The role of a banking market concentration in the effect of monetary policy on bank risk: Evidence from Thailand

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บทบาทของระดับการกระจุกตัวของตลาดธนาคารในประเทศไทยต่อผลกระทบของนโยบายทางการเงินบนความเสี่ยงของธนาคาร

น.ส.ศศิชนก คงทิพย์

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This research investigates the effect of monetary policy on bank risk exposure and the role of banking market concentration in affecting their relationship by using the data of 11 commercial banks listed in the Stock Exchange of Thailand at the quarterly frequency over the period of 2001-2019. The different measurements of bank risk exposure variables and monetary policy indicators given interest rate changes from the previous quarters, interest rate variations relative to their long-term trends, low interest rates and prolonged low interest rates are applied to secure the robustness in estimation results based on dynamic model namely the two-step system GMM estimator, while five variables of macroeconomic conditions and seven variables of bank-specific characteristics are controlled. Further, the focused explanatory variable of banking market concentration by asset size is incorporated as the interaction term with monetary policy indicators to study its effect on the relationship between monetary policy stance and bank risk exposure. Consistent with the previous literature, the main results of this study suggest that bank risk exposure increases when a monetary policy easing is implemented through not only lowering interest rates relative to the previous quarters and their long-term trends, but also low interest rates and the extended period of low interest rates. Though, such impacts on bank risk exposure during an expansionary monetary policy are mitigated by more concentration in banking market.

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1. INTRODUCTION

1.1) Background and Significance of the problem

The banking system has been dedicated to be a key financial intermediary of overall economic units in the Association of South East Asian Nations (ASEAN), well-perceived as an important impetus of global economic growth. Over the past 23 years since the Asian financial crisis throughout 1997-1998, the banking market structure has continually reformed across the countries. In particular, the introduction of the ASEAN Banking Integration Framework (ABIF) in 2014 has encouraged cross-border mergers and acquisition activities to promote the financial sector liberalization and the banking sector stability with the ultimate goal of economic development sustainability for the region, which in turn has raised attention to the issue of the concentration in a local banking market to pursue the financial resource accumulation in efforts to strengthen domestic banks' market position and their capabilities to expand business presences in overseas as concluded by Uddin & Suzuki (2014).

Other than two essential responsibilities of central banks in stabilizing the price level and taming the different phases of business cycles, the main objective of the banking system stability necessitates the participation of central banks because the Global financial crisis in the years of 2007-2009 arguably arises from excessive risk-taking of banks as a consequence of a loose monetary policy. Due to this event, "the risk-taking channel" has been pointed to a transmission mechanism of monetary policy whose stance can affect the banks' risk tolerances or risk perceptions, Borio and Zhu (2012). The accommodative monetary policy stance either to lower interest rates or to hold low interest rates for a consecutive period could incentivize bank risk-taking, probably leading to weakening the stability of financial systems.

In general, banks' behaviors to seek more risky investment projects can be motivated by low interest rates and interest rate declines, which can shape risk perceptions of banks' managers because the risk assessment method, cash flow valuation, and balance sheet of banks are also directly linked to the interest rate risk that also includes banks' criteria setup for financial performance evaluation from expanding their lending for maintaining the required return to achieve banks' financial targets. In

addition to respective banks' risk perceptions, the monetary policy stance of either expansion or contraction and an anticipated policy accommodation of central banks to cushion the economy can also shift risk tolerances of investors. Besides, the positive association between a relaxed monetary policy and bank risk-taking behavior has been broadly documented in the developed countries such as the United States, the Europe, and the United Kingdom during the pre-crisis period from 2002 to 2005 (Jiménez et al., 2014; Rajan, 2011; Taylor, 2007).

After the Global financial crisis, the prolonged period of low interest rates with the intention of central banks to stimulus the economies have further suppressed banks' profitability against the backdrop of the regulatory framework reform that requires higher-quality capital and liquidity of banks to secure banking system resilience to any shocks, which triggers more banking sector consolidation in the developed economies evident by a remarkable fall in a number of market players in the United State and European countries in order to achieve scales efficiencies by reducing overcapacities and enhance profit margins of banks. As documented by Chaffai and Dietsch (1999), banks' overcapacities could bring about an excessive risk-taking in which banks incur risk incremental without the sufficient level of returns. This leads to the investigations on the role of a banking market concentration in affecting the association of monetary policy with bank risk-taking. For instances, a high market power can reduce risk-taking of banks during an expansionary monetary policy due to the possible reasons as follows: less banks' incentive to search for yield from a high barrier to entry of new rivals; lower costs of external capital raising from more access to other alternative sources of funds; better performing in the presence of informational asymmetries problems. Notwithstanding the potential buffering effect of market consolidation, it may cause more risk-taking of banks due to their presumptions of being better protected from "too big to fail" and the relaxation on risk controls because of less competitive pressure.

Similar to other members of ASEAN countries, Thai banking sector has been a primary source of funds to support overall economic activities especially for the private sector which is a significant driving force of Thai economy proven by more than 100% domestic bank credit to private sector over GDP ratio at the fifth rank of

the ratio among ASEAN members in 2019 based on World Bank's data statistics. In addition, the monetary policy implementation has apparently transmitted through the risk-taking channel of banks reflected on a higher percentage of domestic bank credit to GDP from around 100% in 2011 to the approximate range of 110%-115% since 2012 until the present when a relaxed monetary policy has been executed and going through the period of a low interest rate environment in conjunction with a significant hike in Thai-based commercial banks' non-performing loans (NPL) of about 64% from 2011 to 2019 on yearly basis *(Figure1)*. In the meantime, domestic commercial banks of Thailand have started the financial restructure process in the aftermath of the Asian financial crisis since 1997 alongside an increasing number of mergers and acquisitions among small banks over time. Nevertheless, due to the establishment of the Financial Sector Master Plan (FSMP) in January 2004 to endorse the competition and widen the access to a financial resource for reinforcing financial efficiency, it gives rise to new bank licenses issued by the Bank of Thailand (BOT), and then newcomers have entered into a domestic banking industry; for instance, TISCO bank in 2005, Land and House bank in 2006 that signals intensifying the competition environment in the banking system. On top of that, Thai banking market has been highly concentrated over the period from 2001 to 2019, indicated by the concentration ratio of the five largest banks and the Herfindahl- Hirschman Index, according to the report of Prayoonrattana J., Laosuthi T., Chaivichayachat, B. (2020).

However, a number of relevant researches in the context of Thailand representing as a developing economy is sparse to fill the gap of studying the linkage between the role of a banking market concentration and bank risk exposure in response to monetary policy stances. This paper thereby intends to contribute to the current literature by providing more comprehensive understandings on this area in Thailand where the analysis of prior studies has mostly focused on the impact of monetary policy stances from either interest rate changes (M. Chen et al., 2017) or low interest rates (Ratanavararak L. & Ananchotikul N., 2018; Charnvitayapong K., 2020) on bank risk exposure with the unsettling results. That is, Charnvitayapong K. (2020) suggests that bank risk exposure increases in the low interest rate period, whilst there is no statistical significance on this relation for the bank-level data reported by

Ratanavararak L. & Ananchotikul N. (2018). The findings of M. Chen et al. (2017) conclude that banks are likely to undertake more risk when the monetary policy stance is expansionary, but a banking market consolidation is a contributing factor to subside the exert impact of such a monetary shock on bank risk exposure.

Hence, the researcher's advancing objectives are to incorporate such monetary policy stances attributable to the properties of Thai money market by introducing the two separated econometric models to determine the banks' risk exposure given interest rate changes and low interest rates and subsequently to add another determinant of banking market concentration into the consideration on the relationship between each of cited monetary transmission and bank risk exposure that is disregarded in the papers of Ratanavararak L. & Ananchotikul N. (2018) and Charnvitayapong K. (2020). The paper employs the bank-level panel data of 11 commercial banks listed in Thailand at the quarterly frequency under the single period from the first quarter of 2001 to the fourth quarter of 2019. Further, the four models in this study primarily use an econometric model and the estimation method similarly to M. Chen et al. (2017) and Ratanavararak L. & Ananchotikul N. (2018) by taking account of the monetary policy indicators for both such interest rate changes and a low interest rate environment, together with adapting the different measurement approach for a prolonged period of low interest rates using the Hodrick–Prescott filter-based approximation of Altunbas et al. (2012) to illustrate another mean of this indicator through the cyclical effect on interest rate variations. The researcher follows the measurement of a market concentration based on M. Chen et al. (2017), but extends the observation window for this explanatory variable to cover the initiation of the Banking Integration Framework (BIF) in 2014 until 2019.

Concerning Thai banking industry that encounters challenges from eased monetary policy and the unique market structure condition over time, this research seeks to find the specific implications on the connections among monetary policy stances, bank risk, and banking market concentration for delivering the complementary evidence to any related analysis in view of developing countries and suggestions made from the empirical results of the study which could be informative to the decision-making process for monetary authorities such as policymakers to be aware of the side-effects

of monetary policy implementation and regulators in initiating proper policies regarding banking market concentration for ensuring the financial system stability and sustainable growth in the country's economy.

The paper is organized as the following: literature review in section 2; data description, model specification, estimation method in section 3; empirical result in section 4; and conclusion in section 5.

1.2) Research objectives

The research objective of this study is to investigate the effect of banking market concentration on the relationship between monetary policy stances and bank risk exposure in Thailand so as to justify whether a banking market concentration has merit or demerit to the banking system stability when considering the monetary policy transmission through interest rate adjustments. Not only in case of interest rate changes is implemented, low interest rates facing commercial banks are also taken into consideration of determining their impacts on bank risk exposure in response to a change in banking market concentration.

The specified objectives for this research are as follows:

1. To determine the impact of interest rate changes on bank risk exposure.

2. To determine the impact of low interest rates on bank risk exposure.

3. To determine the impact of banking market concentration on the relationship between interest rate changes and bank risk exposure.

4. To determine the impact of banking market concentration on the relationship between low interest rates on bank risk exposure.

2. LITERATURE REVIEW

2.1) Impact of monetary policy on bank risk

There have been several studies on the monetary policy transmission mechanism through the risk-taking channels which can be represented as the lending channel reflected on the balance sheet of the banks (Alpanda & Aysun, 2012). Alternatively stated, the impact of market interest rate movements on banks' risk tolerances is

considered as one of key transmission mechanisms of monetary policy through the bank lending channel (Borio & Zhu, 2012). The extant evidence suggests that when a loose monetary policy implements a decrease in an interest rate, this should drive banks' incentive to more aggressively "search for yield". That is, low interest rates may encourage banks to move toward more risky assets from a low-risk asset portfolio with a low return caused by their business objective to achieve the targeted rate of nominal returns which could potentially emerge from the behavioral bias regardless of the real economic conditions such as inflation, inevitable actions of the institutions searching for yields to meet the required rate of returns by law in some countries, and long-term contracts of committed liabilities that banks are obliged to provide specified returns. Given low policy rates, banks are thus seeking higher yields on assets (Rajan, 2006). According to Ackermann et al., 1999; Kouwenberg and Ziemba, 2007, there are also other driving factors such as a compensation scheme for the management, poor supervision, and legal concerns that provoke excessive risks undertaken by banks during the period of low policy rates.

Another aspect of the monetary policy effect on banks' risk is "valuation effect" in such a way that the valuations on banks' income, asset, and cash flow including their risk measurements are dictated by low interest rates. As suggested by Adrian and Shin, 2009, 2010; Borio and Zhu, 2012, since the effect of low interest rates on banks' valuation increases a value of banks' balance sheets or reduce their risk perceptions by incurring a lower default probability from higher collateral values and less price volatility, the different measurement methods of banks' risk-taking abilities are triggered by low interest rates.

Other than the perspectives of banks on the supply side, greater bank risk-taking could derive from the demand side of investors. The "habit formation" stated by Campbell and Cochrane (1999) could be deemed as one of the plausible explanations to describe the impact of monetary policy on banks' risk. In other words, the changing in investors' risk-taking behavior occurs in the different phases of monetary expansion or contraction. Given a low interest rate environment, the spur of economic activities during the monetary expansion phase induces investors to become less risk-averse.

Furthermore, “insurance effect” is a contributing factor to the positive relationship between the monetary policy and banks’ risk. When monetary policy implementations by the central banks to continually support the economy could be expected to persist, investors are likely willing to take excessive risks from which such accommodative policies may play a role as an insurance against bad times or even for good times (Diamond and Rajan, 2009).

Consistent with the aforesaid evidence, many empirical results (Delis and Kouretas, 2011; Buch et al., 2014; Ioannidou et al., 2015; Jiménez et al., 2014; M. Chen et al., 2017, are second to a significantly positive association of bank risk with monetary policy implementation, particularly in low interest rates during expansionary monetary policy which leads to intensified risk-taking of banks. Likewise, prolonged low interest rates may induce banks to undertake more risk as evidenced by the findings of Ramayandi et al. (2014) in ten Asian countries from 2000 through 2011, and Cecchetti et al. (2017)’s study unveils an increase in the leverage ratio of banks and non-banks during the times of a prolonged monetary policy easing.

Besides the precedent evidences discovered across countries, the existing literature by Ratanavararak L. & Ananchotikul N. (2018) of a low interest rate environment impact on a bank’s profitability and bank risk-taking in Thailand from the first quarter of 2004 to the third quarter of 2017 documents that the effect of low interest rates on bank risk measured by Z-score, risk-weighted asset ratio and Non-performing loan (NPL) ratio using bank-level data of 23 banks at the quarterly frequency are statistically insignificant, presumable by a conservative monetary policy stance, a strong risk management of Thai banks as well as stricter regulations on banks’ operations during the studying period. On the other hand by using loan-level data, low interest rates significantly increase the default risk on loan with a decline in loan portfolio quality of small-and medium-sized banks. Despite an insignificant result of the previous work, Charnvitayapong K. (2020) extends the study of Ratanavararak L. & Ananchotikul N. (2018) with the three different risk measures which are Loan loss provision to gross loan, Capital adequacy ratio, and Leverage ratio by collecting the data of 19 commercial banks from the first quarter of 2001 to the first quarter of 2019

and explores that the impact of a low interest rate environment on bank risk-taking is positive on aggregate.

2.2) Impact of banking market concentration on the relationship between monetary policy and bank risk

The extant studies of banking system concentration impact on bank risk have been controversially documented under the two different respects of recent literature based on the competition-fragility and competition-stability hypotheses. From the viewpoint of the competition-fragility hypothesis as proposed by the studies of Marcus (1984); Keeley (1990); Demsetz et al. (1996), a higher competition among banks reduces a market power (concentration) leading to a thin profit margin that drives bank risk-taking with a climb in NPL levels. Given high competition of banking market, fewer restrictions on lending criteria are imposed by banks to increase their market shares, so the poor-performed borrowers will be likely obtaining loans and thus a hike in NPL levels. Nonetheless, there are some arguments against these results according to the paper of Petersen and Rajan (1995) in which startup firms with a low credit quality receive more bank finance in a consolidated banking industry comparing with those in a more competitive market and the relationship between banking market concentration and NPLs is positively significant, Breuer (2006). For the competition-stability view, the more market power a bank has, the lower default risk it incurs by having a larger capital reserve by comparison with asset size, Keeley (1990). Likewise, Agoraki et al. (2011) shows that banks with a high market power incline to confront the lower levels of credit risk and default probability, and Dell'Ariccia et al. (2014) concludes that dominant banks tend to possess less risk appetite. In contrast to Hussain & Bashir (2019), overly market power banks price higher rates on their loans, which brings about a default of debtors and hence a risk increment.

Aside from the mixed results of studying the relationship between bank risk and such a structural market attribute as a banking market concentration, this study also aims to introduce a monetary policy transmission mechanism into the analysis on whether the concentration of banking system is connected with the effect of accommodative monetary policy by interest rate decreases and low interest rates on bank risk exposure. According to the previous work of Brissimis, Iosifidi, & Delis, 2014, a

monetary policy transmission through risk-taking channels of banks is influenced by banks' market power and there are reasons given in the prior literature why banking market concentration could feasibly affect bank risk exposure in response to the transmission mechanism of monetary policy in many ways as the following. Firstly, a higher market consolidation can prevent new entries of the competitors which results in a larger net interest margin for dominant banks, so they are less willingly to take more risk in searching for yield than smaller banks when a loose monetary policy and, hence a market concentration can wane bank-risk taking (Koetter et al., 2012). Secondly, banks with excessive market power benefit from not only having more access to alternative funding sources, but also acquiring more acknowledge to address the problem of informational asymmetries, which causes relatively lower costs of external capital raising (Kashyap and Stein, 1995; Jayaratne and Morgan, 2000). Thus, these banks' lending is less responsive to an expansionary monetary policy, which could reduce their risk exposure. Thirdly, banks in a more concentrated market are less prone to suffer from the adverse selection problem as stated by Dell'Ariccia and Marquez (2009). Even though lower interest rates during an expansionary monetary policy incentivize banks to lean toward a riskier loan portfolio by weakening their screening standards on borrowers, increases in loan amount to new poor credit quality firms are less substantial in more consolidated markets. Consequently, a market concentration can decrease the impact of relaxed monetary policy on banks' lending. On the contrary, banks holding a market dominance may be driven to take more risk in beliefs of which they are better protected from being "too big to fail" (Afonso et al., 2014) and by undermining risk managements from a lower market competition. Taken altogether, these influences of a banking market consolidation on the relationship between bank risk and a monetary policy transmission are not yet settled, so a banking system consolidation could either increase or decrease bank risk exposure in response to the monetary policy easing.

Besides, a few studies have also been conducted in a similar area by using evidence from Thai banking market structure. The investigation on the relationship between the consolidation in banking market and the lending channel of monetary transmission by Olivero et al. (2011) using bank-level data from Asian and Latin American countries

for the period from 1996 to 2006 finds the evidence that the effectiveness of the monetary policy transmission mechanism through banks' lending channel measured by a loan growth is subsided due to an increase in the banking market consolidation being inferred as lower market competition, as suggested by the empirical study of Khan et al., 2017. Such a conclusion is made by the data set of the banking industry from the selected five prime countries (ASEAN-5) i.e., Malaysia, Indonesia, Singapore, Philippines, and Thailand during the period from 1995 to 2014 with many different measures of a market structure. Khan et al. (2016) developed the original work of Olivero et al. (2011) by proposing several alternative measures of a market structure determinant for banking markets in ASEAN region over the period from 1999 to 2014 and reported the conformable findings that lending channel of banks responding to monetary policy shocks is less sensitive when the competition level reduces.

Although the empirical results of the abovementioned research could draw the implication for the counteracting effect of a banking system concentration on the association between bank risk exposure and a monetary shock, the extant literature regarding the focused analysis of this study still contains inconclusive results. The findings of M. Chen et al. (2017) have shed some light on which a banking industry concentration acts as a factor affecting the relationship between monetary policy transmission and bank risk exposure by using the sample of bank-level panel data from 29 emerging countries including Thailand over the years of 2000-2012 and explore that the impact of monetary policy on bank risk exposure is lessened in more consolidated banking systems. Contrary to the conclusion of Charnvitayapong K. (2020), banks with more assets tend to incur a higher risk, implying that a concentration by asset size may increase banks' riskiness in the low interest rate period.

Yet, the prior investigations on the nexus between a banking market concentration, monetary policy stance, and bank risk exposure in context of Thailand has limited to the particular cases in either interest rate shocks (M. Chen et al., 2017) or low interest rates (Ratanavararak L. & Ananchotikul N., 2018; Charnvitayapong K., 2020) with the different observation period. Further, the interaction term of monetary policy

indicator with a market structure factor considered as a special interest of this study on bank risk exposure has not been studied in a low interest rate environment. Concerning changes in conditions of Thai banking market structure over time, this study using the quarterly data of banks over the period of 2001 to 2019 may explore the different evidence on the role of a market concentration from the prior suggestions of M. Chen et al. (2017) with the annual bank-level data that could be valid till 2012 and at the quarterly frequency will help capturing the short-run dynamic effects of interest rate changes on bank risk. As a result, the researcher analyzes both scenarios of interest rate changes and low interest rates under the single observation period from 2001 to 2019 and the same set of control variables with a primary objective to provide a broader viewpoint for the effect of monetary policy transmission through both interest rate adjustments and low interest rates on bank risk exposure in response to a change in banking market concentration.

3. DATA AND METHODOLOGY

3.1) Hypothesis development and variables

The different indicators of bank risk exposure have been defined in the relevant literatures, which are mostly calculated by using the accounting data. The common measures of bank risk include Z-score index (e.g., Laeven and Levine, 2009; Turk Ariss, 2010; Beck et al., 2013; M. Chen et al., 2017; Ratanavararak L. & Ananchotikul N.; 2018), the nonperforming loan, and loan loss provision (e.g., Delis and Kouretas, 2011; Kasman and Kasman, 2015; Tan, 2016; M. Chen et al. 2017; Ratanavararak L. & Ananchotikul N., 2018; Charnvitayapong K., 2020). The Z-score index is extensively applied for an implication of overall financial stability of individual banks accounting for banks' profitability, leverage, and return volatility, while the nonperforming loan (NPL) and loan loss provision (LLP) are typical measures of credit risk exposure inherent with banks' loan portfolio quality which are regarded as one of the most important types of banks' credit risk to be closely monitored by regulators because greater values of NPL and LLP suggest higher default probability of an individual bank and hence the financial system instability. Other than these risk variables, standard deviations of return on asset and return on equity (e.g., Lepetit et al., 2008; Pennathur et al.; 2012) are adopted to represent the

risks of banks' income to bank itself on aggregate and to shareholders, respectively and other alternative risk proxies of banks proposed by the previous empirical works (e.g., Paligorova and Santos, 2012; Charnvitayapong K., 2020) through banks' financing structure are capital adequacy ratio and leverage ratio. A hike in capital adequacy ratio points to a decline in bank risk, but a rise in leverage ratio amplifies bank risk.

The three risk measures used in this paper rely on accounting data of Thai commercial banks for a quarterly basis are Z-score index ($Z_{i,t}$) represented in the form of the natural logarithm as the level of risk exposure for individual banks at that point of time as can be expressed below, non-performing loan (NPL) to total loans, and loan loss provision (LLP) to total loans because these three variables can describe a wide perspective of banks' risk exposure in terms of banks' credit risk and insolvency risk.

$$Z_{i,t} = \frac{ROA_{i,t} + EA_{i,t}}{\sigma(ROA)_{i,t}}$$

where $ROA_{i,t}$ is the after-tax profit divided by total assets of bank i in quarter t, $EA_{i,t}$ is the ratio of equity to total assets, and $\sigma(ROA)_{i,t}$ is the standard deviation of return on assets. To account for changes in banks' management strategies and lending behaviors over time, the time-varying Z-score with a five-quarter rolling time window is used to generate the mean and standard deviation of ROA over the previous 5 quarters for each observation to allow for changes in their risk exposure in a one-year horizon (Zhang, Xie, Lu, and Zhang, 2016), while using the value of equity-to-total asset ratio for the current period. Further, using the 5-quarter averaged ROA could reflect an aggregate return to be aligned with changes in bank's risk profile over the same period that also includes the persistent effect of banks' profitability during the rolling window. This index is commonly applied in the literature to describe the relationship between the return volatility and a bank's capital, which intuitively explains how much capital and profit of a bank could maintain to absorb its return volatility without becoming insolvent given when its capital drops to zero or can be interpreted as a distance to bank's failure by a number of standard deviations. That is, a bank's return on assets would have to shrink to eliminate all of its equity and a higher value of Z-score denotes a lower risk of bank meaning that a larger number of

a bank's asset return drop would be required to put the bank into insolvency relative to that of a bank with a higher risk and vice versa.

The risk indicators (i.e., Z-score index, ratios of NPL and LLP) used in this study could reflect banks' risk attitude independent of economic conditions since bank risk could be driven by other bank-specific determinants. For instance; in accordance with the investigations based on literature review, banks' profitability could change banks' risk incentive (Rajan, 2006). In other words, more profitable banks are less likely to search for yield with their lending strategies leaning towards a low-risky portfolio and hence their abilities to accelerate a capital accumulation that causes an increase in banks' solvency proxied by Z-score index and lower credit risk proxied by NPL and LLP ratios. The larger profitability of banks could possibly be characterized by facing less information asymmetry (Mankiw, 1986) and less riskiness of operations as can be indicated by NPL and LLP ratio. Besides, the current literature (e.g., Mishra & Modi, 2013; Wang, 2016) finds that higher profitability decreases bank-specific risks as it allows bank to posses a comparative advantage in resilience to shocks. Meanwhile, Bessler et al. (2015) discovers that banks with higher levels of loan loss provision imply more exposure to idiosyncratic risk.

These risk measures are to be statistically tested for determining their relationships with explanatory variables of monetary policy indicators and the banking market structure under the developed four hypotheses as constructed by the literature review in the previous section which will be illustrated as follows:

1. Monetary policy stances have an impact on bank risk exposure. This research contributes to the prior relevant works of M. Chen et al. (2017) centering on solely interest rate movements to represent the monetary transmission mechanism on bank risk exposure, but neglecting the role of low interest rates that dominates the character of Thai money market since the second quarter of 2015. In addition to Ratanavararak L. & Ananchotikul N. (2018) and Charnvitayapong K. (2020) studying bank risk exposure attributable to only a low interest rate environment, the researcher therefore combines both respects into a single period of data set, and these relationships are built into baseline econometric models closely to M. Chen et al. (2017) and Ratanavararak L. & Ananchotikul N. (2018) in equation (1) and equation (2) for

interest rate changes and low interest rates, respectively. The description, measurement, expected sign along with the supporting literature for each concerned variable will be provided after the stated equations as below.

Equation (1): $$\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 \Delta r_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$$

Equation (2): $$\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 Lowrate_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$$

where $\Delta Risk_{i,t}$ is the quarterly change in the risk measure of bank i at time t

b_2, b_3, b_4 are the vectors of a coefficient to be estimated;

α_i are the unobserved bank-fixed effect;

Δr_t *and* $Lowrate_t$ are the vectors of independent variables representing a monetary policy indicator;

$Macro_t$ *and* $BankChar_{i,t-1}$ are the vectors of control variables.

Short-term interest rates perform as the key instrument of a monetary policy under Open Market Operations (OMOs) in the Thai money market[1] by often running counter-cyclical interest rates for maintaining the stability in economic outputs on aggregate. Therefore, the researcher employs the interest rate-based monetary policy indicators by constituting these vectors of interest rate adjustments and low interest rates with the two alternative measurements for each one totaling at the four proxies that comprise the first two symbols of Δr_t_Int and Δr_t_HP for changes in a short-term interest rate and others denoted by $Lowrate_t\_Int$ and $Lowrate_i\_HP$ for a low level of short-term interest rate. In doing so, it enables the researcher to secure the robustness in the empirical results

First, Δr_t_Int is defined by the changes in short-term interest rates commonly used as the measure of monetary policy in the prior studies e.g., Ashcraft (2006), Khan et al. (2016), M. Chen et al. (2017), and its value can be either positive from a higher

[1] The description is based on the website of the Bank of Thailand. See: https://www.bot.or.th/English/BOTStoryTelling/Pages/MonetaryPolicy_StoryTelling_AcademicAndFI.aspx

interest rate than the previous period or otherwise negative as means of tightened and loosened monetary policy stances in order. Unlike Ratanavararak L. & Ananchotikul N. (2018), and Charnvitayapong K. (2020) using the policy rate, the proxy of short-term interest rate in this paper uses three-month interbank interest rates or average interbank overnight lending rates if three-month interbank interest rates are unavailable because it represents the policy rate and assesses the marginal costs of banks' short-term funding, and selecting either one of the two would not cause a statistically significant change in the results owing to high correlations between these two measures as suggested by Borio and Gambacorta (2017) studying the impact of money market rate changes during the low interest rate period on banks' lending dynamics. Second, Δr_t_HP is measured by the Hodrick-Prescott filter (Hodrick and Prescott, 1997) in line with M. Chen et al. (2017) to derive the deviation of short-term interest rates from the benchmark interest rates referring to "natural interest rates", being calculated by Hodrick-Prescott filter[2] known as one of the most frequently used methods for detrending time series data, and such a deviation defines a cyclical component of short-term interest rates with a negative (positive) value interpreted as more expansionary (contractionary) monetary policy stance relative to the normality. Third, $Lowrate_t\_Int$ is the dummy variable taking the value of 1 if the three-month interbank interest rate is lower than the median of interest rates for the whole distribution and 0 elsewhere by the common adoption of Borio and Gambacorta (2017) and Ratanavararak L. & Ananchotikul N. (2018). Fourth, $Lowrate_t\_HP$ is introduced as the development to the proxy of Ratanavararak L. & Ananchotikul N. (2018) and measured by a number of consecutive quarters that the resultant cyclical component of three-month interbank rate implied by the Hodrick-Prescott filter is negative particularly to reflect the prolonged period of low interest rates, similarly to Altunbas et al. (2012). The last two variables suggest that the monetary policy accommodation by holding interest rates at the low levels is enacted when short-term interest rates are below the benchmark rates approximated by the median value of interest rate distribution and the implied interest rates in the long-term trends by

[2] See more details in Appendix B based on the website of the Organisation for Economic Cooperation and Development (OECD), https://www.oecd-ilibrary.org/sites/361fabc3-en/index.html?itemId=/content/component/361fabc3-en

Hodrick-Prescott filter, and vice versa. According to *Figure 3* (Appendix G), the two indicators of a low interest rate environment are divided into the period given the value of 1 where a short-term interest rate is lower than its median at 1.88% for a whole distribution and the prolonged period of low interest rates represented by a number of consecutive quarters being counted when a cyclical component of short-term interest rates based on HP filter is negative. The value of this variable is ranged from 0 to 14, the maximum quarters cumulated on the condition of a negative cyclical component of short-term interest rates.

As reviewed through the existing literature; for example, Campbell and Cochrane (1999), Rajan (2006), Borio and Zhu (2012), Jiménez et al., 2014, Ioannidou et al. (2015), M. Chen et al. (2017), and Charnvitayapong K. (2020), a monetary policy easing in both cases of interest rate declines and low interest rates could induce a bank to expose more risk, so the effect of interest rate changes is expected to be positive on the coefficient of Z-score, but negative on those of NPL and loan loss provision to total loans. As for low interest rates, the study draws the anticipations contrary to the monetary shocks for interest rate changes on the three proxies of bank risk exposure.

2. The role of a banking market concentration has been broadly studied in ASEAN economies arising from the reformation of a banking sector supporting a main part of economic systems through major external shifts such as the financial crises, deregulations, and the recent promotion of Banking Integration Framework under the ultimate goal to strengthen the financial stability and sustain the regional economic development. The consensus on this topic has not yet been drawn whether a bank market concentration has merit or demerit to the sector stability, specifically when introducing a monetary policy transmission. Taking the character of Thai banking market structure into consideration of bank risk exposure in response to monetary policy stances for both changes in interest rates and low interest rates, equation (3) and equation (4) are established and advanced from the two baseline econometric models stated above with adding the interaction terms to measure the marginal effect of banking market concentration on bank risk exposure responding to the monetary policy transmission as exhibited in the following:

Equation (3): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 \Delta r_t + c_1 HHI_t + c_2 (HHI * \Delta r)_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

Equation (4): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 Lowrate_t + c_1 HHI_t + c_2 (HHI * Lowrate)_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

where $\Delta Risk_{i,t}$ is the quarterly change in the risk measure of bank i at time t

b_2, b_3, b_4, c_1 are the vectors of a coefficient to be estimated;

c_2 is the marginal effect of banking market concentration on bank risk exposure in response to a monetary policy transmission;

α_i are the unobserved bank-fixed effect;

Δr_t *and* $Lowrate_t$ are the vectors of independent variables representing a monetary policy indicator;

HHI_t are the vectors of an independent variable representing a market structure indicator;

$Macro_t$ *and* $BankChar_{i,t-1}$ are the vectors of control variables.

In estimating the market structure indicator, this paper selects the measure of market concentration based on the structural approach as employed by M. Chen et al. (2017), Ratanavararak L. & Ananchotikul N. (2018), and Charnvitayapong K. (2020) to the extent that more concentrated market shares of banks lead to lower competitions among market participants as evident by Khan et al., 2017. Instead of using the five-bank concentration ratio (CR5) derived from the shares of the five largest banks' total assets against all banks in the industry, the Herfindahl-Hirschman Index, abbreviated to HHI provides a more accurate measure of a banking market structure by comparison to CR5 because the HHI incorporates the shares of all banks' asset sizes in the sample data set. The Herfindahl-Hirschman Index (HHI_t) is the sum of the squares of total assets' shares of commercial banks listed in the Stock Exchange of Thailand (SET). According to the author's classification criteria used in this research to identify the level of concentration, the indicators of HHI can be divided into three levels: the 10th percentile; 50th percentile; 90th percentile of HHI distribution, such a

level of market concentration is classified as low, moderate, high in tandem. The *Figure 4* (Appendix H) according to the author's calculation demonstrates the market structure in Thai banking system during the sample period.

The prior studies regarding the impact of a banking market concentration on bank risk such as Petersen and Rajan (1995), Breuer (2006) and Hussain & Bashir (2019) find that a banking market concentration intensifies banks' risk appetites which is consistent with the relevant literature conducted in Thailand of M. Chen et al. (2017), Ratanavararak L. & Ananchotikul N. (2018), but documents no strong evidence in overall. Therefore, the structural market indicator for a market concentration is predicted to be negative on the coefficient on Z-score, but positively correlated with those on NPL and LLP ratios.

However, the interaction terms between monetary policy and market concentration measure i.e., $(HHI * \Delta r)_t$, $(HHI * Lowrate)_t$ are counted into the regression and added to the independent variables of Ratanavararak L. & Ananchotikul N. (2018) and Charnvitayapong K. (2020) in order to examine the role of banking market concentration in effecting the relationship between risk exposure of banks and monetary policy stances for interest rate adjustments and a low interest rate environment. Although the previous literature of Charnvitayapong K. (2020) discovers that banks with more assets appear to undertake a greater risk in case of low interest rates, this implication of the concentration proxied by the interaction term of low interest rates with the logarithm of asset size drawn from the findings may not be comparable with this study due to its exclusion of an interactive term of a market structure with a monetary policy indicator. Thus, the result of a main variable of interest is drawn align with the suggestion of M. Chen et al. (2017) that the consolidation in a banking system is considered as a buffer against the adverse influence of a relaxed monetary policy for both cases of interest rate declines and low interest rates on bank risk exposure similarly to Jayaratne and Morgan (2000), Dell'Ariccia and Marquez (2009) and Koetter et al. (2012). Albeit there has been no conclusive result for determining this interaction term in the low interest rate period of Thailand, a monetary policy transmission by holding low interest rates could feasibly share the similar evidence based on the case of lower interest rates that can be

treated as the same stance of a loosened monetary policy. Considering above, the interaction terms between banking market concentration and monetary policy indicator are prospected to be positive on the coefficients of NPL and LLP to total loans, but negative on that of Z-score during an expansionary monetary policy by negative changes in interest rates, and otherwise in the low interest rate period.

This research introduces the series of macroeconomic conditions and bank-specific characteristics as control variables due to the anticipation of bank risk exposure affected by macroeconomic and bank-specific characteristic determinants. By controlling these variables, estimates of coefficients on explanatory variables of the monetary policy indicators, banking market concentration, and interaction terms should be more valid. The researcher adopts the works of Olivero et al. (2011), Borio and Gambacorta (2017), M. Chen et al. (2017), and Ratanavararak L. & Ananchotikul N. (2018) for both sets of control variables.

First, the vectors of macroeconomic condition controls ($Macro_t$) comprise five variables: the quarterly real GDP growth (lngdp) and Inflation based on Consumer Price Index (lncpi) to reflect dynamics in the business cycle conditions. A drop in NPL is significantly affected by GDP growth (Louzis et al., 2012) and the debt repayment capabilities of borrowers are exacerbated by a contraction in their real incomes from higher inflation rate (Makri et al., 2014); the credit-to-GDP gap ratio (creditgap) to account for the variation in credit demand relative to the economic size from its long-run trend. With the sufficient liquidity, a greater loan demand during economic upturns could probably bring about a climb in credit growth, which outweighs a demand increase driven by the economic fundamentals as normally measured by credit-to-GDP growth (Dell'Ariccia et al., 2012). This points to an excessive bank risk-taking with lowering its lending standards to pursue a loan growth by more than organically justified by economic conditions (Jimenez and Saurina, 2006); a dummy variable of crisis (crisis_dummy) that takes the value of 1 if in the crisis period over 2008-2009 and 0 otherwise to incorporate the potential impact on bank risk during the crisis period since banks would tend to bear a greater risk during a crisis period; the yield curve slope (lnys) measured by the difference between the

three-month interbank interest rate and the 10-year government bond yield to consider the interest rate forecast and the investors' expectations on the future monetary policy conditions concerning economic outlooks. As asserted by Albertazzi and Gambacorta (2009), the steeper yield curve as a result of expected monetary tightening to decelerate economic output expansion strengthens banks' profitability characterized by longer maturity of assets than that of liabilities, which implicitly reduces in bank risk exposure.

Second, the vectors of bank-specific characteristic factors ($BankChar_{i,t-1}$) consist of seven variables: Bank's size (lnasset) or the natural logarithm of asset size. A concern of "too big to fail" may arise from a large-sized bank having an incentive to involve with riskier activities when it is believed to be protected by the government if a crisis happens (Afonso et al., 2014); Liquidity ratio (lq) or the ratio of cash and short-term investment to total assets (%). As reported by Cornett et al. (2011), banks will invest in liquid assets as a cushion against the effects of monetary shocks on their lending implying that higher deviations on their returns motivate banks to hold more liquid assets; Deposit growth (dg) or quarterly percentage changes on deposits. Banks are granted with more protection on their supply of loans affected by monetary shocks from acquiring less costly loanable funds for a lower amount of risk premium paid due to a higher dependance on equity capitals (Gunji et al., 2009). In other words, banks with a high financial strength confront a lower exposure to changes in deposit; Capitalization (lneqta) or the ratio of equity to total assets (%). Evidence of which equity ratio of banks to measure financial strength negatively affects a bank's risk is documented by Delis and Kouretas (2011); Cost efficiency ratio (lncost) or the ratio of operating expenses to net revenues (%). The lower efficiency of banks results in lesser risk exposure of banks (Fiordelisi et. al., 2001); Funding diversification (ndsf) or the ratio of non-deposit short-term funding to total short-term funding (%); and income diversification (nii) or the ratio of non-interest income to total operating income (%). Banks with more diversifications in sources of funding and incomes have lower risks and hence less volatility in their returns. (Demirgüç-Kunt and Huizinga, 2010).

3.2) Data and Data Sources

In the previous section, variables are analyzed to construct the possible linkages among indicators of monetary policy, market concentration, and bank risk exposure. This research designs to group explanatory variables based on the cited different proxies by pairing each of monetary policy indicators with the market concentration measure into one regression, totaling four equations for each transmission mechanism of changes in interest rates and the low interest rate period. Following the previous relevant studies of Ratanavararak L. & Ananchotikul N. (2018) and Charnvitayapong K. (2020), the observation window is selected for the period from 2001 to 2019 that spans the different cycles of country's economy, a banking consolidation wave, the Great financial crisis, a transition to the inflation targeting regime, and the prolonged low interest rate environment at the quarterly frequency to highlight the response of bank risk exposure to the monetary policy transmission through short-term interest rate movements.

The bank-level financial data for items on the balance sheets and income statements of 11 commercial banks registered in Thailand is obtained from the different sources: Securities and Exchange Commission (SEC) of Thailand; Datastream; and banks' public financial reports, and the data sample covers only commercial banks to diminish any potential biases characterized by the significant differences across natures and scopes of other business types of financial institutions founded to serve the different goals with the expertise in their business areas. Additionally, Adams and Amel (2011) documents that banks' financial constraints in terms of size, liquidity, capital have statistically significant correlations with coefficients of the structural market indicator (HHI), so using bank-level data for bank-specific characteristics allows the researcher to alleviate a collinearity problem and to obtain more efficient estimation on the interested coefficients by controlling for these bank-level characteristics. Even though it should note that the analysis will emphasize eleven banks whose financial data are affordable depending on the researcher's information resources availability, the biases by ignoring banks without data permission granted for access should not raise an important concern for the resulting estimation due to the relatively small sizes of them comparing with the focused ones.

The data of individual banks on the quarterly basis is also used to estimate risk measures of Z-score index, the ratios of non-performing loans (NPL) with over 90 days past due, and loan loss provision (LLP) to total loans, and the structural market indicator measured by Herfindahl- Hirschman Index (HHI) as well as bank-specific characteristic determinants to be controlled under the regression: a bank's size; liquidity ratio; deposit growth; the ratio of equity to total assets; funding and income diversification; cost efficiency ratio. As for monetary policy indicators, three-month interbank interest rates or average interbank overnight lending rates are adopted as a key instrument of monetary policy implementation, which are collected from the Bank of Thailand database. Besides, macroeconomic control variables: the quarterly real GDP growth; CPI inflation; credit-to-GDP gap ratio; the difference between the three-month interbank interest rate and the 10-year government bond yield are extracted from the World Bank, Bank of Thailand, and Bank for international settlement databases.

As shown below, Table 1 provides the summary of statistics for each variable used in this study and the correlation between the variables is illustrated in the Appendix E. Even though the matrix of correlation represents no high correlation between variables which is not subject to a severe multicollinearity, the standalone variable of HHI is dropped in the estimation of both model 3 and 4 to avoid the multicollinearity problem because it seems to highly correlate with the yield curve slope variable approximately at 0.647, and the prior literature indicates its weak relationship with bank risk variables. Nonetheless, it is included in the descriptive statistics for being used to derive its interaction term with monetary policy indicators which is one of the focused explanatory variables in the research. In addition, this interest interaction term is omitted when taking some bank-specific control variables i.e., lnasset, lq, dg, ndsf into the estimations in model 3 and 4. Thus, those variables are also excluded from these two models.

Table 1: Statistics summary of variables used in this study

Variable	Unit	Obs.	Mean	Std. Dev.	Min	Max	Median
Δzscore	-	723	0.02	0.59	-3.23	3.39	0.01
Δnpl	%	746	-0.10	3.58	-25.17	31.4	-0.05
Δllp	%	782	-0.46	12.62	-352.38	4.00	0.00
Δr_t_int	%	836	-0.00	0.37	-1.33	1.04	-0.01
Δr_t_hp	-	836	0.00	0.77	-1.52	2.00	-0.02
lowrate_int	-	836	0.50	0.50	0.00	1.00	0.50
lowrate_hp	-	836	2.82	3.86	0.00	14.0	1.00
HHI	-	836	0.15	0.01	0.14	0.18	0.15
lngdp	-	539	1.14	1.18	-2.66	2.59	1.38
lncpi	-	825	0.31	0.55	-1.77	1.64	0.38
lnys	-	836	0.81	0.43	-0.19	1.59	0.76
creditgap	-	836	-12.26	22.17	-51.00	16.10	-10.75
crisis_dummy	-	836	0.11	0.31	0.00	1.00	0.0
lncost	-	741	3.52	0.29	1.46	5.125	3.51
lneqta	-	741	2.17	0.47	-1.14	3.43	2.26
nii	%	741	132.16	287.30	-3062.80	2719.96	108.20
lnasset	-	741	20.31	1.06	17.38	21.91	20.50
dg	%	741	2.37	17.82	-99.83	373.50	1.33
ndsf	%	741	7.27	4.99	0.00	29.08	6.16
lq	%	741	12.86	6.61	0.71	54.78	12.50

3.3) Econometric Framework

To summarize, four models are developed through each hypothesis as can be illustrated in four regression equations as follows:

Equation (1): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 \Delta r_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

Equation (2): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 Lowrate_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

Equation (3): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 \Delta r_t + c_2 (HHI * \Delta r)_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

Equation (4): $\Delta Risk_{i,t} = b_0 + b_1 \Delta Risk_{i,t-1} + b_2 Lowrate_t + c_2 (HHI * Lowrate)_t + b_3 Macro_t + b_4 BankChar_{i,t-1} + \alpha_i + \varepsilon_{i,t}$

This study applies the econometric model estimation according to the works of M. Chen et al. (2017) and Ratanavararak L. & Ananchotikul N. (2018). The dependent variables of banks' risk measures, endogenous variables of monetary policy indicators

and their interactions with the banking market concentration determinant, and control variables of bank-specific characteristics and macroeconomic conditions are selected from the literature review. The lagged dependent variable ($\Delta Risk_{i,t-1}$) is introduced as one of regressors for each equation to capture the persistence of bank risk and to limit the problem of omitted variables and a one-period lag is applied in the sense that the periodic risk management of banks would probably be adjusted based on the most recent performance on their risk controls in the past, which had already reflected a consequence of such behaviors in prior periods.

Under the dynamic panel with building an instrument through the lag of dependent variable, the Generalized method of moments estimation (GMM) proposed by Arellano & Bond (1991) is normally applicable and using the "the two-step system GMM estimator" according to Arellano & Bover (1995), Blundell and Bond (1998) could be justifiable to ensures the consistent estimation by mitigating main problems of the endogeneity among explanatory variables, heteroskedasticity, and autocorrelation within banks. By incorporating lagged dependent and control variables as regressors, the Hansen test of overidentifying restrictions for the validity of instruments and Arellano-bond test for autocorrelations are required to perform the GMM estimator. The instrument variable using the lag of dependent variable from 2th quarters until 5th quarters is applied depending upon the result from AR test. Based on Hansen test, the null hypothesis of exogeneous instrument variables cannot be rejected, indicating the valid instrument set.

Further, there is another possible endogeneity concern between the bank-specific control variables and banks' risk measures, so these bank-specific characteristics are one-period lagged, following the prior studies of Olivero et al. (2011), Borio and Gambacorta (2017), M. Chen et al. (2017), and Ratanavararak L. & Ananchotikul N. (2018).

4. EMPIRICAL RESULT

The result of determining the impact of interest rate changes on bank risk exposure using Z-score, NPL ratio, and LLP ratio from Model 1 is shown in Table 2. The first monetary policy indicator in this study is the difference of short-term interest rates between previous and current periods (Δr_t_int) which appears to be positively correlated with the change in Z-score, whilst negatively correlated with those in NPL and LLP ratios as expected at 5% significance level. As for the second monetary policy indicator, the cyclical component of short-term interest rates implied by Hodrick-Prescott filter, HP filter, (Δr_t_hp) that varies during the observation period as illustrated in *Figure 2* (Appendix F), it also ensures the effect of interest rates changes on risk proxies showing the positive relationship with the change in Z-score and the negative relationship with those in NPL and LLP ratios at the same significance level. Given *ceteris paribus*, the result indicates that a loosened monetary policy transmission through lowering short-term interest rates from the previous periods and by even more than their natural interest rates increases bank risk exposure in terms of insolvency risk and credit risk on the quarterly basis, which is consistent with the findings of M. Chen et al. (2017) that an interest rate decrease could induce banks to undertake more risk on the annual basis and the prediction of Jiménez et al., 2014. Another perspective of expansionary monetary policy by holding interest rates at the low level is aimed to explore its effect on bank risk exposure as constructed in Model 2. As anticipated in the previous section, the result shown in Table 3 contains the negative coefficient of the two proxies (i.e., lowrate_int and lowrate_hp) for a low interest rate environment with the change in Z-score and the positive coefficient of these variables with the changes in NPL and LLP ratios with a significance of 5%. These suggest, *ceteris paribus*, a monetary policy easing by holding low interest rates and extended low interest rates intensifies bank risk exposure, which is corresponding to the conclusions of Ramayandi et al. (2014), Charnvitayapong K. (2020). Considering the implication from the results of Model 1 and 2 using the dynamic estimation, the central bank's attempt to boost the economy by either reducing a policy rate or holding a policy rate at the low level puts a pressure on banks' profitability, which could drive banks to lean towards riskier credit portfolios and worsen their financial stabilities.

Moreover, the study also emphasizes the role of banking market concentration in effecting the relationship between monetary policy and bank risk exposure by adding the interaction terms of structural market concentration with monetary policy indicators from the above baseline models as expressed in Model 3 and 4, the result from Model 3 referring to Table 4 represents the same signs on both variables of interest rate changes (Δr_t_int and Δr_t_hp) with the statistical significance of 5% according to Table 2 (Model 1). On the other hand, their interactions with a structural market concentration (HHI*Δr_t_int and HHI*Δr_t_hp) are negatively correlated with the change in Z-score and positively correlated with the changes in NPL and LLP ratios at 5% significance level. Consistent with Jayaratne and Morgan (2000), Dell'Ariccia and Marquez (2009), and M. Chen et al. (2017), these could be interpreted that, *ceteris paribus*, a loosened monetary policy by lowering short-term interest rates increases bank risk exposure, but such an impact on bank risk exposure is counteracted with a higher banking market concentration. Regarding the study on the low interest rate period, the result from Model 4 exhibited in Table 5 describes the coefficients of low interest rate indicators (lowrate_int and lowrate_hp) remain unchanged from Table 3 (Model 2) for their signs. Nonetheless, the opposite signs on coefficients of their interactions with a market concentration (HHI*lowrate_int and HHI*lowrate_hp) are reported. In the prolonged period of low interest rates, those coefficients are statistically significant at 5%, whereas in the period of low interest rates is less statistically significant at 10% in case of using the changes in Z-score and LLP ratio. Given *ceteris paribus*, the result implies that a relaxed monetary policy by holding low interest rates increases bank risk exposure, but the effect of low interest rates on bank risk exposure is mitigated with more concentrated banking market especially during the prolonged period of low interest rates.

Based on the results from Model 3 and 4, a more banking market concentration signaling lower competition could indirectly act as a buffering effect against the adverse impact of a monetary policy transmission through interest rate adjustments on bank risk exposure to the extent that banks in a higher concentrated market would be less likely to lend to the poor-quality borrowers so as to achieve a higher profit margin, albeit the profitability of those bank is suppressed by a decrease in market-

based interest rates or in a low interest rate period due to monetary policy easing. Moreover, this statement can be confirmed through measuring the economic impacts of monetary policy stance on bank risk exposure with more concentration in banking market. The classification of concentration level given in the earlier section of this research is brought to examine changes in bank risk exposure by using the estimated coefficients $b_2 + c_2(HHI)_t$ from Model 3 and 4 referring to the result of Table 4 and 5, where HHI is the measure of concentration level[3] at the 10th percentile, 50th percentile, and 90th percentile of HHI distribution to be calculated. Table 6 exhibits the percentage change in bank risk from interest rate changes and given low interest rates for different concentration levels.

Table 6 Percentage change in bank risk exposure

Interest rate changes relative to the previous quarters			
	Δzscore	Δnpl	Δllp
HHI = 0.1447 (10th percentile)	9.18	-41.11	88.52
HHI = 0.1489 (50th percentile)	8.53	-29.20	-14.69
HHI = 0.1654 (90th percentile)	6.01	17.00	-4.52
Interest rate changes relative to their long-term trends			
	Δzscore	Δnpl	Δllp
HHI = 0.1447 (10th percentile)	-11.18	-170.83	-110.10
HHI = 0.1489 (50th percentile)	-14.20	-149.52	-97.57
HHI = 0.1654 (90th percentile)	-25.95	-66.80	-48.90
Low interest rates			
	Δzscore	Δnpl	Δllp
HHI = 0.1447 (10th percentile)	-18.30	50.41	11.74
HHI = 0.1489 (50th percentile)	-14.52	40.77	10.16
HHI = 0.1654 (90th percentile)	0.17	3.36	4.01
Prolonged low interest rates			
	Δzscore	Δnpl	Δllp

[3] The 10th percentile, 50th percentile, and 90th percentile of HHI distribution is classified as a low, medium, and high level of banking market concentration, respectively.

HHI = 0.1447 (10th percentile)	-0.38	28.23	0.36
HHI = 0.1489 (50th percentile)	-0.19	22.36	0.23
HHI = 0.1654 (90th percentile)	0.52	-0.44	-0.27

As shown in the above table, the result can be interpreted in term of economic impacts as the following. For example, a 1 percentage point decrease in interest rates would decrease Z-score by around 9.2% at the 10th percentile of HHI distribution, but a fall in interest rates of the same unit would reduce Z-scores at a smaller magnitude by around 8.5% and 6.0% for higher levels of concentration at the 50th percentile and 90th percentile, respectively. In the low interest rate period, the concentration level at the 10th percentile would induce a 18.3% decline in Z-score, but such an effect on Z-score would be diminished to 14.5% at the 50th percentile and eventually at the 90th percentile of the concentration level would eventually cause a 0.17% increase in Z-score. These results indicate that the greater value of HHI would yield the lower decrease in Z-score implying the smaller increase in bank risk exposure from a 1 percentage point decrease in interest rates and during low interest rates, reiterating that more concentrated market of banking sector could potentially mitigate bank risk-taking triggered by a monetary policy accommodation.

This study also performs the further investigations by comparing the overall impact of banking market concentration on changes in bank risk exposure in response to the monetary policy relative to the respective impact of monetary policy on bank risk obtained from Table 2 and 3. Such an aggregate impact on bank risk is derived from $b_2 + c_2$ based on the coefficients on the variables in Model 3 and 4 according to the estimation results of Table 4 and 5. Table 7.1 and Table 7.2 represent the comparisons of changes in bank risk exposure between the standalone impact of monetary policy indicators and the interaction term of each monetary policy with a market concentration.

Table 7.1 Percentage changes in bank risk exposure from interest rate changes

Interest rate changes				
	Δr_t_int	HHI*Δr_t_int	Δr_t_hp	HHI*Δr_t_hp
Δzscore	**10.21**	-1.22	**6.52**	-6.22
Δnpl	**-151.50**	23.63	**-47.03**	41.34
Δllp	**-9.30**	5.12	-1.74	**24.23**

Table 7.2 Percentage changes in bank risk exposure during low interest rates

Low interest rates				
	lowrate_int	HHI* lowrate_int	lowrate_hp	HHI* lowrate_hp
Δzscore	**-17.11**	7.46	-0.24	**0.37**
Δnpl	**83.76**	-18.96	4.04	**-11.58**
Δllp	**36.26**	-3.08	0.07	**-0.26**

As for the interpretation in term of economic impacts, the magnitude effect of monetary policy on bank risk exposure measured in the absolute value mainly shares the same conclusion using changes in Z-score, the ratios of NPL and LLP. For instance, a 1 percentage point decrease in interest rates would increase NPL ratio by approximately 47.0% - 151.5%, and there would be about 83.8% hike in NPL ratio during low interest rates. With an increase in market concentration of 0.01 unit, a decrease in interest rates of the same unit would though shrink NPL ratio only about 23.6% - 41.3% and there would be just a 19.0% decline in NPL ratio during low interest rates. These results point out that the magnitude effects of interest rate declines and low interest rates are larger relative to those of market concentration on bank risk exposure. On the contrary to the extended period of low interest rates, a 0.01 unit increase in a market concentration would drop NPL ratio by around 11.6%, which outweighs a 4.0% increase in NPL ratio as a sole effect of prolonged low interest rates. The overall result suggests that the adverse impact of monetary policy easing in cases of interest rate declines and low interest rates on bank risk exposure can dominate the counteracting effect of a banking market concentration, but given the prolonged low interest rates the impact of a market concentration alternatively

considered as banks' competition concerns can play a more crucial role in decreasing bank risk exposure.

Not only the variables of interest, main estimation results from all models used in the study also discover the complementary evidences for the conclusion drawn from the literature review in the prior section as follows. The signs on the 1-quarter lagged dependent variables are significantly negative pointing to the persistence of bank risk of which a decrease in bank risk exposure in a current quarter is influenced by an increase in the exposure in a previous quarter or otherwise. For macroeconomic variables, a real GDP growth widens, the ratios of NPL and LLP fall significantly and constantly in Model 1 and Model 2. A better economic condition associated with a higher economic output could result in a larger income and thus improving borrowers' repayment capabilities. In contrast to the study's expectation, the relation of CPI inflation is significantly negative with NPL ratio in all models and significantly positive with Z-score in Model 1 and 2. These indicate that an increase in inflation leads to a decline in the real value of non-performing loans signaling a higher asset quality and thus the strengthening in banks' financial substance, as evidenced by Nikolov and Popovska-Kamnar (2016). Although most coefficients of creditgap show a significantly positive relation with NPL ratio explaining that banks' intent to serve an overly credit demand could bring about a climb in NPL as predicted, using LLP ratio and Z-score primarily delivers the opposite implications by having significantly negative and positive relations with creditgap in order. It suggests that banks are likely to be optimistic during an economic upturn and tend to have a positive reaction to an excessive credit demand. As a result, loan loss provision set by banks declines, and hence an increase in the profitability of banks reflected on the value of Z-score. The coefficients of crisis dummy with using LLP ratio and Z-score at a 5% significance are mostly against the earlier anticipation indicating that during a crisis time, banks may understate a reserve probably by setting a lower loan loss provision so as to broaden the amount of net loan to avoid the conflict with regulators and monetary authorities that demand an ample credit supply to boost up the economy, which conforms to the previous literature of Ozili (2015). By decreasing such an expected credit loss, this could raise the profitability of banks that broadens the value

of Z-score. The signs on the yield curve slope variables mainly match with the study's prediction for its statistically significant relation with Z-score and LLP ratio. The steeper yield curve enhances banks' profit margin which could discourage them to take on more risk. For bank-specific characteristic determinants, most coefficients of cost efficiency variables align with the expected relations to be positive with Z-score and negative with the ratios of NPL and LLP. These reflect a lower ability of banks to control operating costs reduces banks' riskiness. The variables of asset size are significantly positive correlated with the ratios of NPL and LLP in most models implying that larger-sized banks incur greater risk exposure in line with Charnvitayapong K. (2020). The signs on equity ratio variables are mainly beyond the expectations showing a significant negative and positive relations with Z-score and the ratios of NPL and LLP, respectively. Similar to J. Blum (1999) and Iannotta et al. (2007), an increase in capital results in a greater bank risk exposure. The results from the asset size and equity ratio variables refer to "too-big-to-fail" in which excessive risk-taking of systemic banks can be led by the government bailout options (Kim & Santomero, 1988). The variables that describe banks' diversifications in terms of incomes and funding sources largely represent a significant negative relation with the ratios of NPL and LLP, respectively indicating that a higher diversification of banks into non-interest incomes and non-deposit funding sources decreases their risk exposure. The main signs on deposit growth variables are significantly negative and positive associated with Z-score and the ratios NPL and LLP, respectively suggesting that banks with higher deposit growths expose to a climb in risk exposure as their sources of funding are more likely to be affected by interest rate shocks. Lastly, the variables of liquidity ratio mainly have a significantly negative and positive association with Z-score and LLP ratio in tandem as previously predicted, which explains banks hold more liquid assets to absorb an increase in risk exposure.

Dependent variable	Table 2 (Model 1): Impact of interest rate changes on bank risk exposure					
	Δzscore	Δnpl	Δllp	Δzscore	Δnpl	Δllp
$\Delta zscore_{t-1}$	-0.787***			-0.0273		
	(0.169)			(0.293)		
Δnpl_{t-1}		-1.322***			-1.116***	
		(0.235)			(0.171)	
Δllp_{t-1}			-1.087***			-0.998***
			(0.0918)			(0.0716)
Δr_t_int	10.21**	-151.5**	-9.302**			
	(3.757)	(59.96)	(3.884)			
Δr_t_hp				6.522**	-47.03**	-10.51**
				(2.623)	(18.01)	(4.249)
$lngdp_t$	-0.165*	-6.267**	-6.598**	-0.0142	0.398	-3.588**
	(0.0848)	(2.640)	(2.541)	(0.0703)	(0.296)	(1.379)
$lncpi_t$	3.856**		1.103**	3.479	-69.35**	4.008**
	(1.489)		(0.410)	(2.141)	(26.27)	(1.385)
$creditgap_t$	0.711**	0.883**	0.657**	-0.268*	4.068**	0.151
	(0.278)	(0.330)	(0.248)	(0.137)	(1.809)	(0.0941)
$crisis\_dummy_t$		35.66				
		(23.97)				
$lnys_t$		137.6**				
		(51.92)				
$lncost_{t-1}$			6.082**			-1.742
			(2.422)			(1.237)
$lnasset_{t-1}$	3.158**	-5.612**	0.0331	1.435*	11.24**	0.601**
	(1.271)	(2.135)	(0.0292)	(0.728)	(4.815)	(0.223)
dg_{t-1}	-0.158**	0.560**	-0.0493**	-0.0148	-0.195	0.0731*
	(0.0607)	(0.228)	(0.0172)	(0.0249)	(0.128)	(0.0367)
$lneqta_{t-1}$	-20.16**			-14.64**	-45.24**	
	(8.159)			(6.328)	(19.28)	
$ndsf_{t-1}$	-1.650**	1.844**	-1.291**	0.496	-10.43**	-0.159
	(0.648)	(0.719)	(0.487)	(0.335)	(4.577)	(0.193)
nii_{t-1}	-0.00437**	0.00541**	-0.00310**	0.0000972	-0.0266**	-0.000123
	(0.00176)	(0.00240)	(0.00115)	(0.000738)	(0.0115)	(0.000462)
lq_{t-1}	-0.124*	0.878**	0.221**	-0.377**	0.368	0.0461*
	(0.0590)	(0.362)	(0.0849)	(0.151)	(0.246)	(0.0243)
AR (1)	0.298	0.053	0.101	0.274	0.191	0.032
AR (2)	0.572	0.533	0.133	0.471	0.806	0.373
AR (3)	0.342	0.063	0.073	0.035	0.022	0.054
AR (4)	0.111	0.070	0.106	0.039	0.087	0.041
AR (5)	0.369	0.197	0.072	0.036	0.07	0.042
Hansen J	1.000	1.000	1.000	1.000	1.000	1.000
Number of banks	11	11	11	11	11	11
Observations	445	458	458	445	458	458

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. P-value's Arellano-Bond (AR) test for Autocorrelation is reported until the fifth-order in the first-differenced errors and the 2-quarter lagged of dependent variable is employed in the model estimation. Hansen J reports P-value's Hansen J test of overidentifying restrictions.

Dependent variable	Table 3 (Model 2): Impact of low interest rates on bank risk exposure					
	Δzscore	Δnpl	Δllp	Δzscore	Δnpl	Δllp
$\Delta zscore_{t-1}$	-0.929**			-0.629**		
	(0.369)			(0.238)		
Δnpl_{t-1}		-0.871***			-2.204***	
		(0.123)			(0.601)	
Δllp_{t-1}			-1.321***			-0.708***
			(0.169)			(0.108)
lowrate_int	-17.11**	83.76**	36.26**			
	(6.963)	(32.97)	(13.81)			
lowrate_hp				-0.243**	4.041**	0.0708**
				(0.0985)	(1.623)	(0.0280)
$lngdp_t$	0.461*	-4.609**	-0.955**	-1.012	-0.298	0.505
	(0.221)	(1.920)	(0.370)	(0.705)	(0.747)	(0.285)
$lncpi_t$	9.674**	-19.40*	-7.568**	20.31**	-250.2**	-0.423
	(3.787)	(8.820)	(3.249)	(7.483)	(99.47)	(0.255)
$creditgap_t$	0.0673**	-0.323	-0.0440**	0.172**	-1.789**	-0.0338**
	(0.0276)	(0.376)	(0.0196)	(0.0638)	(0.708)	(0.0137)
$crisis\_dummy_t$					127.5*	
					(60.82)	
$lnys_t$						
$lncost_{t-1}$	1.422		-2.762*			-8.028**
	(2.003)		(1.352)			(3.121)
$lnasset_{t-1}$	0.0806	22.47**	-0.307	0.0696	-0.196	1.452**
	(0.399)	(9.495)	(0.206)	(0.0644)	(0.196)	(0.562)
dg_{t-1}	-0.127**	0.407**	0.217**	-0.0606**	1.060**	0.0313**
	(0.0497)	(0.166)	(0.0834)	(0.0209)	(0.439)	(0.0129)
$lneqta_{t-1}$		-202.2**		-0.660*		
		(83.34)		(0.297)		
$ndsf_{t-1}$	0.0853*	-1.191	-0.113**	0.0245	0.683*	-0.104**
	(0.0389)	(1.200)	(0.0457)	(0.0206)	(0.328)	(0.0408)
nii_{t-1}	-0.000262	-0.0175*	0.000848*	-0.0000965	-0.00426**	-0.000252
	(0.000174)	(0.00806)	(0.000392)	(0.000158)	(0.00161)	(0.000189)
lq_{t-1}	-0.0159	-3.614**	0.0820**	0.0370	-0.285*	-0.113**
	(0.0309)	(1.448)	(0.0362)	(0.0217)	(0.130)	(0.0419)
AR (1)	0.308	0.066	0.035	0.06	0.07	0.087
AR (2)	0.066	0.138	0.074	0.115	0.429	0.767
AR (3)	0.639	0.097	0.051	0.018	0.139	0.222
AR (4)	0.632	0.071	0.072	0.038	0.073	0.188
AR (5)	0.655	0.047	0.050	0.033	0.105	0.180
AR (6)	0.153	-	-	-	-	-
Hansen J	1.000	1.000	1.000	1.000	1.000	1.000
Number of banks	11	11	11	11	11	11
Observations	445	458	458	445	458	458

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. P-value's Arellano-Bond (AR) test for Autocorrelation is reported until the sixth-order in the first-differenced errors and the 2-quarter and 5-quarter lagged of dependent variable is employed in the model estimation. Hansen J reports P-value's Hansen J test of overidentifying restrictions.

Dependent variable	Table 4 (Model 3): Impact of banking market concentration on the relationship between interest rate changes and bank risk exposure					
	Δzscore	Δnpl	Δllp	Δzscore	Δnpl	Δllp
$\Delta zscore_{t-1}$	3.457*			1.068		
	(1.594)			(0.718)		
Δnpl_{t-1}		-1.985**			0.561	
		(0.631)			(0.494)	
Δllp_{t-1}			-1.199***			0.0217
			(0.140)			(0.371)
Δr_t_int	31.37**	-447.8**	-106.9**			
	(13.34)	(174.7)	(44.24)			
HHI*Δr_t_int	-153.4*	2811.0**	619.2**			
	(70.45)	(1107.5)	(258.9)			
Δr_t_hp				92.18**	-899.0**	-538.5**
				(37.73)	(353.8)	(217.3)
HHI*Δr_t_hp				-714.4**	5033.2**	2961.1**
				(317.4)	(1985.2)	(1195.7)
$lngdp_t$	-0.877**	6.785**	-0.555*	-1.367**	-16.48**	3.892**
	(0.312)	(2.595)	(0.296)	(0.563)	(6.624)	(1.567)
$lncpi_t$	-6.217**	-38.08*	-0.735	4.246	-132.9**	13.37**
	(2.433)	(18.96)	(0.935)	(4.023)	(53.07)	(5.308)
$creditgap_t$	0.629**	4.435*	-0.329	0.110	16.61**	-2.754**
	(0.245)	(2.084)	(0.213)	(0.140)	(6.642)	(1.104)
$crisis\_dummy_t$	8.036*	76.60	9.323*	-20.24	-254.2**	-5.556*
	(3.662)	(47.90)	(4.363)	(13.44)	(100.8)	(2.576)
$lnys_t$	-3.349*	219.7**	11.01*	-1.424	-111.5**	-154.4**
	(1.756)	(98.50)	(5.768)	(8.763)	(45.51)	(62.37)
$lncost_{t-1}$	26.14**	7.325	-11.30**	5.040	83.19**	2.901
	(10.23)	(11.56)	(4.612)	(3.852)	(35.25)	(1.773)
$lneqta_{t-1}$	-36.00**	-71.47	12.30**	-6.336	41.85*	37.81**
	(14.03)	(41.34)	(5.430)	(7.925)	(22.69)	(14.94)
nii_{t-1}	-0.0104**	-0.0111*	0.00467*	-0.00133	-0.130**	-0.000431
	(0.00413)	(0.00561)	(0.00209)	(0.00171)	(0.0519)	(0.000250)
AR (1)	0.057	0.099	0.176	0.065	0.057	0.087
AR (2)	0.417	0.623	0.313	0.544	0.436	0.583
AR (3)	0.009	0.047	0.191	0.000	0.499	0.004
AR (4)	0.000	0.268	0.119	0.085	0.064	0.035
AR (5)	0.057	0.515	0.268	0.226	0.026	0.238
Hansen J	1.000	1.000	1.000	1.000	1.000	1.000
Number of banks	11	11	11	11	11	11
Observations	445	458	458	445	458	458

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. P-value's Arellano-Bond (AR) test for Autocorrelation is reported until the fifth-order in the first-differenced errors and the 2-quarter and 3-quarter lagged of dependent variable is employed in the model estimation. Hansen J reports P-value's Hansen J test of overidentifying restrictions.

Dependent variable	Table 5 (Model 4): Impact of banking market concentration on the relationship between low interest rates and bank risk exposure.					
	Δzscore	Δnpl	Δllp	Δzscore	Δnpl	Δllp
$\Delta zscore_{t-1}$	-0.353			0.868		
	(0.279)			(0.613)		
Δnpl_{t-1}		-0.546			-0.140	
		(0.455)			(0.243)	
Δllp_{t-1}			-0.553***			-0.646***
			(0.167)			(0.131)
lowrate_int	-147.6*	379.7**	65.88*			
	(69.67)	(160.4)	(31.83)			
HHI* lowrate_int	893.7*	-2276.0**	-374.2*			
	(427.5)	(973.2)	(188.2)			
lowrate_hp				-6.692**	228.9**	4.728**
				(2.760)	(94.59)	(1.874)
HHI* lowrate_hp				43.63**	-1386.8**	-30.20**
				(17.77)	(575.0)	(12.06)
$lngdp_t$	-0.392**	0.213	0.243*	0.0320	9.621**	-0.0531
	(0.138)	(1.616)	(0.118)	(0.0523)	(3.956)	(0.0385)
$lncpi_t$	-2.899*	-18.47	-2.709*	0.944***	-20.44**	-0.262
	(1.348)	(13.33)	(1.344)	(0.240)	(8.888)	(0.255)
$creditgap_t$	0.400**	6.126*	-0.172**	0.166**	13.93**	-0.0910**
	(0.162)	(3.099)	(0.0760)	(0.0674)	(5.549)	(0.0338)
$crisis\_dummy_t$	13.86**	-211.4**	-2.965	12.81**	81.02**	-6.340**
	(5.839)	(88.68)	(1.818)	(4.630)	(35.19)	(2.713)
$lnys_t$	22.09**	7.833	-1.575	-0.492	329.5**	-0.116
	(8.791)	(33.36)	(1.170)	(0.624)	(129.3)	(0.675)
$lncost_{t-1}$	0.0543	68.49	-5.181**	10.23**	-150.7**	-5.528**
	(1.410)	(51.98)	(2.074)	(3.982)	(59.10)	(2.181)
$lneqta_{t-1}$	-3.948	-74.39	6.330**	-16.50**	184.9**	8.868**
	(2.423)	(76.26)	(2.524)	(6.497)	(74.29)	(3.475)
nii_{t-1}	0.000778	-0.0548*	-0.000340	-0.00177**	-0.0512**	0.000844*
	(0.000731)	(0.0261)	(0.000226)	(0.000696)	(0.0211)	(0.000439)
AR (1)	0.244	0.121	0.708	0.046	0.081	0.062
AR (2)	0.416	0.774	0.803	0.431	0.548	0.807
AR (3)	0.163	0.608	0.697	0.738	0.621	0.361
AR (4)	0.080	0.371	0.689	0.214	0.094	0.056
AR (5)	0.381	0.430	0.580	0.050	0.316	0.147
Hansen J	1.000	1.000	1.000	1.000	1.000	1.000
Number of banks	11	11	11	11	11	11
Observations	445	458	458	445	458	458

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. P-value's Arellano-Bond (AR) test for Autocorrelation is reported until the fifth-order in the first-differenced errors and the 2-quarter and 3-quarter lagged of dependent variable is employed in the model estimation. Hansen J reports P-value's Hansen J test of overidentifying restrictions.

5. CONCLUSION

The main objective of this study is to examine the linkage among monetary policy stances, bank risk exposure, and banking market concentration in Thai banking industry using bank-level data of 11 commercial banks listed in the Stock Exchange of Thailand on quarterly basis over the period from 2001 to 2019. For the two baseline models, the three alternative dependent variables are introduced in term of changes in bank risk measures and the independent variables of interest are monetary policy indicators given interest rate changes from the previous period, interest rate variations relative to their long-term trends, low interest rates, and protracted low interest rates. Besides, the interaction term between monetary policy indicators and banking market concentration by asset size is one of focused explanatory variables and added into those models for determining its impact on the bank risk exposure in response to monetary policy indicators. All models are estimated using the two-step system GMM dynamic panel regression and control for macroeconomic conditions and bank-specific characteristics. To the best of the researcher's knowledge, the study is the first to examine the impact of banking market concentration on the association between bank risk exposure and a low interest rates environment in Thailand.

The findings of this study are mostly consistent with the previous literature in supporting the hypothesis of an increase in bank risk exposure when implementing an expansionary monetary policy transmission through lowering interest rates relative to the previous quarter and their long-term trends. Similarly, a climb in bank risk also appears in low interest rates including the extended period of low interest rates. These evidences point to the unintended side-effect of relaxed monetary policy executed by Bank of Thailand aiming to expand the country's economic activities. However, such adverse impacts of monetary policy easing on bank risk exposure are alleviated with a higher banking market concentration in both cases of a decrease in interest rates and low interest rates. Furthermore, the overall results based on economic impact measurements explore that the impact of a monetary policy easing can dominate the effect of market concentration on bank risk exposure, but limited to the extended period of low interest rates where the concentration in banking market plays a more crucial role in reducing bank risk exposure. Despite this, other implications from

bank-specific variables for banks' asset size and equity ratio primarily raise a caution of "too big to fail"; a larger size of banks can also result in a greater risk exposure. Hence, the policies imposed by the authorities in charge to encourage more concentration in Thai banking market should be prudentially executed to a certain extent.

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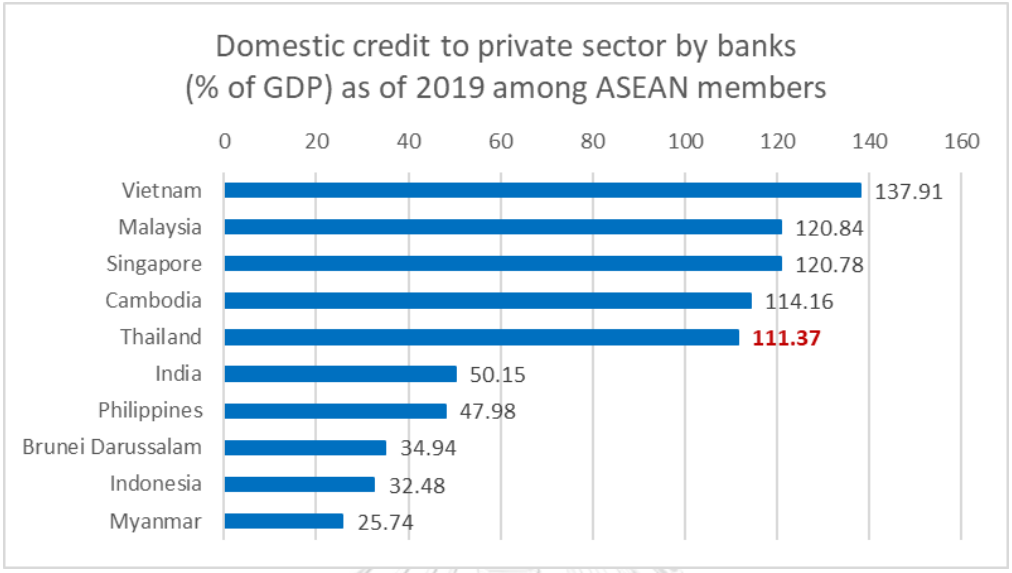
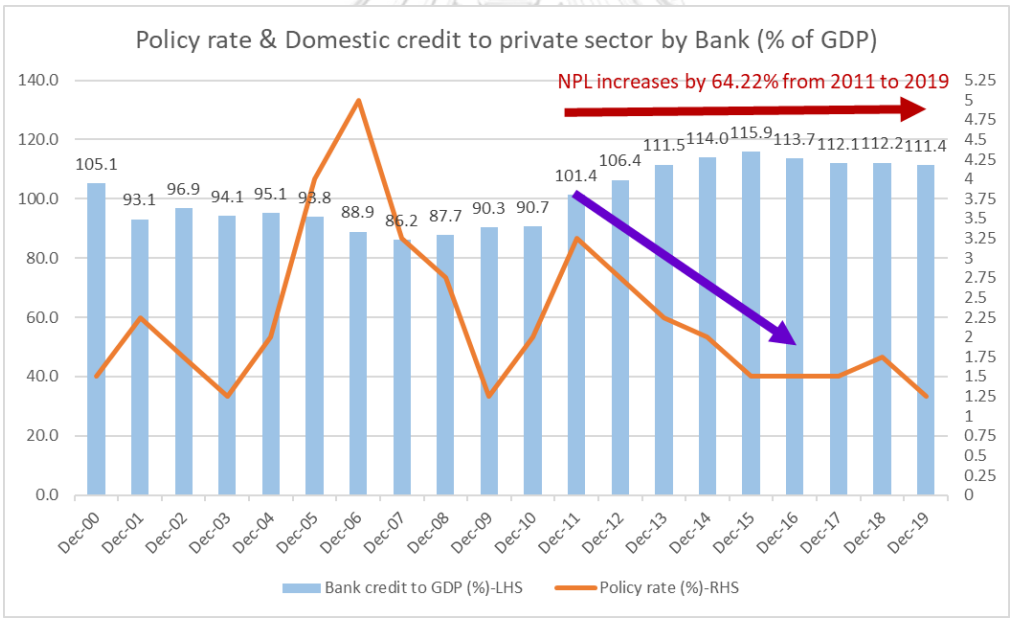
APPENDIX

Appendix A (Figure1): Policy rate, Domestic credit to private sector by Bank over GDP (%), and NPL





(Source: World Bank and Bank of Thailand)

Appendix B: Trend estimation method by the Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997).

The HP filter is the best known and most widely used method for empirical macro analysis to separate the trend from the cycle expressed in the below equation:

$Y_t = T_t + C_t$, where Y_t is the original series, T_t is the trend component, and C_t is the cyclical component.

The HP-Filter extracts the trend component by minimizing the deviation of the original series from the trend component (T_t) and the curvature of the estimated trend as shown in the following function:

$$MIN_T\{\sum_{t=1}^{T}(Y_t - T_t)^2 + \lambda \sum_{t=2}^{T-1}[(T_{t+1} - T_t) - (T_t - T_{t-1})]^2\}$$

where λ is smoothing parameter. The higher the value of λ, the smoother is the estimated trend. As recommended by Hodrick and Prescott (1997), λ equals to 100, 1600, 14400 inputs for yearly, quarterly and monthly data, respectively.

Appendix C: List of Commercial banks registered in Thailand in the study's sample data set.

No.	Commercial banks	Sample period
1.	Bangkok Bank Public Company Limited	2001-2019
2.	Kasikorn Bank Public Company Limited	2001-2019
3.	Siam Commercial Bank Public Company Limited	2001-2019
4.	Krung Thai Bank Public Company Limited	2001-2019
5.	TMB Bank Public Company Limited	2001-2019
6.	Bank of Ayudhya Public Company Limited	2001-2019
7.	CIMB Thai Bank Public Company Limited	2001-2019
8.	Kiatnakin Bank Public Company Limited	2001-2019
9.	Thanachart Capital Public Company Limited	2002-2019
10.	Tisco Financial Group Public Company Limited	2010-2019
11.	LH Financial Group Public Company Limited	2012-2019

Appendix D: The definitions of variables and the expected relations of banks' risk measures with Monetary policy indicators, Market structure determinant, Interaction term, Macroeconomic conditions, and Bank-specific variables.

Variables	Expected sign			Descriptions
	Z-score	NPL ratio	LLP ratio	
Dependent variables				
Z-score	N.A.			Natural logarithm of [(ROA+EA)/σ(ROA)]: ROA is five-quarter averaged after-tax return on assets; EA is capital-to-asset ratio; σ(ROA) is the standard deviation of return on assets over five quarters. A higher score indicates a lower probability of bank insolvency or a stronger financial standing of bank.

NPL ratio	N.A.			Nonperforming loan (NPL) to total loans. A greater value indicates a more bank risk exposure.
LLP ratio	N.A.			Loan loss provision (LLP) to total loans. A greater value indicates a more bank risk exposure.
Independent variables				
Δr_t_Int	Positive	Negative	Negative	Difference of short-term interest rate (%) between previous and current periods. A positive (negative) value represents a contractionary (expansionary) monetary policy stance.
Δr_t_HP	Positive	Negative	Negative	Cyclical component of short-term interest rates implied by Hodrick-Prescott filter. A positive (negative) value indicates the monetary policy is more tightened (loosened) comparing with their long-term trend.
$Lowrate_t\_Int$	Negative	Positive	Positive	A dummy is equal to 1 when the short-term interest rate is below sample median, and 0 otherwise.
$Lowrate_t\_HP$	Negative	Positive	Positive	Number of consecutive quarters that the cyclical component of short-term interest rate based on Hodrick-Prescott filter approach is negative.
HHI_t	Negative	Positive	Positive	Herfindahl-Hirschman Index, defined as sum of the squares of individual banks' market share in total assets. A higher value suggests a higher degree of market concentration.
$(HHI * \Delta r)_t$	Negative	Positive	Positive	Marginal effect of a bank market concentration on bank risk exposure when short-term interest rates change.
$(HHI * Lowrate)_t$	Positive	Negative	Negative	Marginal effect of a bank market concentration on bank risk exposure when short-term interest rate is below the benchmark given low interest rates or prolonged low interest rates.
Macroeconomic conditions				
GDP growth rate (lngdp)	Positive	Negative	Negative	Logarithm of 1+Quarterly real GDP

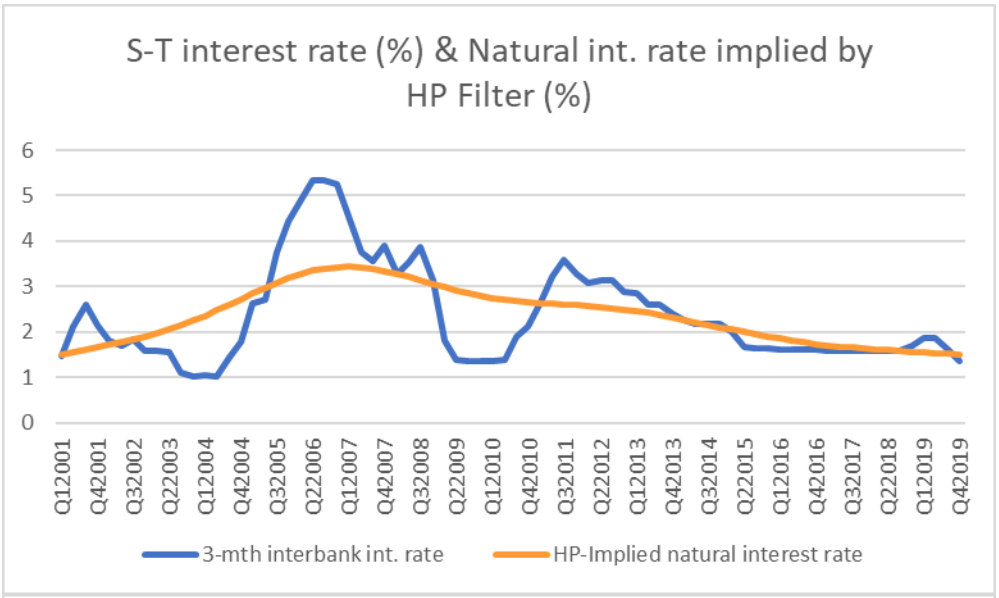
				growth rate (%)
CPI Inflation (lncpi)	Negative	Positive	Positive	Logarithm of 1+Quarterly change of Consumption price index (%)
Credit-to-GDP gap ratio (creditgap)	Negative	Positive	Positive	Difference between the credit-to-GDP ratio and its long-run trend.
Crisis (crisis_dummy)	Negative	Positive	Positive	A dummy is equal to 1 for the global financial crisis from 2008-2009, 0 for other periods.
Yield curve slope (lnys)	Positive	Negative	Negative	Logarithm of 1+Difference between the three-month interbank interest rate and the 10-year government bond yield (%)
Bank-specific characteristic				
Size (lnasset)	Negative	Positive	Positive	Natural logarithm of asset size
Liquidity ratio (lq)	Negative	Positive	Positive	Ratio of cash and short-term investment to total assets (%)
Deposit growth (dg)	Negative	Positive	Positive	Quarterly percentage change in banks' deposits (%)
Equity ratio (lneqta)	Positive	Negative	Negative	Logarithm of 1+ Ratio of equity to total assets (%)
Funding Diversification (ndsf)	Positive	Negative	Negative	Ratio of non-deposit short-term funding to total short-term funding (%)
Cost efficiency ratio (lncost)	Positive	Negative	Negative	Logarithm of 1+ Ratio of operating expenses to net revenues (%)
Income Diversification (nii)	Positive	Negative	Negative	Ratio of non-interest income to total operating income (%)

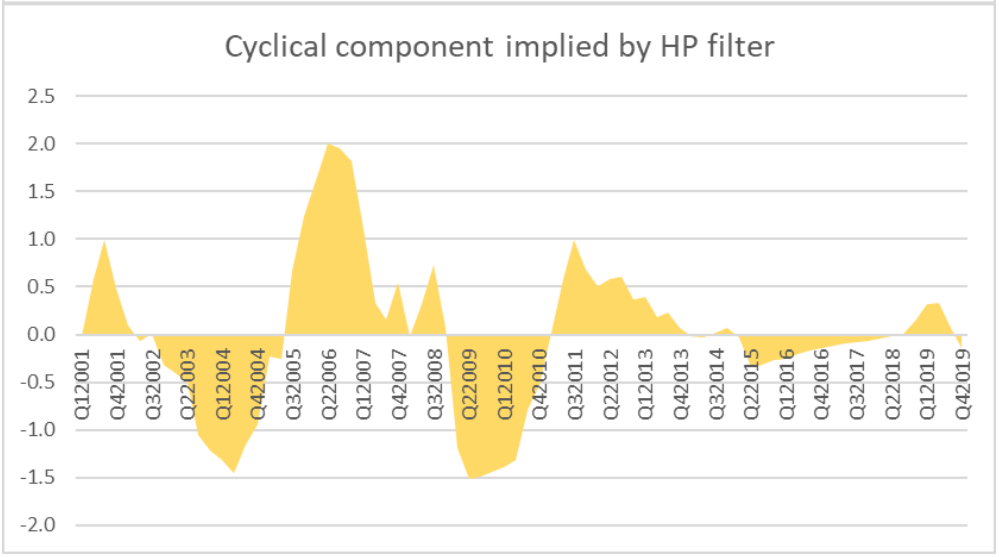
Appendix E: Matrix of Correlations between variables

Variables	Δzscore	Δnpl	Δllp	Δr_t_int	Δr_t_hp	lowrate_int	lowrate_hp	HHI	lngdp	lncpi	lnys	creditgap
Δzscore	1.000											
Δnpl	-0.169	1.000										
Δllp	-0.131	-0.084	1.000									
Δr_t_int	0.108	-0.009	0.017	1.000								
Δr_t_hp	-0.062	-0.077	-0.007	0.081	1.000							
lowrate_int	-0.018	0.124	0.003	-0.142	-0.619	1.000						
lowrate_hp	0.084	0.028	0.018	0.159	-0.523	0.491	1.000					
HHI	0.059	0.051	0.006	0.034	-0.354	0.288	0.144	1.000				
lngdp	-0.111	0.011	0.019	-0.311	-0.046	0.217	-0.032	-0.108	1.000			
lncpi	0.025	-0.017	0.003	0.342	-0.093	-0.061	0.067	0.100	-0.091	1.000		
lnys	0.138	0.015	-0.004	0.174	-0.672	0.375	0.290	0.647	-0.040	0.242	1.000	
creditgap	-0.027	-0.019	0.001	-0.162	-0.026	0.013	0.081	-0.736	0.188	-0.311	-0.467	1.000
crisis dummy	0.037	-0.067	-0.028	-0.107	-0.214	0.013	-0.068	0.152	-0.095	0.153	0.176	-0.073
lncost	0.057	-0.043	-0.177	0.109	-0.100	-0.054	0.046	0.063	-0.043	0.153	0.086	-0.077
lneqta	-0.045	-0.009	0.046	0.053	-0.032	0.087	0.148	-0.305	0.083	-0.057	-0.207	0.327
nii	0.033	-0.137	-0.110	-0.048	0.016	-0.008	0.037	-0.072	0.033	-0.033	-0.107	0.093
lnasset	0.005	-0.013	-0.021	-0.049	0.030	0.020	0.016	-0.195	0.065	-0.111	-0.132	0.258
dg	0.053	-0.035	-0.007	0.094	0.121	-0.124	-0.041	-0.109	0.087	0.041	-0.054	0.082
ndsf	-0.034	0.012	-0.056	-0.044	0.067	0.034	0.063	-0.411	0.079	-0.182	-0.286	0.520
lq	0.098	-0.085	-0.062	0.101	0.061	-0.047	-0.018	0.108	-0.007	0.046	0.083	-0.149

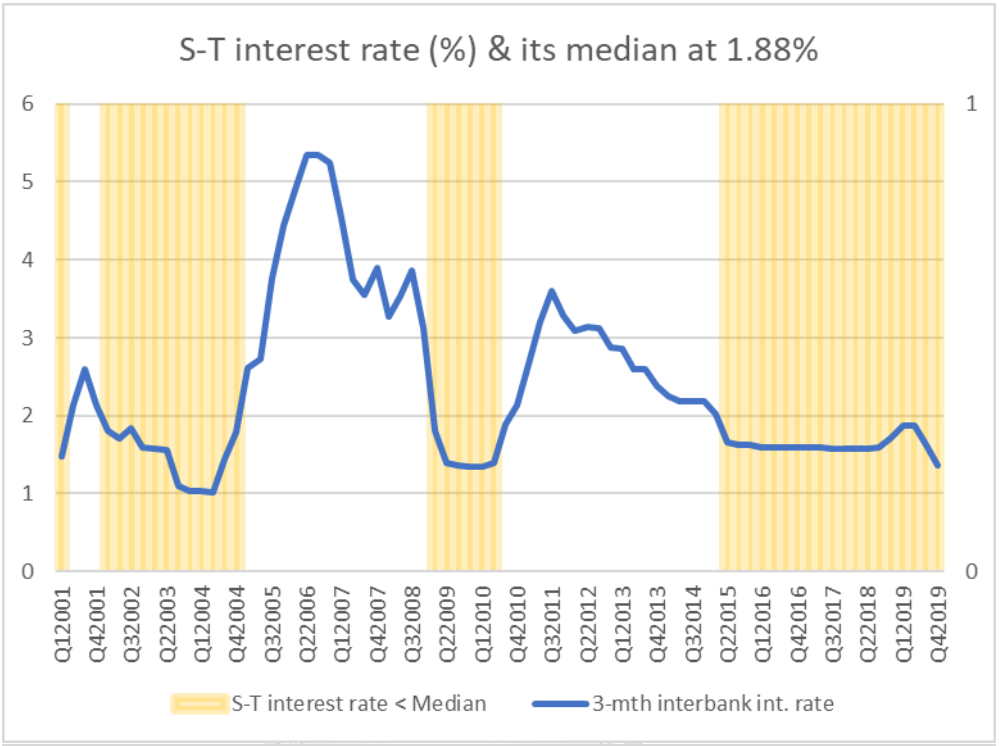
Variables	crisis dummy	lncost	lneqta	nii	lnasset	dg	ndsf	lq
crisis dummy	1.000							
lncost	0.157	1.000						
lneqta	-0.016	-0.114	1.000					
nii	-0.013	0.027	-0.053	1.000				
lnasset	-0.035	-0.144	-0.100	0.106	1.000			
dg	-0.105	0.139	-0.036	0.020	0.045	1.000		
ndsf	-0.133	-0.167	-0.001	0.065	0.209	0.019	1.000	
lq	0.038	0.030	-0.129	0.031	0.432	0.152	-0.136	1.000

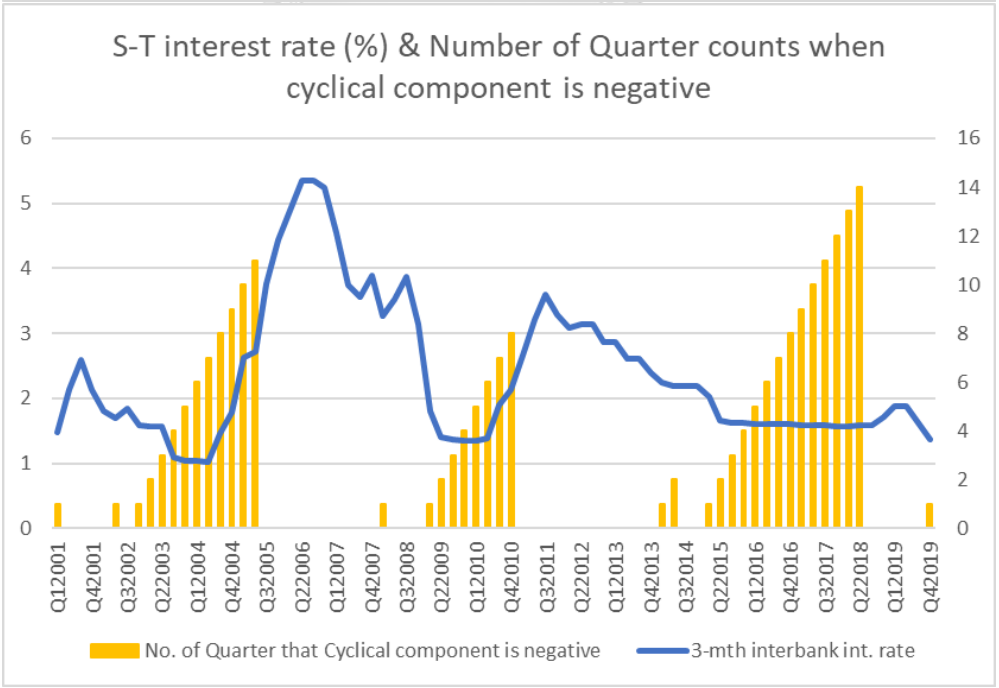
Appendix F (Figure 2): Cyclical component of short-term interest rates implied by Hodrick-Prescott filter (HP filter)



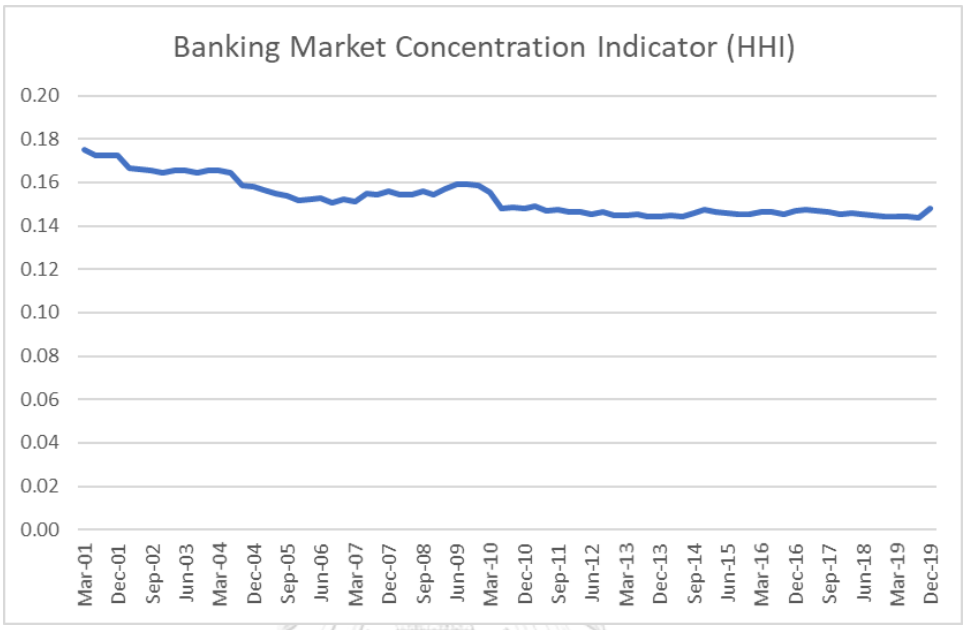


Appendix G (Figure 3): The period where the 3-month interbank interest rate is lower than its median distribution at 1.88% and the number of consecutive quarters being counted when the cyclical component of the 3-month interbank interest rate based on HP filter approach is negative.





Appendix H (Figure 4): Banking market concentration in Thailand during the sample period according to Author's calculation.



VITA

NAME Sasichanok Khongtip

DATE OF BIRTH 30 April 1993

PLACE OF BIRTH Bangkok