂MLR/∂RP and ∂DEPOSIT/∂RP as -181.85 and -38.67 basis points, respectively. The long-run interest rate pass-through is positive but incomplete for the interbank rate, while it turns out to be negative for the loan rate and the deposit rate. The speed of adjustment coefficients reveal that deviations from the long-run equilibrium are corrected at a rate per month of 10.18% for the loan rate, 40.70% for the deposit rate, 13.91% for the interbank rate, and 33.66% for the policy rate. The negative adjustment coefficient on the interbank rate means that when the interbank rate is too high relative to the long-run equilibrium, it falls back toward the equilibrium level. On the other hand, the positive adjustment coefficients of the loan rate, the deposit rate, and the policy rate imply that when the interbank rate is too high, these interest rates will rise toward the long-run equilibrium.

Our estimates of long-run interest rate pass-through are compared with those of two other studies for Thailand in Table 7. Both studies estimate long-run pass-through using monthly data and the error correction model (ECM). The degree of long-run pass through obtained from our VEC estimates is noticeably different from our ARDL results and the other two studies because the policy rate is treated as endogenous in the multivariate VEC allowing for joint adjustment in response to changes in the banking sector interest rates. On the other hand, the policy rate is treated as exogenous in the univariate ARDL and ECM approaches, so the pass-through degree is a result of a permanent 100-basis point increase in the policy rate. Our attention is focused on the ARDL and ECM results instead of the VEC results for two reasons. First, endogeneity of the policy rate in VEC seems unrealistic because the monetary authority does not tend to adjust the policy rate on a monthly basis in response to

Table 6
VEC estimation results for interest rate pass-through.

Cointegrating vector ($\boldsymbol{\beta}$)	
Loan rate (MLR)	−0.1940***
Deposit rate (DEPOSIT)	−0.9123***
Interbank rate (INTERBANK)	1
Policy rate (RP)	−0.3528***
Intercept	1.1085***

	Δloan rate	Δdeposit rate	Δinterbank rate	Δpolicy rate
Adjustment coefficient ($\boldsymbol{\alpha}$)	0.1018	0.4070***	−0.1391	0.3366***
Adjusted R-squared	0.4645	0.6091	0.5471	0.7791
AIC	−2.1893	−1.9873	−1.4624	−1.9983
F-statistic	5.0489***	8.2744***	6.6374***	17.4583***
LM B-P test[a]	15.3654 (p-value = 0.4981)			
White heteroskedasticity test	1130*** (p-value = 0.2585)			

Note: *, **, and *** indicate significance of 0.10, 0.05, and 0.01, respectively.
[a] The number of lags used in the LM B–P test shown 7, but the test is performed on 1 up to 7 lags and all of the null hypotheses are accepted indicating no serial correlation in the disturbance up to 7 lags.

Table 7
Comparison of the long-run interest rate pass-through in Thailand across studies.

	This study		Disyatat and Vongsinsirikul (2003)	Charoenseang and Manakit (2007)
Sample period	2007–2016		1989–2002	2000–2006
Method	VEC	ARDL	ECM	ECM
Loan rate	−1.8185	0.4344	0.36	0.2543
Deposit rate	−0.3867	0.5811	0.35	0.5268
Interbank rate	0.3528	0.9748	–	0.9639

Note:
1. The deposit rate in Charoenseang and Manakit (2007) is the average of 3 and 6 month time deposit rates.
2. The policy rate in the previous two studies is the 14-day repurchase rate.

changes in the banking-sector interest rates. Second, our ARDL results for pass-through are more appropriate for simulating the dynamic impacts of a permanent change in the policy rate by 100 basis points on bank loan supply and portfolio allocation.

Our ARDL pass-through estimates for the loan and deposit rates are considerably higher than those of Disyatat and Vongsinsirikul (2003). This might be due to a more competitive and mature banking sector in Thailand after 2002 which may be expected to facilitate interest rate pass-through. On the other hand, our ARDL estimates for the deposit rate and the interbank rate are very close to those of Charoenseang and Manakit (2007), although their loan rate estimate is much stickier than ours, perhaps because their sample spans a recession period following the financial crisis of 1997 when banks might have been reluctant to raise the loan rate for fear of losing market share. Both our ARDL results and those of Charoenseang and Manakit shown almost complete pass-through from the policy rate to the interbank rate, implying that the interbank rate is well under the control of the Bank of Thailand. Hence, in the next section, it is imperative to focus on whether bank loan supply is sensitive to a change in the interbank rate as evidence of the existence of the bank lending channel. Past studies in which the interbank lending rate was adopted as a monetary policy indicator include Kubo (2008) for Thailand, Altunbaş et al. (2002) for the EU, and Gambacorta (2005) for Italy.

Despite the evidence that a policy rate adjustment results in movement in bank interest rates, including the loan rate, the existence of the bank lending channel is still ambiguous. A rise in bank loan rates after a monetary tightening may not necessarily cause a shift in bank loan supply, especially in the presence of asymmetric information and credit rationing (Stiglitz and Weiss, 1981). In order to resolve this identification problem, we turn to the question of whether a rise in the policy rate can induce banks to adjust their loan supply, as well as other balance-sheet items. We estimate the time-dependent elasticities of bank loan supply and demand for funding, and use these elasticity estimates to explore changes in the structure of bank balance sheets after a rise in the policy rate is transmitted to the banking sector interest rates.

4.2. Estimation of bank supply and demand equations and elasticities

In this section, we estimate bank supply equations for loans and investment and demand equations for funding from deposits, debt issuance, and interbank borrowing (Eqs. (5)–(9)) using our balanced panel data set and the GMM technique described in Section 3. The first-order lagged dependent variables are included as regressors to capture partial adjustment in the dependent variables where coefficients, λ_j for $j = 1, 2, 3, 4, 5$, represent the speed of adjustment. These right-hand side dependent variables are instrumented by all other regressors regarded as predetermined, and the second-order lagged dependent variables regarded as the exogenous variables excluded from the regression. Following Kashyap and Stein (1995), we first estimate the equations using the full sample of all banks and then using the samples for big banks and small banks separately. The estimation results are reported in Table 8.

Table 8 illustrates the responsiveness of changes in bank loans, investments, deposits, debts issued, and interbank borrowings to changes in the relevant interest rates. The Hausman statistic tests of the comparison between the results of equation-by-equation OLS and the GMM estimates indicate that endogeneity is detected and that GMM estimation is thus warranted. In addition, the p-values of the Sargan tests for the three regressions are 0.16, 0.21, and 0.21, so we accept the null hypotheses at above the 90% confident level that our specified instruments are valid, i.e. they are uncorrelated with the error terms.

Almost all estimates in Table 8 are highly statistically significant. Two groups of these estimates deserve special attention and should be interpreted before proceeding to further analysis. First, in all but one case, the estimates of λ_2 and λ_3 do not lie within the proper range of 0 to 1 despite their statistical signficance. We thus infer that there is no partial adjustment process toward long-run equilibrium for bank investments and deposits, and will abstain from using these estimates for computation of the time-dependent elasticites and the analysis of dynamic adjustment. Note further that λ_1 for the big-bank group is equal to 0.25, which is substantially smaller than the small-bank group's comparable estimate of 0.76. That implies that loan adjustment toward long-run equilibrium is much slower for big banks than for small banks, maybe because by nature big banks concentrate on lending long-term to large companies, while small banks usually focus on short-term lending to small-and-medium enterprises (SMEs). Hence, big banks may be more constrained in adjusting lending.

Table 8
GMM estimates of bank supply and demand equations.

	All banks	Big banks	Small banks
α_{12}	−506	9050***	−10436***
	(622)	(306)	(525)
α_{13}	−45304***	−1174	−78905***
	(3094)	(4162)	(3170)
α_{14}	−11108***	−20934***	−2237***
	(1150)	(1196)	(316)
α_{15}	−6164***	−9396***	−13131***
	(1107)	(608)	(556)
α_{23}	−10219***	−19753***	9368***
	(1008)	(571)	(678)
α_{24}	1828***	2711***	−313*
	(367)	(296)	(160)
α_{25}	6585***	2276***	8831***
	(626)	(274)	(325)
α_{34}	6198***	12,128***	1824***
	(995)	(1181)	(324)
α_{35}	−13027***	−13645***	−1056**
	(1035)	(913)	(430)
α_{45}	−3330***	−3875***	−3230***
	(473)	(487)	(140)
λ_1	0.10***	0.25***	0.76***
	(0.03)	(0.02)	(0.01)
λ_2	1.85***	1.64***	1.45***
	(0.04)	(0.02)	(0.01)
λ_3	−0.34***	−0.24***	0.85***
	(0.04)	(0.02)	(0.01)
λ_4	0.50***	0.50***	0.76***
	(0.03)	(0.01)	(0.02)
λ_5	0.60***	0.61***	0.81***
	(0.04)	(0.02)	(0.02)
Sargan test (p-value)	0.16	0.21	0.21
Hausman test statistic	1340.85***	2215.7***	95.79***

Note:
1. α units are billion Thai baht per one percentage point change in interest rate.
2. Standard errors are shown in parentheses.
3. Instruments for the first-order lagged dependent variables, $\Delta x_{j,t-1}$ for $j = 1,2,3,4,5$, include the second-order lagged dependent variables, i.e. $\Delta x_{j,t-2}$ as well as all predetermined variables, i.e. $\Delta\sqrt{p_k/p_j}$ for $j,k = 1,2,3,4,5$ and $j \neq k$.
4. *, **, and *** denote statistical significance at 0.10, 0.05, and 0.01, respectively.

Second, but more importantly, the statistical significance of α_{15}, α_{25}, α_{35}, and α_{45} for all bank sizes represents responsiveness of bank loans, investments, deposits, and borrowings to a change in their respective interest rates relative to the interbank rate. Since we have shown that there is almost complete pass-through from the policy rate to the interbank rate, these results imply that the central bank can, ceteris paribus, influence banks' portfolio management including loans via an adjustment in the policy rate. In other words, these findings support the existence of the bank lending channel hypothesis.

The parameter estimates for the supply and demand equations provide the information needed to calculate own- and cross-price elasticities using Eqs. (10)–(13). Table 9 reports the derived own- and cross-price elasticities for all banks in the immediate run, evaluated at the arithmetic means. These elasticities represent percentage changes in the volume of bank outputs and inputs with respect to a change in their respective interest rates of one basis point ceteris paribus. Note that the sum of elasticities in each row is equal to zero, reflecting the zero-degree homogeneity in prices of supply and demand by construction.

Note first that loan supply (x_1) is quite elastic with respect to its own interest rate (p_1) and the deposit rate (p_3). A 100 basis point increase in the loan rate increases loan supply by 3.14% while a 100 basis point increase in the deposit rate reduces loan supply by 2.16%. On the other hand, the loan supply is inelastic with respect to the borrowing rate on debt instruments (p_4). Similarly, the elasticity of loan supply with respect to the rate of return on investment (p_2) is close to zero and statistically insignificant. To be highlighted, the elasticity of loan supply with respect to the interbank rate is negative and significantly different from zero. A 100 basis point increase in the interbank rate will cause loan supply to decrease by 0.41%. Since we have shown complete pass-through from the policy rate to the interbank rate, this finding means that monetary tightening by an increase in the policy rate will have a negative impact on bank lending, which is evidence to support the existence of the bank lending channel in Thailand.

Regarding the substitution between sources of loanable funds, our findings indicate that deposits and debts issued are complements to each other, but both are substitutes for interbank borrowing. The cross-price elasticities of demands for funding from deposits (x_3) and debt issued (x_4) with respect to the interbank rate (p_5) are 0.0125 and 0.0409, respectively.

Table 9
Immediate-run supply and demand elasticities for all banks.

	Loan rate (p_1)	Investment yield rate (p_2)	Deposit rate (p_3)	Debt instrument rate (p_4)	Interbank rate (p_5)
Loan supply (x_1)	0.0314***	−0.0003	−0.0216***	−0.0054***	−0.0041***
Investment supply (x_2)	−0.0020	−0.0013*	−0.0248***	0.0046***	0.0236***
Deposit demand (x_3)	0.0479***	0.0091***	−0.0653***	−0.0042***	0.0125***
Debt demand (x_4)	0.1485***	−0.0208***	−0.0522***	−0.1164***	0.0409***
Interbank demand (x_5)	0.0385***	−0.0366***	0.0532***	0.0139***	−0.0689***

Note:
1. *, **, and *** denote statistical significance at 0.10, 0.05, and 0.01, respectively.
2. All elasticites are evaluated at the arithmetic means.

This suggests that banks can alleviate the negative impact on their loans of tightening monetary policy by raising funds from deposits and debts issued. This also explains why the loan supply is not very sensitive to the interbank rate and monetary policy.

It seems puzzling why the market loan rate substantially increases after a rise in the policy rate, as established by the ARDL results in Section 4.1, despite a quite inelastic loan supply with respect to the interbank rate as shown in the first row of Table 9. That demand for bank loans might be relatively more inelastic is one possible interpretation to reconcile these results. Thailand's bond markets are still immature, so a majority of Thai corporations, especially SMEs, must rely heavily on bank loans, and find it difficult to substitute with bonds. This is evident by a large share of bank loans to total credit and very low cross-price substitution elasticity between bank loans and bonds found by Mahathanaseth and Tauer (2012).

Next, we look for differential responsiveness across bank sizes by comparing the elasticities of the big bank group against the small bank group in Table 10. The loan supply for big banks is much more inelastic than for small banks with respect to the loan rate. A 100 basis point increase in the loan rate results in just a 0.54% increase in the loan supply of big banks versus a 13.02% increase for small banks. Correspondingly, the loan supply of big banks is far less sensitive to all other interest rates, including the interbank rate, than that of small banks. A 100-basis point increase in the interbank rate brings about reductions in the loan supplies of big banks and small banks of 0.31% and 1.91%, respectively. This is consistent with prediction of Kashyap and Stein (1995) that monetary policy is mainly channeled through small banks which are usually less liquid and less well capitalized than large banks.

It appears that both big banks and small banks are able to substitute for interbank borrowings with deposits and external debt, whereas deposits and external debt are complements to each other, perhaps due to risk diversification practices. Nevertheless, the degree of substitutability of deposits for interbank borrowing for the small banks is much smaller than for big banks, probably because of small banks' limited ability to compete for savings with big banks and other depository institutions by raising their deposit rates in the face of the tightening monetary policy. As a result, big banks are less prone to substitute for interbank borrowings with relatively costly debt issuance than small banks, i.e. the cross elasticities of demand for debt funding with respect to the interbank rate are 3.12% and 6.71% for big and small banks, respectively.

Interestingly, the cross-price elasticity of demand for external borrowing with respect to the loan rate for big banks is very large, at 19.36% compared with that for small banks of only 4.85%. On the other hand, the elasticity of demand for deposits with respect to the loan rate of the small banks is quite high at 16.22%, whereas for big banks it is only 0.08% and not significantly different from zero. In other word, if the loan rate increases, big banks will acquire additional funding mainly by issuing debt instruments whereas small banks turn to acquiring deposits. Also, it can be seen in Table 1 that the loan-to-deposit ratios for small banks are higher than for big banks at 119.71% and 110.28%, respectively. These are amazingly high,

Table 10
Immediate-run supply and demand elasticities by bank size.

	Loan rate (p_1)	Investment yield rate (p_2)	Deposit rate (p_3)	Debt instrument rate (p_4)	Interbank rate (p_5)
Big Banks					
Loan supply (x_1)	0.0054***	0.0025***	−0.0002	−0.0045***	−0.0031***
Investment supply (x_2)	0.0225***	−0.0072***	−0.0239***	0.0037***	0.0049***
Deposit demand (x_3)	0.0008	0.0101***	−0.0146***	−0.0049***	0.0085***
Debt demand (x_4)	0.1936***	−0.0179***	−0.0548***	−0.1521***	0.0312***
Interbank demand (x_5)	0.0443***	−0.0077***	0.0313***	0.0103***	−0.0782***
Small Banks					
Loan supply (x_1)	0.1320***	−0.0162***	−0.0941***	−0.0026***	−0.0191***
Investment supply (x_2)	−0.0902***	−0.0423***	0.0610***	−0.0020*	0.0734***
Deposit demand (x_3)	0.1622***	−0.0187***	−0.1428***	−0.0027***	0.0021**
Debt demand (x_4)	0.0485***	0.0066*	−0.0297***	−0.0925***	0.0671***
Interbank demand (x_5)	0.1074***	−0.0733***	0.0067**	0.0196***	−0.0604***

Note:
1. *, **, and *** denote statistical significance at 0.10, 0.05, and 0.01, respectively.
2. All elasticites are evaluated at the arithmetic means.

Table 11
Portfolio response to a 100 basis point increase in the policy rate by bank size (in %).

	Loans		Investments		Deposits		Debt issued		Interbank	
Quarter	Big Banks	Small Banks	Big Banks	Small Banks	Big Banks	Small Banks	Big Banks	Small Banks	Big Banks	Small Banks
1	−0.06	−2.20	−0.11	7.46	−0.16	−2.08	9.01	7.17	−3.47	−0.25
2	−0.01	−0.96	0.10	5.74	−0.25	−0.49	15.78	8.92	−3.49	1.68
3	−0.03	−1.29	0.07	6.31	−0.13	−0.77	17.70	9.21	−4.32	0.82
4	−0.08	−1.67	0.06	6.58	−0.06	−1.04	17.92	9.21	−5.07	0.01
5	−0.13	−1.90	0.06	6.70	−0.03	−1.18	17.63	9.17	−5.58	−0.47
6	−0.17	−2.02	0.06	6.75	−0.01	−1.23	17.28	9.13	−5.89	−0.73
7	−0.21	−2.07	0.06	6.77	0.00	−1.25	17.00	9.11	−6.07	−0.87
8	−0.24	−2.10	0.06	6.78	0.01	−1.26	16.81	9.10	−6.18	−0.95
9	−0.26	−2.10	0.07	6.79	0.01	−1.25	16.69	9.10	−6.23	−0.99
10	−0.28	−2.11	0.07	6.79	0.02	−1.25	16.62	9.10	−6.27	−1.01
11	−0.30	−2.11	0.07	6.79	0.02	−1.25	16.57	9.10	−6.28	−1.02
12	−0.31	−2.11	0.07	6.79	0.02	−1.24	16.55	9.09	−6.29	−1.03
Long Run	−0.34	−2.11	0.07	6.79	0.02	−1.24	16.51	9.10	−6.31	−1.03

and reflect heavy reliance on sources of funding other than deposits. We infer from these findings that big banks should have a greater ability to raise external funds from borrowing to finance loans than small banks. These results are consistent with the Kashyap and Stein (1995) view that small banks have greater difficulty raising funding through external borrowing than big banks because they face more information problems and thus a higher external finance premium.

The relationship between loans and investments differs between big and small banks. For big banks, the positive cross-price elasticity of investment supply with respect to the loan rate implies that loans and investments are complements, perhaps due to risk diversifying strategies and economies of scope in production of loans and investments. On the other hand, for small banks, the cross-price elasticity of investment with respect to the loan rate is negative, suggesting that these are competing outputs. In other word, small banks face a tradeoff between extending loans and liquidating investments as a result of their financial constraint and limited ability to raise external funding.

In summary, we find that the loan supplies of both big and small banks are sensitive to the interbank rate, small banks more so than big banks. This provides evidence for the transmission of monetary policy through the bank lending channel. In addition, we find that both big and small banks are able to raise funding from deposits and debt issuance to alleviate the impact of monetary tightening. However, small banks are less effective in raising external funding than big banks.

4.3. Portfolio allocation dynamics

Under our transmission mechanism, an increase in the policy rate, on the one hand, raises the loan rate regarded as banks' marginal revenue, but on the other hand, it raises the deposit rate and the interbank rate, which constitute banks' marginal cost of funds. In this section we explore the dynamic effects of these processes on bank lending and portfolio allocation choices.

We simulate the responses of loans, investments, deposits, debt issuance, and interbank borrowing by multiplying the time-dependent elasticities computed from Eqs. (7)–(10) by the dynamic pass-through effects from the policy rate to the loan rate, deposit rate, and interbank rate obtained from the ARDL regressions. That is, we simulate the impact of simultaneous changes in p_1, p_3, and p_5 on x_1, x_2, x_3, x_4, and x_5. We assume that an increase in the policy rate does not affect the interest rates associated with bank investments and debt instruments thus keeping p_2 and p_3 constant over time due to our inability to simulate the pass-through effect for these items.[13]

Table 11 provides a picture of how big and small banks adjust their portfolio allocations over 12 quarters in response to a 100 basis point increase in the policy rate. The long-run impacts of a 100-basis point increase in the policy rate on loans are -0.34% for big banks and -2.11% for small banks. The adjustment paths for loans are illustrated graphically in Fig. 2. Clearly the monetary tightening has much greater dampening effect on the lending behavior of small banks, while big banks are quite insensitive to the monetary contraction. This is consistent with the Kashyap and Stein (1995) framework that monetary policy is mainly channeled through small banks because of their lower capacity to raise external funds.

As for investment, big banks see a decline of 0.11% in the first quarter, but then a turn around for an increase of 0.07% in the long run. By contrast, for small banks investment rises substantially by 6.79% in the long run. The increases in investment contradict the assessment of Kashyap and Stein (1995) that banks should liquidate some of their holdings in response to the liquidity squeeze imposed by monetary contraction. This may be the case for big banks in the short run. Longer term, big banks are able to obtain funding from other sources to sustain their lending. For small banks, investments and loans appear

[13] We use monthly data for estimation of interest rate pass-through but quarterly data for estimation of the time-dependent elasticities. To achieve compatibility, we match cumulative pass through for the third month of each quarter with the quarterly data, i.e., the cumulative pass-through for the third, sixth, ninth, and twelfth months corresponds with the first, second, third, and fourth quarters, respectively.

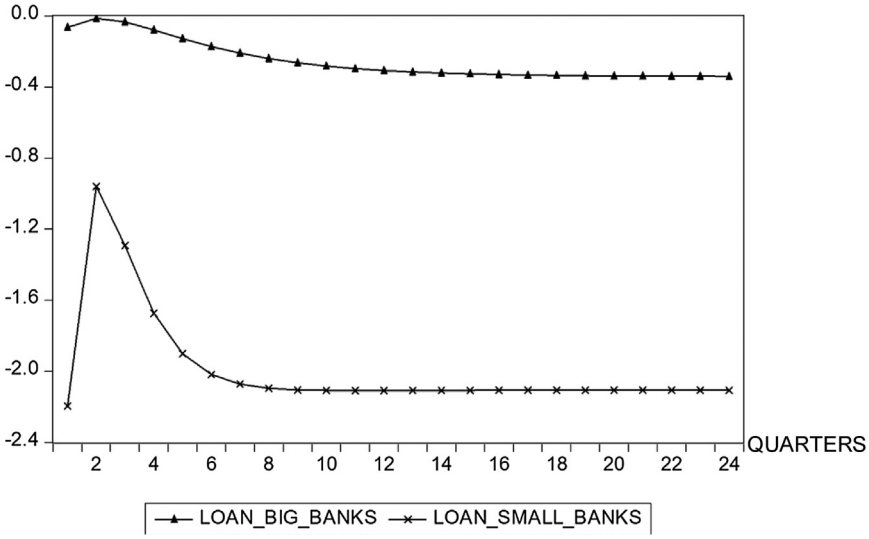

Fig. 2. Loan response to a 100-basis point increase in the policy rate by bank size (in %).

to be competing outputs. A contraction in lending by small banks due to a tightening in monetary policy may motivate them to divert funds from relatively high risk loan provision toward lower risk investments in securities and bonds.

Fig. 3 illustrates by bank size the responses in interbank borrowing and debt issued to a policy rate change. We have already shown that an increase in the policy rate has almost complete long-run pass-through to the interbank rate. Thus, an increase in the policy rate will raise the interbank rate resulting in a decline in the demand for interbank borrowing by 6.31% for big banks and 1.03% for small banks in the long run. At the same time, both big and small banks are able to allay this adverse impact by issuing more debt instruments. After monetary tightening, the volume of debt issued by big banks rises by 16.51% and for small banks by 9.10% in the long run. It is clear that big banks have greater capacity to replace interbank borrowings with new debt creation than small banks, probably because of a lower external finance premium.

Finally, the deposit rate, too, rises due to pass-through from a policy rate increase. For small banks, the higher cost of deposits along with the accompanying decline in loan supply lowers the demand for deposits by 1.25% in the long run. However, for big banks, demand for deposits changes negligibly because loan supply declines only slightly, and this is mostly offset by relatively low cost debt issuance to substitute for the reduction in interbank borrowing.

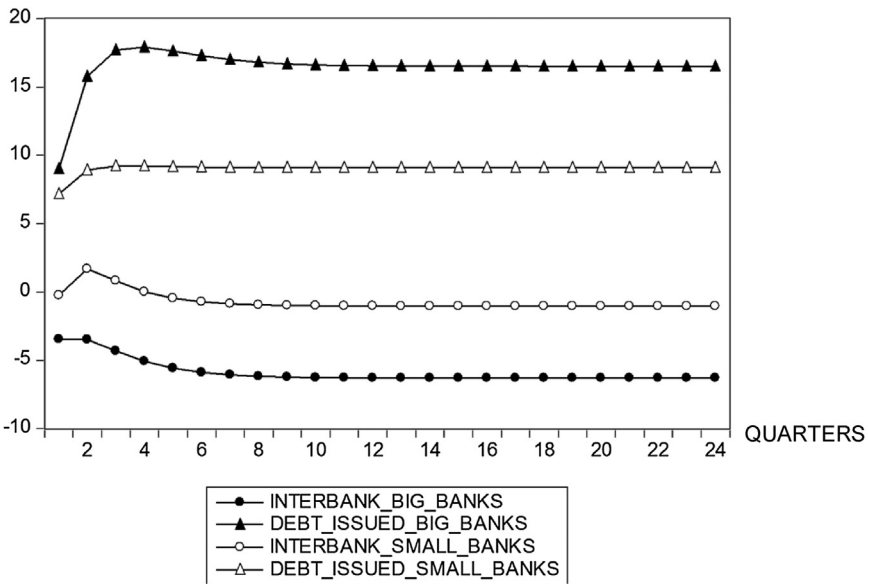

Fig. 3. Response of debt issuance and interbank borrowing to a 100 basis point increase in the policy rate by bank size (in %).

Overall, our findings are consistent with the monetary policy transmission mechanism through the bank lending channel. That is, a monetary policy tightening can cause banks to curtail their loan supply in the long run, because a rise in the policy rate increases loan production costs relative to the loan rate. In addition, the monetary tightening appears to have a greater impact on the loan supply of small banks than big banks. For big banks the impact of a monetary tightening on loan supply largely subsides because of the substitution of debt issuance for foregone interbank borrowing.

5. Conclusion

We investigated the importance of the bank lending channel in Thailand against the argument that ongoing financial development might have downgraded the intermediary role of the banking sector as well as its role as a conduit of monetary policy transmission. To this end we used disaggregated bank balance sheet to estimate not only the degree of pass-through from the policy rate to bank market rates, but also the own- and cross-price elasticities of banks' supply of loans and demand for funding. With this information we were able to simulate the outcome of an increase in the policy rate for bank portfolio structure, including loans.

We find complete pass-through from the policy rate to the interbank rate, implying perfect substitution between interbank loans and central bank loans, such that the interbank rate is shown to be an effective target rate. On the other hand, the pass-through from the policy rate to loan and deposit rates is incomplete. The low and sluggish impact of the policy rate on bank retail rates might be associated with remaining market imperfections and financial frictions in the Thai economy despite progress toward deregulation. Comparing our results to previous studies, however, we find an increase in the speed and magnitude of the impact of the policy rate on loan and deposit rates, which might be attributable to increased competition, more foreign penetration, and deregulation under the financial master plans introduced by the Bank of Thailand during 2004 - 2014. The higher degree of interest rate pass-through could facilitate and amplify the impact of monetary policy through the bank lending channel.

The estimated own- and cross-price elasticities assert not only that bank lending responds to the interbank rate (i.e., the effective target rate), but also that the loan supply of small banks is far more sensitive to the interbank rate than that of big banks. Low cross-price elasticity of demand for deposits with respect to the interbank rate, especially for small banks, indicates low substitutability of deposits for borrowings from the interbank market. This finding suggests a disinclination of banks to offset a drainage in loanable funds caused by monetary tightening by acquiring more deposits, which complements the finding of a low degree of policy rate pass-through to the deposit rate. Instead, external debt issuance appears to substitute for borrowing from the interbank market. Still, it is more difficult for small banks to acquire external funds by issuing debt than it is for big banks. This supports the hypothesis that small banks face a higher external debt premium than big banks.

Finally, we explored the dynamics of bank portfolio adjustment by incorporating the derived time-dependent elasticities with the interest rate pass-through estimates. We found that in the long run, monetary tightening induces banks to curtail their loan supply and their demand for interbank borrowing which they partly replace with debt issuance. These findings suggest that, in addition to the direct interest rate channel, the impact of monetary policy in Thailand is partly channeled through the credit provision of the banking sector. Therefore, notwithstanding ongoing development of the Thai financial sector, the Bank of Thailand can implement monetary policy to effectively control fluctuations in the real economy in both the short run and long run, through interest rate adjustments that transmit to consumption and investment expenditures of households and firms which are bank-loan dependent. However, the Bank of Thailand must be aware in the conduct of monetary policy that its actions will affect bank balance sheets and consequently the soundness of the banking system.

There are still some interesting issues left for future research. First, bank loan supply could be disaggregated into various types by purpose, such as consumption, investment, housing, and agriculture, each of which might respond differently to monetary policy. Second, due to data limitations on the interest rate paid on bank debt instruments and the yield rate on investments in held in bank portfolios, the pass-through of the policy rate to these rates was not estimated. Estimation of pass-through to these rates will allow for more realistic dynamic simulations of bank portfolio adjustment in response to monetary policy action. Third, it would be useful to estimate the demand for bank loans using data on bank customers to explore how they react to changes in bank loan rates.

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