

Bank Competition, Efficiency and Stability in Macau

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Abstract

Macau has the uppermost population density and the fourth-highest GDP per capita in the world. Macau's banking system is regarded as one of the most important indicators of Macau's economic growth during its transformation into a wealthy and modern metropolis, which calls for thorough research to explore the relationship of bank competition, efficiency and stability in Macau. In this study, we use a sample of 26 Macau banks from its return to China in 1999 to 2016 to determine that bank competition does cause efficiency in Macau over the period. We also find indications of a positive but not significant connection between bank market power and bank fragility including income volatility and insolvency risk. Moreover, this study finds no evidence that the size of operations proxied by total bank loans and total assets would impact bank efficiency, indicating that economies of scale or bank market share don't necessarily bring about efficiency in Macau. Our evidence contributes to the literature by being the first to thoroughly examine and ascertain the relation of bank competition, efficiency and stability in Macau. The findings provide meaningful implications to the practitioners and policymakers to make sound decisions accordingly, especially to closely monitor and maintain a proper level of competition in Macau's banking sector.

JEL classification: F33, G21, L11

Keywords: banking competition, market structure, efficiency, financial stability, Macau banks

1. Introduction

The word "Finance" can be translated as "the circulation or movement of money" in Chinese. If you want to witness a really spectacular view of cash flow, you should pay a visit to Macau, China. Many call Macau the Las Vegas of Asia. It has been ranked as the world's largest gambling center since 2006 (Sheldon, 2015) and Macau's gross gaming revenue reached around four times as high as that of Las Vegas in 2016. Between 1999 and 2016, Macau's Gross Domestic Product (GDP) increased by an annualized growth rate of 12% and soared from Macanese Pataca (MOP) 52 billion (USD 6.5 billion) to MOP 362 billion (USD 45.1 billion), Macau's GDP per capita reached MOP 560 913 (USD 70 160), (Note 1) among the wealthiest in the world, ranking the 4th globally just behind Luxembourg, Switzerland, and Norway, in 2016. (Note 2) In addition to its fast pace of economic growth, Macau also successfully maintains a very low unemployment rate, a decent level of social welfare, and a high life expectancy (Sheng & Gu, 2018).

Originally known as Portuguese Macau, it was controlled by the Portuguese empire beginning in the 1500s until Macau's handover to China on December 20, 1999 (Sheldon, 2015). Macau has managed to keep its status as an independent economic region since its return to China. It preserves the free market system and adopts a free trade policy for continued development. The World Trade Organization evaluated Macau in 2002 and 2007 and recognized Macau as one of the most open regions in the world. In terms of Index of Economic Freedom, Macau was ranked 9th in the Asia-Pacific region and 37th out of 178 economies worldwide in 2016. (Note 3)

Upon its return to China in 1999, Macau's four pillar sectors were manufacturing, construction and real estate, financial services, and gaming (Sheng & Gu, 2018). Banks, including the ones in Macau, play an essential role in providing financial services to firms and households (The World Bank, 2018). The extant literature posits that banks issue transaction accounts; provide the backup source of liquidity to all other institutions, financial and nonfinancial; and act as the transmission belt for monetary policy. Banks must be competitively viable and efficient in order to preserve essential bank functions (Corrigan 1982). Moreover, banks reduce information asymmetry between

borrowers and lenders by monitoring and screening debtors to minimize moral hazard and adverse selection problems (Hughes & Mester, 2013). Banks serve as a critical component of the payment system whose activities directly or indirectly impact economic stability, and any bank failure can result in systemic crisis (Fethi & Pasiouras, 2009).

Macau's banking industry had enjoyed rapid growth along with the local economy from 1999 to 2016. The bank operations indicated by bank total assets which grew from MOP 139 billion to MOP 1390 billion, total net loans from MOP 42 billion to MOP 783 billion and interest income from MOP 8 billion to MOP 30 billion, were highly correlated to Macau's GDP growth (with the correlation coefficient of 2.976***, 1.802***, and 0.061***, respectively, untabulated) (Note 4) during this time period. Such correlation provides evidence of a solid connection between Macau's banking system and its economic growth during Macau's transformation into a wealthy and modern metropolis. However, the size of 26 banks in Macau and their market shares varied significantly in terms of total assets and total loans. As of 2016, the top three banks in Macau, Bank of China (BOC), Industrial and Commercial Bank of China in Macau (C-ICBC) and Tai Fung Bank (TaiFung), a BOC affiliate were subsidiaries of banks located in Mainland China. Together, they dominated the banking market in Macau with more than 65% share of total loans and total bank assets.

So far, there has been no in-depth research on Macau's banking system, which performs the essential functions in its fast growth since 1999 leading to one of the wealthiest economies globally. Due to the strong connection to economic growth and relatively high market concentration, it is time for a thorough study of Macau's banking sector with a focus on the key linkage related to bank competition, efficiency, and stability.

To the best of our knowledge, we are the first to use a sample of 26 banks, which covers all the banks with normal operations in Macau from its return to China in 1999 to 2016, to conduct a comprehensive review of Macau's banking system. By using the Lerner index and the Herfindahl-Hirschman Index (HHI) indicating bank competition and Distribution Free Approach (DFA) measuring bank efficiency, through the Granger causality test, we demonstrate that bank competition does Granger cause efficiency in Macau over the period. Our findings also indicate a positive but not significant connection between bank competition and stability. More specifically, bank market power proxied by the Lerner index has an insignificantly positive connection to bank fragility including income volatility and insolvency risk, which echoes the direction of the competition-stability theory in Macau, though the results are statistically insignificant. Furthermore, our analysis finds an insignificantly negative linkage between bank size proxied by the rank of total loan and total assets, and bank efficiency, which indicates that economies of scale or market share don't necessarily bring about efficiency in Macau's banking industry.

Our findings not only contribute to the literature but also provide sound implications to the practitioners and policymakers. This research provides robust empirical evidence that bank competition causes efficiency in Macau. The growing market concentration may eventually change the landscape of the bank competition and negatively affect bank efficiency in Macau. Therefore, bank competition should be a key observation constantly under the scrutiny of policymakers in Macau. Our results also suggest a potential linkage between high market power and high bank income volatility and insolvency risk. Therefore, based on the relatively high level of market concentration demonstrated by both the market share and the Lerner index in this research, one possible suggestion to the policymakers is to consider specific antitrust measures to discourage the growing market power of top players in the banking sector.

Furthermore, based on our findings that bank size doesn't necessarily result in economies of scale in Macau's banking industry, it becomes a meaningful task for large banks with low efficiency to benchmark against the small but high-efficiency counterparts to benefit from their best practices. The large banks may learn from the small banks like WH and First Commercial Bank to streamline their operations to improve their efficiency. After all, a more competitive and efficient banking industry would bring more low-cost financial resources to Macau's economy and better support its future growth.

The remainder of this study is organized as follows: Section 2 provides a review of literature and research proposition development; Section 3 describes the sample data and research design; Section 4 presents the analysis of the results; and Section 5 offers the conclusions and directions for future research.

2. Literature Review and Research Propositions

2.1 Bank Competition and Efficiency

The recent global financial and economic crisis has highlighted the crucial position of banks in the economy. Banks play a critical role in the payment system, the provision of credit (Beck, Demirgüç-Kunt, & Maksimovic, 2004), the

transmission of monetary policy, overall industrial and economic growth (Claessens & Laeven, 2005), and maintaining financial stability (Boyd & De Nicoló, 2005; Boyd, De Nicoló, & Smith, 2004). The essential role of banks in the economy makes the issue of banking competition extremely important (Bikker, Shaffer, & Spierdijk, 2012).

The majority of the literature studies about bank competition conclude that banks operate in monopolistic competitive environments (Beck, Demirgüç-Kunt, & Levine, 2006; Claessens & Laeven, 2004). Bank competition indicators can be categorized into two groups: structural and conduct indicators (Dubovik & Kalara, 2018). The Structure-Conduct Performance (SCP) paradigm uses the structure of the market to determine the conduct of the firms affecting their performance and argues that concentration measures serve as proxies for the level of competition (Bain, 1956). The advantage of using SCP approach, e.g., HHI, is that concentration measures are relatively easy to observe without requiring data on the prices and costs of firms. However, it receives criticism through the theory of the contestable markets, which argues that, if the costs of entry and exit are low, even a highly concentrated market can be competitive (Baumol, Panzar, & Willig, 1983). Contrary to SCP, the New Empirical Industrial Organization suggests that competition can be directly captured through the conduct assessment of firms through demand elasticities or market dynamics (Bresnahan, 1989). Popular conduct measures of competition include the Lerner index, the Panzar and Rosse H-statistic (Panzar & Rosse, 1987), and the Boone indicator (Boone, 2008). While the H-statistic and Boone indicator summarize only the total activities of banks, descriptive statistics like HHI and the Lerner index, to a certain extent, being robust measures of competition at the individual bank level, are widely used in the banking industry among others by the European Commission (Dubovik & Kalara, 2018). In this study, we choose the Lerner index to measure bank competition and HHI for the robustness check.

Some studies find that bank competitive conditions have deteriorated on average during the 2000s, while market power further grew after the financial crisis years (Beck, De Jonghe, & Schepens, 2013; Clerides, Delis, & Kokas, 2015). Nevertheless, the empirical results are differentiated across the region and market groups. Apergis (2015) identifies evidence in favor of monopolistic competition and decline competition after the recent financial crisis in the banking sectors of emerging market economies spanning the period of 2000 to 2012. Staikouras and Koutsomanoli-Fillipaki (2006) conduct a multi-country analysis for the EU right after the enlargement to 25 member countries and find evidence of larger banks performing more competitively and with new banking members demonstrating higher levels of competition. However, using the Lerner index over the period of 2002 to 2011, Fungáčová, Pessarossi and Weill (2013) observe no increase in bank competition in China. Due to the strong connection between Macau's economic growth and its banking sector, it is meaningful to study the competitive condition of banks in Macau and how it evolves after 1999.

Besides bank competition, another critical aspect of the banking industry is bank performance or efficiency. It is crucial to improve bank performance by identifying reasons for inefficient resource allocation and encouraging the best practices. Bank performance is usually evaluated through frontier efficiency analysis, which benchmarks the efficiency of banks with the best performing ones in the sector and then results can be employed for further analysis and best practices sharing (Bhatia, Basu, Mitra, & Dash, 2018). Frontier efficiency, which overcomes the shortcoming of the ratio and regression analysis through benchmarking techniques comparing the performance with the peers on scale, revenue, cost, profit and technology utilization (Banker, Cummins, & Klumpes, 2010). The results gained from efficiency analysis can help management to pinpoint the opportunity areas where the bank is underperforming in comparison to its competitors to set future directions for improvement. The frontier efficiency methodology includes non-parametric and parametric approaches. Non-parametric approaches typically include Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) analysis. Parametric techniques normally include Stochastic Frontier Approach (SFA) and DFA (Bhatia et al., 2018).

Non-parametric approaches are not restrictive regarding functional form specification and the distribution of the random error. DEA focuses on decision-making units (DMUs), which convert a given amount of inputs to specific output (Charnes, Cooper, & Rhodes, 1978). These DMUs don't assume a particular functional form/shape for the frontier in the conversion process of inputs to outputs and envelop the observations under a frontier. DEA is flexible and allows for various assumptions regarding returns to scale and input- or output-oriented model. However, DEA does not allow for random error. Any deviation from the frontier in DEA would be treated as inefficiency which may lead to overstatement (Berger & Mester, 1997). As a modified version of DEA, FDH estimator is introduced to relax the convexity assumption of DEA (Deprins, Simar, & Tulkens, 1984). Another measure stemmed from DEA is the Malmquist index which evaluates the efficiency change over time (Tone, 2004). However, all nonparametric approaches are sensitive to extreme values and don't allow for noisy data (Simar & Wilson, 2013).

Parametric approaches do not suffer from the drawback of non-parametric methods. Instead, they proceed with assumed specific functional form and the distribution of random error. SFA is applied as an econometric frontier approach to the bank performance analysis, in which inefficiencies are assumed to strictly follow half-normal (asymmetric) and random errors are expected to follow standard normal (symmetric) distribution (Ferrier & Lovell, 1990). DFA is another parametric frontier technique to address the criticism of SFA's arbitrary and strict assumptions. DFA relaxes distributional assumptions and assumes inefficiencies to be stable over time. It treats the expected value of random error to be zero, over a period of time. We select DFA to measure bank efficiency in this study.

It is important for policymakers to identify the competition-efficiency relationship in their market and set suitable guidelines accordingly. Theoretically, the competition-efficiency relationship can be grouped along two dimensions: causation and direction (Koetter, Kolari, & Spierdijk, 2008). Starting from causation, the efficient structure hypothesis posits that bank efficiency determines the market structure. Peltzman (1977) argues that concentration actually signals efficiency rather than collusion. The most efficient banks possess a long-run competitive advantage and acquire market shares which leads to more market power and higher market concentration (De Jonghe & Vennet, 2008; Demsetz, 1973).

In contrast, the market structure, structure-performance, and competition-efficiency hypotheses posit a reverse causality to assume that the bank's market power determines efficiency. Among them, the "quiet life" hypothesis argues that, when market power prevails, bank managers may not have incentives to work diligently to lower the costs and maximize the profits, thereby reducing cost efficiency, namely, a quiet life (Berger & Hannan, 1998). Delis and Tsionas (2009) use a sample of European banks to provide empirical evidence on the analysis of efficiency and market power and report a negative relationship between market power and efficiency, in line with the predictions of the "quiet life" hypothesis.

In terms of direction, the "quiet life" hypothesis is not always supported by the empirical findings. Maudos and de Guevara (2007) find a positive relationship between bank market power and cost efficiency in EU-15 countries over from 1993 to 2002, which rejects the "quiet life" hypothesis. Employing an industrial organization-based approach to large data sets for European and U.S. banks, Schaeck and Čihák (2008) use Granger causality tests to establish the link between bank competition and profit efficiency measures, and demonstrate that high competition (or lower market power) does indeed increase bank efficiency. A later study on the evolution and convergence of competition in 27 banking systems of European Union for the period of 2004 to 2010 confirms the competition-efficiency hypothesis in terms of cost and profit efficiency, which states that an increase in banking competition levels would bring an increase in the efficiency level of banks (Andrieș & Căpraru, 2014).

Furthermore, there is ambiguous or even contradictory evidence on the competition-efficiency relationship. Using a sample of European banks, Casu and Girardone (2006) do not determine a clear connection between efficiency and competition. A similar study finds no significant relationship between bank competition and efficiency in China (Fungáčová et al., 2013), which is supported by Tan (2016) who uses the Lerner index as a competition measure to test its impact on bank profitability and finds no robust effect of competition on Chinese bank profitability. A more recent study of the Chinese banking industry indicates that higher competition leads to lower profitability, where the structure-performance hypothesis holds better than the efficient structure paradigm (Tan, Floros, & Anchor, 2017). However, Koetter, Kolari, and Spierdijk (2008) posit that competition and efficiency are intertwined. They use a structural model to find support for the efficient structure hypothesis rather than the "quiet life" hypothesis for the U.S. banks.

Although Macau banks' size, deposit and loan business, and non-interest income have grown at an average rate of 10% (Gong & Lin, 2011) and banks have been playing an essential role in Macau's impressive economic growth since its return to China, there are only a few empirical studies on the banking efficiency in Macau. Mendes and Rebelo (2000) use the classic Malmquist index to measure the productivity changes of 17 banks in Macau from 1990 to 1997. Fu and Vong (2011) use DEA approach to find that the operations of banks in Hong Kong and Macau maintain high technical efficiency of over 97%. They also argue that banks in Macau are slightly more efficient and more sensitive to macroeconomic changes than their counterparts in Hong Kong over the period of 1995 to 2006. This study only involves a limited number of large commercial banks in Macau and, by using DEA method, excludes the impacts caused by random errors in efficiency assessment. Another research conducted by Gong and Lin (2011) uses the Bootstrap DEA model and the Malmquist index to evaluate the operational efficiency of the banking industry in Macau from 2001 to 2008 and explores the impact of capital adequacy ratio, loan-to-deposit ratio, asset size, non-interest revenue ratio, market power, economic growth, inflation rate and real interest rate on efficiency scores. They conclude that the loan-to-deposit ratio has a positive effect on the efficiency of Macau banks. On the contrary,

the scale of banks, non-interest business, and efficiency are negatively correlated. The productivity of the banking industry, which is closely linked to the fluctuations in the economy of Macau, makes no significant improvement from 2001 to 2008 (Gong & Lin, 2011). However, there has been no in-depth research on the relationship between bank competition and efficiency in Macau.

It is clear that the inconclusive evidence on bank competition-efficiency relationship in other markets and the lack of thorough exploration in Macau lead to our first research proposition to examine the causation between bank efficiency and competition in Macau with the following hypotheses:

H1: The null hypothesis is “competition does not Granger cause efficiency,” and the alternative hypothesis is “competition does Granger cause efficiency.”

H2: The null hypothesis is “efficiency does not Granger cause competition,” and the alternative hypothesis is “efficiency does Granger cause competition.”

2.2 Bank Competition and Bank Stability

Banks form a part of the payment system, and consequently, banking activities directly or indirectly affect economic stability. Any bank failure can cause a systemic crisis (Fethi & Pasiouras, 2009). One focus of the existing literature is on the relationship between bank competition and bank stability as the center of banking sector policy debate among academics and policymakers (Diallo, 2015).

There are two strands of the literature, namely the “competition-stability” and the “competition-fragility” views. According to the competition-stability theory, banks with greater market power result in higher bank risk due to the higher interest rates charged to loan customers which would increase loan portfolio risk and intensify moral hazard and adverse selection problems. Monopolistic banks charge higher loan rates, which may induce borrowers to take on risky investments resulting in the potential increase of loan defaults and causing a higher probability of bank failure (Boyd & De Nicoló, 2005). Furthermore, larger banks are often more likely to have deposit insurance and the government's safety net so that they are inefficiently managed and more likely to fail. With the protection provided by public guarantees, large bank managers may take on risky investments. Mishkin (1999) suggests the so-called ‘too-big-to-fail’ concept and argues that, along with the size of banks, the moral hazard problem becomes more severe. The competition-stability hypothesis is supported by empirical evidence from the banks in the U.S. (De Nicolo, Jalal, & Boyd, 2006), European (Schaeck & Čihák, 2014; Uhde & Heimeshoff, 2009) and 55 emerging and developing countries (Amidu & Wolfe, 2013). In summary, the less competition, the more risk.

Under the alternative competition-fragility theory, banks with greater market power also have less overall risk exposure. More competition erodes banks' market power, reduces profitability, and causes decreased franchise value and induces banks' risk-taking (Berger, Klapper, & Turk-Ariss, 2009). The charter value hypothesis (Keeley, 1990) or franchise value hypothesis provides banks with a valuable source of monopoly power (Hellmann, Murdock, & Stiglitz, 2000). Higher franchise value is expected to reduce risk-taking incentives and increase capital due to the growing opportunity costs when bankruptcy occurs. In other words, the less competition, the less risk. Banks in the U.S. with high charter value operate more safely who hold more capital and take on less portfolio risk, mainly through diversifying their lending activities (Demsetz, Saidenberg, & Strahan, 1996). Studying data on 69 countries from 1980 to 1997, Beck et al. (2006) find that crises are less likely in economies with more market concentration in banking systems. The competition-fragility theory is also supported by empirical evidence from Spain (Saurina Salas, Jiménez, & Lopez, 2007) and Latin American countries (Yeyati & Micco, 2007). Furthermore, an increase in competition will have a larger impact on banks' fragility in countries with stricter activity restrictions, lower systemic fragility, more generous deposit insurance better-developed stock exchanges, and more effective systems of credit information sharing (Beck et al., 2013).

The existing literature also provides disputable results. Banking data from Gulf Cooperation Council (GCC) market support for both competition-stability and competition-fragility views in the area (Saif-Alyousfi, Saha, & Md-Rus, 2018). Intensified competition decreases insolvency risk and credit risk but increases liquidity risk in the Chinese banking industry (Tan & Floros, 2018). Martinez-Miera and Repullo (2010) suggest a nonlinear relationship between competition and bank risk-taking who propose a U-shaped relationship between bank competition and bank failure risk. Again, there has been no research on the relationship between bank competition and stability in Macau.

The relationship between bank competition and stability remains a widely debated issue. Meanwhile, it is also an unexplored area in Macau, which leads to our second research proposition to examine the association between bank competition and stability with the null hypothesis that “bank competition does not impact bank stability in Macau” (H3).

2.3 The Effect of Bank Size on Efficiency

Another argument on bank efficiency is related to bank size. In microeconomics, economies of scale mean the cost advantages that companies manage to gain due to the growth of their scale of operation, or simply say that firms can do things more efficiently with increasing size (Chandler, 1977). There are studies of banks in different markets that provide support to a positive effect of bank size on efficiency. Without risk and quality factors, inefficiency decreases with the growth of bank size in Japan (Altunbas, Liu, Molyneux, & Seth, 2000). Similar findings are available in the European banking systems (Cavallo & Rossi, 2002; Lang & Welzel, 1996), Latin American countries (Carvallo & Kasman, 2005), and Asian countries like India, Bangladesh, Pakistan and Sri Lanka (Perera, Skully, & Wickramanayake, 2007).

However, there are contradictory results arguing that bank size is positively related to inefficiency. Large banks, particularly in separated banking countries, show significant diseconomies of scale (Allen & Rai, 1996). Similar empirical evidence is found in the Chinese banking sector by examination of bank ownership and size (Kumbhakar & Wang, 2007). Additional support from 10 of the European Union countries shows that, for medium-size and huge banks, bank size is negatively related to cost and profit efficiency (Maudos, Pastor, Pérez, & Quesada, 2002).

Moreover, there are mixed results regarding the relationship between bank size and banking efficiency presented in the extant literature. Some argue that such a tie varies depending on bank size by category. Large banks show significant inefficiency while small ones show significant scale economies in the Ukrainian banking sector (Mertens & Urga, 2001). Others find that the large state-owned banks and smaller banks are more efficient than medium-sized banks in China (Chen, Skully, & Brown, 2005). Using the case of Italian banks, researchers find that there is no clear relationship between asset size and bank efficiency (Girardone, Molyneux, & Gardener, 2004). The examination of the cost efficiency of the U.S. banks by employing both parametric and non-parametric frontier techniques finds no indication that large banks are more cost efficient than small banks (Ferrier & Lovell, 1990).

The debate on bank size and efficiency is still unsettled. Furthermore, there is no prior research related to the effect of bank size on efficiency in Macau, which leads to our third research proposition to explore the relationship between bank size and bank efficiency with the null hypothesis that “bank size has no impact on bank efficiency in Macau” (H4).

3. Sample and Research Design

3.1 Data

The sample data are retrieved from the annual financial statements of the banks in Macau over the period of 1999 to 2016 available through AMCM's website. AMCM requires every bank in Macau to provide its annual financial statements, including the balance sheet and income statement, then releases such information through its website to the public. At present, there are 29 banks in Macau, of which 10 are locally incorporated (including the Postal Savings Office), and 19 are branches of overseas banks. The sample used in this research consists of 26 banks in Macau with 388 firm-year observations in total (some banks started their operations after 1999). Postal Savings Office; Banco Delta Asia (BDA) which was designated by the U.S. Department of the Treasury as primary money laundering concern under the USA PATRIOT ACT and sanctioned as complicit in a North Korean illegal activity in September 2005; and Agricultural Bank of China which just opened its Macau branch in the second half of 2017, are excluded in this research. Therefore, the sample used in this research covers all the banks with normal operations in Macau from 1999 to 2016.

3.2 Bank Competition

In this study, we use conduct indicator of the Lerner index to measure bank competition in Macau and structural indicator of HHI in the robustness check. The Lerner index, formalized by Abba Lerner in 1934, is widely used in the banking industry (Berger et al., 2009). It estimates the market structure by measuring the strength of monopoly power. The Lerner index quantifies the markup of price over marginal cost, indicating the bank's ability to set the price above its marginal cost. The index (Lerner or COM) ranges from a high of 1 to a low of 0. In a perfectly competitive market, the set price is supposed to be equal to its marginal cost ($P=MC$) and therefore, Lerner=0, such a bank will have no market power. A greater index means higher market power or lower competition. It serves as an inverse measure of competition. The Lerner index, according to Berger et al. (2009), measures competition of each period at the bank level can be calculated as:

$$\text{Lerner or } COM = \frac{(P-MC)}{P} \quad (1)$$

where P is the price of the bank. In the banking industry, interest revenues from loans dominate the performance of

each bank. The price is computed as interest income divided by net loans, which are total loans minus non-performing loans. Following the existing literature (Fernandez de Guevara & Maudos, 2009; Tai, 2012), a translog function is constructed to find out the marginal cost of each bank (MC) by including three inputs prices (labor, physical capital, and borrowed funds) and one output value (loans). We use the following translog cost function as:

$$\ln TC = \alpha_0 + \alpha_1 \ln y + \frac{1}{2} \alpha_2 (\ln y)^2 + \sum_{j=1}^3 \beta_j \ln w_j + \sum_{j=1}^3 \sum_{k=1}^3 \beta_{jk} \ln w_j \ln w_k + \sum_{j=1}^3 \gamma_j \ln y \ln w_j + \varepsilon \quad (2)$$

where the price of output (y) is measured by loans, and input prices for labor, physical capital, borrowed funds are computed by the ratio of personnel expenses to total assets (w_1), depreciation expenses for physical capital to fixed assets (w_2), and interest expense to borrowed funds (w_3). Total Costs (TC) is the sum of w_1 , w_2 and w_3 . Therefore, the estimated coefficients of the cost function are used to measure the marginal cost.

$$MC = \frac{TC}{y} (\alpha_1 + \alpha_2 \ln y + \sum_{j=1}^3 \gamma_j \ln w_j) \quad (3)$$

The Lerner index of each bank for each period can be computed using equation (1) after the marginal cost and the price of output are calculated based on that bank's financial statements.

3.3 Bank Efficiency

To measure bank efficiency in Macau, we use DFA, a parametric approach, based on the earlier panel data approach developed by Schmidt and Sickles (1984). DFA separates the inefficiency term and the random error term. Due to the presence of random interference and inefficiency, the sample banks deviated from the efficient frontier bank, which refers to the bank that obtains the maximization of profit with minimum input based on given technical conditions and external market factors. In DFA analysis, the efficient frontier bank has its efficiency as 100%. DFA does not specify the specific form of inefficiencies but assumes that inefficiencies are stable over time while random error tends to average out (Schmidt & Sickles, 1984). This method requires the use of time-series and panel data in the regression, and the estimation of the bank's efficiency is a mixed estimate. Assume that the bank's cost function has the following logarithmic form:

$$\begin{aligned} \ln TC_{it} &= \ln f(y_{it}, w_{it}) + \varepsilon_{it} \\ \ln TC_{it} &= \ln f(y_{it}, w_{it}) + \ln x_i + \ln v_{it} \end{aligned} \quad (4)$$

where,

TC is the total cost of i bank in the t period,

$f(y_{it}, w_{it})$ is the cost function, y_{it} is the output price,

w_{it} are the input prices,

x_i is the inefficient factor of the i bank,

v_{it} is the random error for the i bank in the t period.

Under DFA's assumptions, each bank's inefficiency term remains constant for a certain period of time, except for all other elements in the equation (4) that are allowed to change over time.

The uniqueness of the DFA efficiency frontier function parameter is that it does not estimate the entire continuous time series panel data as a single cost function. Instead, it uses a year-by-year data to separately estimate a cost function. The difference in costs due to changes in technology and regulations in different years will be reflected by the parameters of the annual cost function. In addition, the inefficiency term and the random error term must be treated as a compound error in the estimation, as $\varepsilon_{it} = \ln x_i + \ln v_{it}$. Since the mean of the random error term is zero during the t period, the mean of the compound error term is the inefficiency.

The definition of the distribution-free estimation for bank i is as follows:

$$dfe_i(T) = \frac{1}{T} \sum_{t=1}^T \ln \varepsilon_{it} = \ln \hat{x}_i \quad (5)$$

where, T is the number of sample observation period, and the efficiency level of the investigated bank is a relative value to the efficiency level of the best performing bank in the sample:

$$EFF_i(T) = \exp[dfe_{min}(T) - dfe_i(T)] \quad (6)$$

where,

$EFF_i(T)$ is the efficiency level of bank i ,

$0 < EFF_i(T) \leq 1$, $dfe_{min}(T)$ is the minimum of all investigated bank inefficiencies, $EFF_i(T)$ increases with bank's cost efficiency.

3.4 Causality between Bank Competition and Efficiency

To explore the relationship between bank competition and efficiency, the Granger causality test is used in this study. The advantage of this method is that it incorporates error correction so that the Granger causal analysis method can test long-term causality and short-term causality. Determining the direction of causality between competition (COM) and efficiency (EFF) can be tested by the two equations as:

$$COM_t = \alpha_0 + \sum_{i=1}^m \alpha_i COM_{t-1} + \sum_{j=1}^n \alpha_j EFF_{t-j} + u_t \quad (7)$$

$$EFF_t = \beta_0 + \sum_{i=1}^m \beta_i EFF_{t-1} + \sum_{j=1}^n \beta_j COM_{t-j} + v_t \quad (8)$$

where

i represents the individual bank and t denotes time

$\alpha_i, \alpha_j, \beta_i, \beta_j$ = parameters to be estimated

α_0, β_0 = individual bank fixed effect

u_t, v_t = error terms

COM_{t-1} = The Lerner index indicating bank competition of bank i at $t-1$

COM_{t-j} = j^{th} lagged Lerner index indicating bank competition, $j=1, 2, \dots, n$

EFF_{t-1} = cost efficiency of the bank i at $t-1$

EFF_{t-j} = j^{th} lagged cost efficiency, $j=1, 2, \dots, n$

Granger's causality indicates that the relationship between the Granger cause and do not Granger cause. It focuses on the confirmation of the direction of influence rather than the complete causality (Granger, 1969; Gujarati, 2003).

3.5 Bank Stability

In this study, following Agoraki, Delis, and Pasiouras (2011) and Soedarmono, Machrouh, and Tarazi (2011), financial stability is measured by bank income volatility, insolvency risk, and capitalization. The standard deviation of banks' return on average assets (SROA) and that of banks' return on average equity (SROE) are proxies of bank income volatility that reflects bank risk-taking strategies. SROA is computed from the return on average assets (ROAA) values taken from period t to $t-2$ (a three-period rolling window). Analogically, SROE is calculated from the return on average equity (ROAE) using a three-period rolling window. To measure bank insolvency risk, the Z-score method based on ROAA is applied. The Z-score (ZROA) represents the number of standard deviations that the bank's ROAA has to fall below its expected value before equity is completely exhausted. Therefore, a higher Z-score can be interpreted as lower in bank insolvency risk (Soedarmono et al., 2011).

ZROA is formulated as follows:

$$ZROAi, t = (ROAAi, t + EQTAi, t) / (SROAi, t) \quad (9)$$

where

i represents the individual bank and t denotes time

For robustness check, we also use the Z-score measure based on ROAE (ZROE) which is formulated as follows:

$$ZROEi, t = (ROAEi, t + 1) / (SROEi, t) \quad (10)$$

Banks may reduce financial fragility by maintaining higher levels of capital that protect them from external economic and liquidity shocks (Amidu & Wolfe, 2013). The leverage ratio can also serve as a measure to discipline bank moral hazard (Blum, 2008). To account for the levels of bank capitalization, we use the equity to total assets ratio (EQTA), as an indicator of leverage.

Following Soedarmono et al. (2011), we also include the four control variables. The loan-to-deposit ratio (LDR), which indicates bank liquidity that may affect bank default probability, is used to control for bank-specific characteristics. The loan growth rate (LOANG) is included since excessive loan growth can result in higher bank risk and lower capital ratios (Foos, Norden, & Weber, 2010). The ratio of operating expenses to total assets (OVERHEAD) is a control for the differences in technical efficiency (Agoraki et al., 2011). Bank size (SIZE), defined as the logarithm of banks' total average assets to control for higher risk-taking to address "too big to fail" effects in larger banks (Mishkin, 2006).

To assess the impact of bank competition, proxied by the Lerner index, on financial stability, proxied by SROA, SROE, ZROA, ZROE and EQTA, we construct equation (11) following the existing literature (Agoraki et al., 2011; Soedarmono et al., 2011).

$$STABILITY_{i,t} = \alpha_1 LERNER_{i,t} + \alpha_2 LDRI_{i,t} + \alpha_3 LOANG_{i,t} + \alpha_4 OVERHEAD_{i,t} + \alpha_5 SIZE_{i,t} + \varepsilon_{i,t} \quad (11)$$

where

i represents the individual bank and t denotes time

Our main variable of interest is α_1 , the coefficient on the Lerner index, which captures the change in the association between bank competition and stability. A significantly positive α_1 between SROA/SROE and the Lerner index testifies the competition-stability view, while a significantly negative one indicates the competition-fragility view. In the meantime, a significantly negative α_1 between ZROA/ZROE and the Lerner index attests the competition-stability view, while a significantly positive one indicates the competition-fragility view in Macau.

3.6 Bank Size

We use loan rank (Tai, 2012) and the logarithm of total assets (Chen et al., 2005) to indicate bank size to examine the effect of bank size on bank efficiency measured by DFA approach mentioned in 3.3 to examine H4 of “bank size has no impact on bank efficiency in Macau.”

4. Results and Analysis

4.1 Descriptive Statistics

As indicated in Table 1, the size of the banks and their operations varied significantly in terms of total assets and total loans. In the year 2016, Bank of China (BOC) and its affiliate Tai Fung Bank (TaiFung) had 40% and 10% share of total loans, respectively, in Macau. BOC, with MOP 456 billion of total loans and MOP 538 billion of total assets, led the local banking sector, followed by Industrial and Commercial Bank of China Limited (C-ICBC) and TaiFung. The top three players occupy over 65% market share in both total loans and total assets, which indicates a relatively high market concentration. Banco Nacional Ultramarino S.A. (BNU), the other issuing bank authorized by AMCM to issue local banknotes denominated in Macanese Pataca (MOP) besides BOC, had a share of 4.4% of total loans and 4.3% of total assets. Citibank had only MOP 2 million total loans and MOP 5 million total assets which made it the smallest bank in Macau.

Table 1. Total Loans and Total Assets, 2016

<i>Bank</i>	<i>Total Loans (MOP Million)</i>	<i>Total Assets (MOP Million)</i>
BOC	455,684	538,464
TaiFung	113,039	152,894
C-ICBC	175,257	209,557
WH	28,478	31,830
BPI	874	877
BNU	51,158	68,497
CITIC	2,097	2,765
Construction Bank	37,123	38,667
Wing Lung	13,822	14,006
SinoPac	3,249	3,369
Chinese Bank	1,455	2,106
Guangfa	22,241	26,731
Comercial Portugues	10,468	10,930
HSBC	21,502	23,152
Hua Nan	4,547	4,657
Standard Chartered	2,520	3,033
Chong Hing Bank	2,726	2,949
First Commercial Bank	1,671	1,774
Luso	99,954	129,491
Banco Comercial	16,949	19,445
DBS	3,516	4,581
Hang Seng	13,773	17,044
Citibank	2	5
East Asia	6,959	7,541
Bank of Communications	49,629	58,793
Novo	854	951

Table 2 shows descriptive statistics of the key variables in 2016 used in the quantitative analysis. Two output variables, bank total loans had an average of MOP 43.8 billion and net loans of MOP 30.0 billion. Both had a high standard deviation of MOP 93.9 billion and MOP 61.5 billion, respectively, which indicates that the size of bank operations varied widely in Macau. Price of labor (w_1) had a mean of 0.36%. Price of physical capital (w_2) had a mean of 25.96% and a standard deviation of 31.79%. Price of borrowed funds defined (w_3) was 1.30% on average. Among other characteristics, average total assets were MOP 52.9 billion and average total costs were MOP 720 million. Both had wide variations. Price of loan, on average, was 3.86%, which indicated an interest margin of 2.56% in 2016.

Table 2. Descriptive Statistics, 2016

	<i>Mean</i>	<i>Standard Deviation</i>
<i>Output</i>		
Loans (MOP Million)	43,829	93,873
Net loans (MOP Million)	30,029	61,522
<i>Input prices</i>		
Price of labor (%)	0.36	0.34
Price of physical capital (%)	25.96	31.79
Price of borrowed funds (%)	1.30	1.95
<i>Other characteristics</i>		
Total assets (MOP millions)	52,850	112,145
Total costs (MOP millions)	720	1,609
Price of loans (%)	3.86	1.80

Note: N=26 banks

4.2 Bank Competition, Efficiency, and Causality

Table 3 summarizes the mean, median and standard deviation of the Lerner Index for the sample banks from 1999 to 2016. Since the Lerner index, ranging between 0 to 1, is an inverse measure of the competition, the level of competition of the Macau banking industry can be observed through its fluctuation over that period. Immediately after Macau's return to China in 1999, the competition in its banking sector started to decrease till 2003. The competition increased around the global financial crisis in 2007 and 2008 and decreased again in the recent two years. Using the Lerner index's mean of 0.5856 and median of 0.6119 in 1999 to compare against the most recent mean of 0.6307 and median of 0.6643 in 2016, it indicates an overall lower level of competition or higher level of market concentration in 2016 than 1999.

Table 3. Lerner Index for All Banks, 1999-2016

<i>Year</i>	<i>Mean</i>	<i>Median</i>	<i>Standard Deviation</i>
1999	0.5856	0.6119	0.3021
2000	0.6672	0.6756	0.1468
2001	0.6342	0.6818	0.1974
2002	0.6877	0.7350	0.1750
2003	0.6986	0.7338	0.1602
2004	0.6076	0.6951	0.2160
2005	0.6251	0.6297	0.1615
2006	0.6375	0.5937	0.1698
2007	0.5238	0.5069	0.2152
2008	0.5263	0.5262	0.1869
2009	0.5949	0.6386	0.2431
2010	0.6211	0.6446	0.1756
2011	0.6192	0.6579	0.1862
2012	0.5409	0.5951	0.2714
2013	0.6186	0.6585	0.1847
2014	0.5868	0.6157	0.1996
2015	0.6177	0.6715	0.1945
2016	0.6307	0.6643	0.1873

The comparison of the Lerner index of individual banks in 1999 vs. 2016 is displayed in Table 4, which is used to signal the change of their market power in the competition. The increase of a bank's Lerner index reflects greater market power in the competition. On the contrary, the decrease of the Lerner index reflects the lower market power in the competition. 12 out of 26 banks, including the top three banks by size, managed to gain more market power over the years. Other 14 banks, including BNU, lost their market power at the same time.

Table 4. Lerner Index for Individual Banks, 1999-2016

<i>Bank</i>	<i>1999</i>	<i>2016</i>	<i>Comment</i>
BOC	0.5791	0.6019	Greater market power
TaiFung	0.5987	0.6070	Greater market power
C-ICBC	0.4598	0.5834	Greater market power
WH	0.6250	0.6024	Less market power
BPI	0.9932 ¹	0.9944	Greater market power
BNU	0.7224	0.6876	Less market power
CITIC	0.1869 ¹	0.6989	Greater market power
Construction Bank	0.5484	0.3735	Less market power
Wing Lung	0.6687 ²	0.7850	Greater market power
SinoPac	0.4278	0.7178	Greater market power
Chinese Bank	0.5910	0.1655	Less market power
Guangfa	0.5263	0.4151	Less market power
Comercial Portugues	0.9638	0.8842	Less market power
HSBC	0.7030	0.7265	Greater market power
Hua Nan	0.7112 ³	0.8731	Greater market power
Standard Chartered	0.8930 ³	0.7477	Less market power
Chong Hing Bank	0.7907	0.7556	Less market power
First Commercial Bank	0.5520 ⁴	0.6161	Greater market power
Luso	0.3692	0.2719	Less market power
Banco Comercial	0.6281	0.5290	Less market power
DBS	0.6576	0.6853	Greater market power
Hang Seng	0.3507 ⁵	0.7090	Greater market power
Citibank	0.9994	0.8110	Less market power
East Asia	0.7434 ⁶	0.5025	Less market power
Bank of Communications	0.5038 ⁷	0.4110	Less market power
Novo	0.8144	0.6434	Less market power

Note: Started its operation in the year of ¹ 2005; ² 2011; ³ 2013; ⁴ 2010; ⁵ 2004; ⁶ 2001; ⁷ 2007.

The DFA approach is employed for all 26 banks operating through the study period to explore the banking efficiency in Macau from 1999 to 2016. Table 5 shows OCBC Wing Hang Bank Limited (WH) was the most efficient bank in Macau throughout the entire study period. All other banks had values between 1 and 0. Higher efficiency led to an efficiency score closer to 1. First Commercial Bank and Chong Hing Bank had an efficiency score of 0.9905 and 0.9771, respectively, indicating that there were the highly efficient banks next to WH. Luso (efficiency score of 0.6842), Citibank (0.7401), the Chinese Bank and TaiFung (both at 0.8062) were the least efficient banks in Macau. Being the top three banks in terms of total loans and total assets, BOC (0.8304), C-ICBC (0.8076) and TaiFung (0.8062) had efficiency scores lower than the mean and median. It showed that the top three banks had 16.96%, 19.24% and 19.38% possibility of output improvement under the conditions of no extra input. Between two issuing banks, BNU (0.9044)'s efficiency score was higher than BOC (0.8304). Among the 26 banks in the survey, there were only 10 banks whose efficiency score was higher than 0.9. Most banks have the opportunity to improve efficiency or the possibility of an increase in output at the current level of input. The initial comparison using bank size (Table 1), market power (Lerner index in Table 4) and bank efficiency (Table 5) indicates that large banks with greater market power were actually less efficient than their smaller counterparts.

Table 5. Banking Efficiency, 1999-2016

<i>Bank</i>	<i>Efficiency Score</i>
BOC	0.8304
TaiFung	0.8062
C-ICBC	0.8076
WH	1.0000
BPI	0.8858
BNU	0.9044
CITIC	0.9669
Construction Bank	0.9252
Wing Lung	0.8962
SinoPac	0.8366
Chinese Bank	0.8062
Guangfa	0.8123
Comercial Portugues	0.9567
HSBC	0.8938
Hua Nan	0.8765
Standard Chartered	0.8903
Chong Hing Bank	0.9771
First Commercial Bank	0.9905
Luso	0.6842
Banco Comercial	0.8602
DBS	0.9276
Hang Seng	0.8559
Citibank	0.7401
East Asia	0.9484
Bank of Communications	0.9261
Novo	0.8273

Table 6 displays the average Lerner index (an inverse indicator of competition) and efficiency score for all 26 banks in the sample from 1999 to 2016. A negative, but not statistically significant relationship between the Lerner index and efficiency can be observed over that period, which seems to imply competition and efficiency were heading in the same direction. Another noticeable observation is that, right after the global financial crisis, Macau's banking sector experienced relatively high competition and high efficiency from 2009 to 2012.

Table 6. Average Lerner Index and Efficiency Score, 1999-2016

<i>Year</i>	<i>Lerner Index</i>	<i>Efficiency Score</i>
1999	0.5856	0.6497
2000	0.6672	0.6407
2001	0.6342	0.6935
2002	0.6877	0.7051
2003	0.6986	0.6655
2004	0.6076	0.6639
2005	0.6251	0.5673
2006	0.6375	0.8284
2007	0.5238	0.6795
2008	0.5263	0.5623
2009	0.5949	0.7760
2010	0.6211	0.7742
2011	0.6192	0.7737
2012	0.5409	0.8059
2013	0.6186	0.7600
2014	0.5868	0.5419
2015	0.6177	0.7374
2016	0.6307	0.7705

Table 7 presents a key conclusion of our research through the pairwise Granger causality test, which addresses our first research proposition to examine the causality between bank efficiency and competition in Macau. The p -Value of 0.029 for the test of “competition does not Granger cause efficiency” leads to a rejection of H1 null hypothesis. Therefore, the alternative hypothesis “competition does Granger cause efficiency” should be accepted. Such finding provides empirical evidence to support that a high level of competition would cause high efficiency in the banking industry in Macau, which offers valuable support to the practitioners and policymakers to encourage competition in Macau’s banking sector. The H2 null hypothesis of “efficiency does not Granger cause competition” has the p -Value of 0.130 and cannot be rejected, which provides no evidence to judge the causation from efficiency to competition in Macau’s banking sector. The conclusion drawn for the first research proposition regarding the causality between bank competition and efficiency is in line with the competition-efficiency hypothesis (Berger & Hannan, 1998). One possible explanation is that banks were forced to lower the costs to improve efficiency to respond to decreasing market power in a more competitive market environment. A good example is that banks in Macau were having an overall relatively low Lerner index (indicating less market power or greater competition) but high efficiency score right after the 2008 financial crisis (between 2009 to 2012).

Table 7. Pairwise Granger Causality Test Results, 1999-2016

<i>Null Hypothesis</i>	<i>F-Statistics</i>	<i>p-Value</i>
<i>Competition does not Granger cause efficiency</i>	33.363	0.029
<i>Efficiency does not Granger cause competition</i>	6.996	0.130

To test the robustness of the conclusion related to our first research proposition, we use HHI instead of the Lerner index as the indicator of market concentration or competition in Macau, and find very similar results on H1 and H2 null hypotheses (p -Value of 0.029 and 0.340 respectively) demonstrated in Table 8, which, again, support competition does Granger cause efficiency in Macau.

Table 8. Pairwise Granger Causality Test Results Using HHI and Efficiency Score, 1999-2016

<i>Null Hypothesis</i>	<i>F-Statistics</i>	<i>p-Value</i>
<i>Competition does not Granger cause efficiency</i>	9.014	0.029
<i>Efficiency does not Granger cause competition</i>	3.289	0.349

4.3 Bank Competition and Stability

Table 9 summarizes the results related to the second research proposition of “whether there is an association between bank competition and stability in Macau.” The previous study of Asia markets around Macau finds that the degree of market power (LERNER) is positively correlated to bank income volatility proxied by either SROA or SROE. Higher LERNER further intensifies bank insolvency risk proxied by ZROA or ZROE. Moreover, higher LERNER is also associated with an increase in capital ratios (EQTA) (Soedarmono et al., 2011). Our findings demonstrate the same direction between each dependent variable indicating bank stability and the independent variable, the Lerner index, indicating inverse competition or market power, as Soedarmono et al. (2011). In particular, in Equation (11), α_1 is 0.380 (SROA), 44.100 (SROE), -10.255 (ZROA), and -3.110 (ZROE), respectively, which seems to point towards the path of competition-stability theory, but none of α_1 is statistically significant (*p*-value above 10%). Therefore, we cannot reject the null hypothesis of H3 stating that “bank competition does not impact bank stability in Macau.”

Table 9. The Nexus between Bank Competition and Stability

	<i>SROA</i>	<i>SROE</i>	<i>ZROA</i>	<i>ZROE</i>	<i>EQTA</i>
LERNER_i	0.380 (0.285)	44.100 (47.465)	-10.255 (18.588)	-3.110 (11.297)	0.327 (1.483)
LDR_{i,t}	0.010 (0.060)	1.493 (8.394)	1.610 (2.130)	0.004 (0.225)	0.934* (0.493)
LOANG_{i,t}	8.778*** (0.394)	0.211*** (0.027)	0.195 (2.498)	-0.443** (0.207)	0.002 (0.002)
OVERHEAD_{i,t}	0.429 (5.225)	0.158 (0.591)	0.878*** (0.298)	-0.008 (0.025)	0.123*** (0.038)
SIZE_{i,t}	-0.150 (0.103)	-13.930 (9.220)	4.818 (4.631)	0.974** (0.431)	-1.132** (0.546)
R-square	0.11	0.23	0.12	0.12	0.09
Obs.	292	295	304	312	286

Notes: 1. SROA, SROE, ZROA, ZROE are calculated using a three-year rolling window. All independent variables are calculated as one-year lag to avoid reverse-causality. ***, **, * indicates significance level at 1%, 5%, and 10%, respectively. 2. To eliminate the impacts of apparent outliers, observations with an independent variable outside 2 standard deviations are omitted. Thus, the observation numbers of different regressions are not consistent.

4.4 Bank Size and Efficiency

In Table 10, the Spearman Rank Correlation is used to examine H4 of “bank size has no impact on bank efficiency in Macau” by exploring the relationship between efficiency proxied by efficiency rank and bank size proxied by loan rank in 2016. The correlation coefficient between efficiency rank and loan rank is negative (-0.1159), but not statistically significant (*p*=0.5729). Thus, we cannot reject the null hypothesis of H4. The economies of scale don’t necessarily bring about efficiency in Macau’s banking industry, which is consistent with the findings in the U.S. market (Ferrier & Lovell, 1990) and Italian banks (Girardone et al., 2004). Our result also partially echoes, at least from the direction perspective, the previous finding of a negative correlation between the scale of bank and efficiency in Macau (Fu & Vong, 2011). One possible explanation is that large banks open and maintain more branches in this tiny market, which would certainly increase their costs but may not necessarily generate additional output or loans proportionately. Another possibility is that small banks can rely on new technologies such as online banking and mobile banking to efficiently penetrate the market without adding additional branches and personnel.

Table 10. Spearman Rank Correlation between Efficiency and Size

<i>Bank</i>	<i>Efficiency Rank</i>	<i>Loan Rank, 2016</i>
WH	1	8
First Commercial Bank	2	22
Chong Hing Bank	3	19
CITIC	4	21
Comercial Portugues	5	14
East Asia	6	15
DBS	7	17
Bank of Communications	8	6
Construction Bank	9	7
BNU	10	5
Wing Lung	11	12
HSBC	12	10
Standard Chartered	13	20
BPI	14	24
Hua Nan	15	16
Banco Comercial	16	11
Hang Seng	17	13
SinoPac	18	18
BOC	19	1
Novo	20	25
Guangfa	21	9
C-ICBC	22	2
TaiFung	23	3
Chinese Bank	24	23
Citibank	25	26
Luso	26	4

Note: The correlation coefficient between efficiency rank and loan rank was negative (-0.1159), but not statistically significant ($p=0.5729$). Thus, we cannot reject the H4 indicating that efficiency rank is independent with loan rank, which means a bank's loan size does not have significant impacts on its relative efficiency.

To test the robustness of this conclusion, we use individual bank efficiency score instead of efficiency rank as the indicator of bank efficiency, and the logarithm of total assets instead of loan rank as the indicator of bank size to find a similar result. The correlation coefficient between bank efficiency and size is negative (-0.000 16), but not statistically significant ($p= 0.9811$, untabulated).

5. Conclusions, Limitations and Future Research

The banking industry is critical to the success of Macau's local economy and its future development. In this study, using a sample of 26 banks in Macau including all banks with normal operations to represent the evolvement of Macau's banking industry after its return to China in 1999 to 2016, we are the first as we know of to thoroughly explore the relationship of bank competition, efficiency, and stability in Macau. Our research contributes to the literature by identifying that bank competition does cause efficiency in Macau over that period. We also find indications of a positive but not significant connection between Macau bank competition and bank stability. Thirdly, this study finds no clear evidence that bank size would impact efficiency. Economies of scale or market share don't necessarily bring cost efficiency in Macau's banking industry.

The aforementioned findings have strong implications for academics, practitioners, and policymakers. Locally, the top three players in the banking sector already controlled over 65% share of total loan and total assets, and managed to successfully gain greater market power. It is particularly meaningful for the policymakers to closely monitor the market concentration and the market power of the leading players to maintain bank efficiency and financial stability in this small but wealthy market.

There are several limitations of our study. First, due to the relatively small size of the Macau market, we can only include 26 banks in our research which may cause a concern of sample size. Second, for each key variable, such as bank competition and efficiency, we choose a limited number of measures in this study. Furthermore, endogeneity has always been an issue, especially in complicated causality relations related to bank competition and efficiency.

For future research, we recommend using different methods to capture bank competition and efficiency to verify our results. To mitigate the endogeneity issue, Gaussian Mixture Model, instrumental variables, fixed-effect models, and additional more meaningful control variables can be considered as effective remedies (Li, 2016) in the future study.

Research on bank competition and efficiency has been a popular stream of literature in the past two decades. Different measures and approaches have been adopted to study the banking industry in various markets. With China's "One Belt, One Road" initiative and the "Guangdong-Hong Kong-Macau Greater Bay Area" (GBA) development plan, Macau would play a more active role in the regional even global economy. Based on the findings of our research, it would be fruitful to further benchmark Macau's banking sector against its counterparts in the Pearl Delta area and Hong Kong to identify opportunity areas for its future improvement. Such comparison would also offer more insights to the banking industry in the GBA which composes a unique sample set with strong multilateral economic ties under different social systems, regulatory environment, and market conditions.

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Notes

Note 1. The Statistics and Census Service Department, Macau SAR. (2016). The Per Capita GDP. Retrieved from <http://www.dsec.gov.mo/TimeSeriesDatabase.aspx>

Note 2. Statistics Times. (2016). GDP Per Capita Ranking. Retrieved from <http://statisticstimes.com/economy/projected-world-gdp-capita-ranking.php>

Note 3. The Heritage Foundation (2016). 2016 Index of Economic Freedom. Retrieved from https://www.heritage.org/index/pdf/2016/book/index_2016.pdf

Note 4. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.