Le, Tu D. Q.

Article

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Geographic expansion, income diversification, and bank stability: Evidence from Vietnam

Tu DQ Le[1,2]*

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*Corresponding author: Tu DQ Le, IBT, University of Economics and Law, Viet Nam
E-mail: tuldq@uel.edu.vn

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Abstract: This study empirically examines the impact of geographic expansion and income diversification on bank stability in Vietnam between 2006 and 2015 using the system generalized method of moments (GMM). The findings show that in general geographic expansion can enhance bank stability while income diversification per se does not. The results also indicate that state-owned commercial banks could only benefit from geographic expansion rather than from income diversification. However, foreign ownership tends to promote bank stability when pursuing both strategies. Our research has implications for bank supervisors, policy-makers, and bank managers.

Subjects: Economics; Finance; Banking; Credit & Credit Institutions

Keywords: Geographic diversification; income diversification; bank stability; Vietnam; GMM
JEL Classification: G21; G28; G30

1. Introduction

The global banking system is likely to further re-structuring in aftermath of the recent crisis. The number of financial services firms has declined significantly in recent years and the typical surviving firm becomes larger, more diversified, and operates in more places than ever before (DeYoung et al., 2009). These can be explained by the fact that a wave of financial deregulation allows banks to take full advantage of new production processes. Additionally, technological advances and financial innovations have drastically altered the competitive and strategic conditions faced by banks.[1] Altogether, these forces allowed commercial banks to expand into product and geographic markets that were previously off-limits.

ABOUT THE AUTHOR

Dr. Tu Le is a researcher at the Institute for Development & Research in Banking Technology, University of Economics and Law, Vietnam. His works focus on efficiency and productivity measurement in the field of banking and finance, and the industry sector, and the impact of e-commerce on economic growth. His recent papers have been published in Cogent Economics & Finance, International Journal of Managerial Finance, Managerial Finance, and Pacific Accounting Review, and Post - Communist Economies.

PUBLIC INTEREST STATEMENT

A wave of financial deregulation allows banks to take full advantage of new production processes. Additionally, technological advances and financial innovations have drastically altered the competitive and strategic conditions faced by banks. Altogether, these forces allowed commercial banks to expand into product and geographic markets that were previously off-limits. The question may arise as "can diversification, both geographic expansion and income diversification reduce bank risk?" By taking them into consideration, we attempt to test whether the joint effect of geographic expansion and income diversification could improve bank stability in Vietnam. Given the diversified structure of the Vietnamese banking system, this allows us to further test whether this relationship may differ among bank ownership.

One of the main concerns of bankers and policy-makers is to address the question of whether diversification reduces bank risk because empirical evidence provides mixed findings on the diversification effect. Several studies show that the pursuit of income diversification may lower the overall probability of default, especially for large banks (Köhler, 2015; Shim, 2013; Tsai et al., 2015) or in some emerging markets (Meslier et al., 2014; Nguyen et al., 2016; Pennathur et al., 2012). However, others report that the income diversification may increase risk because much of the funding is in the form of non-deposits (Demirgüç-Kunt & Huizinga, 2010). Regarding geographic diversification, a cross-country study by Le et al. (2020) emphasizes that global expansion tends to reduce bank solvency. Several studies in the U.S show conflicting results (Goetz et al., 2016; Meslier et al., 2016). In short, the pursuit of these two strategies can bring both benefits and costs to bank stability. A disagreement in empirical evidence of diversification benefits may well be a function of how diversification is measured (Elsas et al., 2010). This necessitates researching the effects of income diversification and geographic expansion on bank stability.

Vietnam has emerged as one of the fast-growing economies in the world and is considered Asia's next dragon (Le, 2018).[2] Because of the relatively underdeveloped stock markets,[3] the Vietnamese banking system is the backbone of the economy with its contribution of 16–18% to the Gross Domestic Product (Le, 2019; Stewart et al., 2016). In which the traditional lending and deposit markets were mainly competitive among local banks. Since the entry into the World Trade Organization in 2007, an increasing number of foreign banks and joint-venture banks and foreign bank affiliates were licensed to operate in the Vietnamese financial market. This has led to fierce competition for deposits and loans, thereby reducing interest income for domestic banks.[4] To maintain their stable income stream, domestic banks have diversified away from their traditional lending businesses into non-traditional activities. Banks, however, may face the trade-off between non-interest income (NII) and net interest margin (Le, 2017b). Furthermore, new regulation, especially the Decision 13/2008/QD-NHNN was introduced in 2008 to remove the geographical constraints of commercial banks by loosening the capital requirements on opening branches and/or additional branches in different provinces. Indeed, although there was a reduced number of banks from 2006 to 2015 due to several merger and acquisition activities, the total number of bank branches in 2015 was more than twice as high as that in 2006 (Le et al., 2019). This thus allows banks to establish national branch networks. In other words, the competition among geographically diversified banks in more than one geographical market is increased. All in all, this raises a concern about whether bank diversification improves bank solvency. As such Vietnam offers an interesting case to investigate this critical issue.

Our study contributes to the extant literature in several ways. First, most studies examine the impact of either income diversification or geographic diversification on bank stability. Our study is the first attempt to examine the joint effect of income diversification and geographic diversification on bank stability. Second, the evidence of the effect of geographic expansion in emerging is very limited, especially in the Asia-Pacific region. Our study adds more evidence of geographic expansion to the literature by examining its effect on bank stability in Vietnam. Third, using a unique dataset, we also verify the possibility of an interaction between geographic expansion and income diversification may affect banks' behavior. This study is the first attempt to extend the role of bank ownership in examining the relationship between both diversification strategies and bank stability (state-owned commercial banks (SOCBs) vs privately owned commercial banks (POCBs), listed versus non-listed banks, and foreign-owned versus domestic banks). Since Vietnam witnessed several M&A cases,[5] we further examine whether this link may vary between merged and non-merged banks. Together, this thus would provide a better understanding of diversification characteristics in the Vietnamese banking system.

In this study, we use a unique dataset highly representative of the Vietnamese banking system over 2006–2015 where there appears a remarkable change in bank regulation on branch networks as mentioned above and this period also allows us to further investigate the impact of the restructuring program on bank stability. The findings show that Vietnamese banks seem to benefit from geographic expansion rather than from income diversification. Less stable banks are

associated with greater technical efficiency, holding more liquid assets, and large size. In general, SOCBs are more stable than POCBs. A positive impact still holds in the case of SOCBs with greater geographic expansion but not for both. In contrast, foreign ownership tends to improve bank solvency, regardless of geographic expansion, and income diversification. The results of robust checks confirm our main findings.

The remainder of this study is organized as follows: Section 2 presents the literature review on the relationship between diversification and bank stability. Section 3 describes the data and methodology used. Section 4 discusses the empirical results while Section 5 concludes.

2. Literature review

The literature on the relationship between bank diversification and bank risk can be divided into two strands. The first strand is to investigate the effect of diversification in terms of different product lines on bank risk while the second strand is to examine the relationship between geographic expansion and bank risk.

2.1. Income diversification

Portfolio theory suggests diversification will lower a banks' risk if it involves adding assets whose returns are imperfectly correlated with existing assets (Chiorazzo et al., 2008). Thanks to economies of scope, diversification may improve bank stability through cost-saving due to the joint production of a wide range of services and revenue improvements via cross-selling various fee-based financial products as well as traditional lending-based services (Klein & Saidenberg, 2000). Given information asymmetry, banks may gain valuable information on their customers by offering a service that might bring an advantage in the provision of other services,[6] thus reducing bank risk. On the other hand, diversification with increasing the size and scope of banks' activities may cause the cost of complexity (Rajan et al., 2000). More diversified banks may take advantage to operate with greater leverage, as there appears little or no regulatory capital requirements on several fee-based activities, and to make riskier investments.

Most studies in the literature focus on this strand and show conflicting findings. Early studies suggest that diversification strategy may have the potential to reduce risk (Gallo et al., 1996; Kwast, 1989), and a hedge against insolvency risk and reduces the effect of costly financial distress (Froot & Stein, 1998). These studies conclude that a negative relationship between diversification and bank risk holds if non-traditional activities must be at a relatively low level. The US evidence shows that diversification benefits are ambiguous. A study by Stiroh (2004) finds that increased fee-based income is accompanied by greater market risks and return volatility. His findings are in line with those by Calmès and Liu (2009) in Canada, suggesting that income diversification is associated with greater income volatility. Indeed, a shift towards free-based income sources increases earnings volatility that accounts for leverage effects (DeYoung & Roland, 2001) and worsens the bank's risk-return trade-off (DeYoung & Rice, 2004; Stiroh & Rumble, 2006). Recently, Van Oordt (2014) also shows that diversification via securitization leads to instability for individual banks and the whole banking system.

For other developed markets, several studies show that income diversification provides substantial benefits for Italian banks (Chiorazzo et al., 2008) or even selected European banks (Köhler, 2015). However, several studies using European data indicate that banks engaging more in fee-based activities suffer greater beta risk (Baele et al., 2007) and higher risk and higher insolvency risk (Lepetit et al., 2008), or increase revenue volatility (Mercieca et al., 2007). Empirical evidence in Australia is also mixed. Rossi et al. (2009) show that loan portfolio diversification tends to increase profit efficiency and reduce banks' realized risk. B. Williams (2016) documents that income diversification tends to increase bank risk. Furthermore, Laeven and Levine (2007) using international data conclude that there exists a diversification discount in multiple activities financial firms, due to the effect of agency problems. Their findings are comparable with those by Nguyen (2012) in 28 countries.

When reviewing the literature on the impact of income diversification on bank risk in emerging markets, mixed findings are also found. Lee et al. (2014) suggest that non-traditional activities reduce bank risk in middle- and low-income countries, and such gain vary among bank types and country-specific. However, their findings also emphasize that diversification tends to raise bank risk in high-income countries, thus supporting the findings of other studies as mentioned above. These findings are in line with other studies such as Moudud-Ul-Huq et al. (2018) in ASEAN-5, Meslier et al. (2014) in the Philippines, Pennathur et al. (2012) in India, and Sanya and Wolfe (2011) in 11 emerging economies. Similarly, Nguyen et al. (2012) show that banks with market power seem more stable when adopting a revenue diversification strategy. However, the opposite results are found in several studies by Lee et al. (2020) using cross-country data, Zhou (2014), and Li and Zhang (2013) in China. In the context of Vietnam, few studies attempt to examine the impact of income diversification on bank risk. Studies by Batten and Vo (2016), and Le (2017b) demonstrate that income diversification is associated with greater risk. Taken together, we, do not expect a priori relationship between income diversification and bank stability.

H1: There is no impact of income diversification on bank stability.

2.2. Geographic expansion

Theoretically, geographic diversity can improve efficiency, spread idiosyncratic risk, and decrease agency costs, and enhance corporate valuations. More specifically, geographic expansion could boost market valuations via mitigating exposure to idiosyncratic local shocks (Diamond, 1984). In contrast, the view of distance related to geographic diversification suggests that as a bank expands geographically, senior managers of headquarters face difficulty to monitor the branch managers (Deng & Elyasiani, 2008). This may increase distance-related agency conflicts and bank risk-taking.

In the second strand, few studies that are conducted in the US show mixed results. Goetz et al. (2016) show that the geographic expansion across metropolitan statistical areas of a bank holding company can reduce risk, and does not affect loan quality. This confirms the early findings of Deng and Elyasiani (2008). However, Meslier et al. (2016) found that only intrastate diversification of small banks and interstate expansion of very large institutions reduces default risk, and at some point, more geographically diversified outweigh the benefits. The geographic expansion also may reduce the ability of a bank's headquarter to monitor its branches, with deteriorated loan quality (Acharya et al., 2006; Berger et al., 2005). In the same vein, Le et al. (2020) using cross-country data show global expansion tends to increase bank insolvency but loans distributed to advanced markets and developing countries may have the potential to enhance bank solvency. We, therefore, do not expect a priori relationship between geographic expansion and bank stability.

H2: There is no impact of geographic expansion on bank stability.

When banks may have expanded their branch networks to capture new opportunities for business growth, they may face increasing competitive pressure due to the effect of multimarket contacts (Le, 2020d; Le et al., 2019). Along with it, the presence of foreign banks enhances further the competitive environment in the Vietnamese banking system. When traditional business activities are no longer their advantages, this may further encourage them to shift away from traditional lending businesses to non-traditional activities to serve customers' needs better and diversify their risk (Le, 2017b). Following these above arguments of the individual effect of geographic expansion and income diversification on bank risk-taking, we however contend that when pursuing aggressively these strategies simultaneously, the costs of diversification may outweigh the benefits due to increased complexity issues and/or agency costs. This is the first attempt to

consider both geographic expansion and income diversification effects on bank stability in Vietnam. The following hypothesis is formed:

H3: There is no joint impact of income diversification and geographic expansion on bank stability.

2.3. Control variables

The literature also suggests that bank stability is affected by other bank-specific and macroeconomic factors. We only consider the common factors that have been found in prior studies as follows.

Bank efficiency reflects the ability of a bank to produce its existing level of output with the minimum inputs (input-oriented) or to produce maximum output from a given set of inputs (output-oriented) (Farrell, 1957). As per the bad management hypothesis, inefficient banks may fail to control operating costs or monitor borrowers, thus resulting in higher risk. This hypothesis is supported by the findings of Fiordelisi et al. (2011) and Le et al. (2019). However, others found the opposite results (Le, 2018). As per the skimping costs hypothesis, banks tend to skimp on operating costs by reducing credit monitoring, collateral valuing, and marketing activities to achieve short-run economic efficiency (Berger & DeYoung, 1997; Le, 2018). These activities, however, would deteriorate loan quality thus, leading to higher risk.

Following prior studies, bank stability is also affected by different categories of bank size (Le et al., 2019). Because larger banks can invest in more advanced technology, they will have better risk management (Pennathur et al., 2012). Also, a larger size allows banks to expand into more business lines and with a wider range of customers. On the other hand, larger banks have more incentive to increase their risk than smaller banks due to the effect of too-big-to-fail. Smaller banks could benefit both from greater operating flexibility, for example, being capable of adapting their strategies very quickly to the changing economic condition, and from lower fixed operating costs (Chiorazzo et al., 2008).

Bank liquidity refers to the ability of a bank to quickly raise cash at a reasonable cost (Berger & Bouwman, 2009). Liquid banks are expected to be safer and have less risky portfolios. Accordingly, more funds invested in liquid assets given their low return relative to other assets would reduce bank profitability. However, banks with higher liquidity levels have greater profitability (Bourke, 1989). According to the expected bankruptcy cost hypothesis, an increase in the relative liquid assets holdings of banks decreases its probability of default (Bordeleau & Graham, 2010). In other words, banks with liquidity problems may have to borrow from the market even at an exceptionally high rate which ultimately results in a significant reduction in the bank's earnings and higher risk.

Bank ownership measures the stake held by the party in the bank and determines the way that banks should operate. The literature suggests three different ways that bank structure can affect bank risk-taking. First, several studies that attempt to examine the impact of state ownership on bank risk show mixed findings (Agusman et al., 2014; Ehsan & Javid, 2018). Second, there is a lack of consistency in the evidence of the impact of foreign ownership on bank risk. Foreign banks can transfer high technology, better managerial skills, and a wide range of good financial services to local partners—thus, increasing bank stability (Le et al., 2019). Even though domestic banks with foreign shareholdings have superior technical and financial resources, they may suffer from more severe information-asymmetry problems. These issues may arise from the cultural differences between foreign and domestic shareholders. Therefore, foreign ownership may promote banks' insolvency (Tacneng, 2015). Finally, listing in the stock market may have influenced bank risk-taking. Several studies emphasize that listed banks tend to have higher asset quality (Luo, 2003), are more stable than non-listed banks (Le et al., 2019). Other studies, however, highlight no evidence that listed banks do not outperform non-listed ones (García-Herrero et al., 2009).

Market concentration measures the extent to which market shares are concentrated between a small number of banks in the banking system. The view of "concentration-stability" posits that a highly concentrated banking system with greater market power and lower competitive pressure tends to increase profits and increase the franchise value. Consequently, this discourages bank managers to increase their risk-taking (Liu et al., 2012; Salas & Saurina, 2003). However, the notion of "competition-stability" suggests that competition reinforces stability. A cross-country study by Nicoló et al. (2004) shows that more concentrated banking systems exhibit higher levels of systemic risk than less-concentrated ones. The less competitive banking system will allow banks to charge a higher interest rate which will affect the lending market by reducing borrowers' profits. Thus these borrowing firms have more incentives to take more risky projects and investments which in turn increasing fragility and bank crisis (Boyd & De Nicolo, 2005).

Banking literature suggests that bank performance is also influenced by bank reforms (Lin & Zhang, 2009). Due to the impact of the global financial crisis 2007–08 and the lax regulatory environment and inefficient credit management of local commercial banks in Vietnam, these together resulted in the proliferation of non-performing loans over the period 2007–2011 (Le, 2019). To address this problem, the restructuring program was introduced with its key terms of reference including reassessing the financial health of credit institutions in terms of bad debt and capital requirements. Accordingly, banks were mainly required to address their non-performing loans and improve their lending procedures, thus restricting to advance more loans as before. Therefore, this restriction may promote bank stability in Vietnam. For this reason, the effect of the restructuring program is also considered in our study.

3. Data and methodology

3.1. Data

The data as indicated in Table 1 was manually collected from annual reports and the audited financial statements of individual Vietnamese banks from 2006 to 2015 following Vietnamese Accounting Standards.[7] Our study only considers domestic banks as they are main-active players while foreign bank affiliates, 100% foreign-owned banks, and joint-venture banks are somewhat limited to operate in the Vietnamese banking system.[8] This, therefore, arrives at a total of 319 observations for an unbalanced panel data of 40 banks. The sample includes five SOCBs[9] and 35 POCBs[10] which together accounted for more than 80% of total assets in the industry. Table 2 shows some descriptive statistics of variables in our sample.

The data shown in Figure 1 describes the development of bank branches and the fluctuation of the non-interest income of Vietnamese banks between 2006 and 2015. The uptrend of bank branches can be observed from 2006 to 2012 due to reducing capital requirements on opening additional branches in 2008. However, the number of bank branches had started to reduce in the latter due to the restructuring credit program in response to the GFC, in which banks are limited to advance new loans and meet a new minimum charter capital requirement. This constrains branch expansions of Vietnamese banks. When observing income diversification, there appears a similar phenomenon. There was an upward trend and reached a peak in the year 2011. Since then, Vietnamese banks seem to less diversify their income to non-traditional activities.

3.2. Methodology

This study primarily aims at investigating the impacts of geographic expansion and income diversification on bank stability in the Vietnamese banking system. Taking into account the extant literature, as well as Vietnamese banks' characteristics, both bank-specific and macroeconomic factors are considered as mentioned above. One of the critical issues that may arise is endogeneity[11]: as an example, banks with poor management may fail to control operating costs, thus resulting in higher risk. Greater risk banks are also subject to more regulatory scrutiny—thus they may be required to hold a greater level of liquid assets and to be prudent to advance new lending. The causality could also go oppositely because banks that face greater risk are required to

Table 1. Definitions of variables

Variable		Definition	Expected sign
Z-score	Bank stability	The natural logarithm of *Z-score* and $Z-score_{i,t}=\frac{\overline{ROA_i}+EQUITY_{i,t}}{\sigma_{ROA_i}}$ where $\overline{ROA}$, the mean of *ROA* over the sample period; *EQUITY*, the ratio of total equity to total assets; σ_{ROA}, the standard deviation of *ROA* that is calculated based on the observations of *ROA* over the examined period	Dependent variable
Z-score $_{t-1}$	Persistence of bank stability	A lagged variable of bank stability	+
GEO	Geographic expansion	Calculated as: $GEO_i=\sum_{j\in m}HHI_j(\frac{d_{ij}}{d_i})$ where HHI_j is the Herfindahl—Hirschman Index in market *j* and d_{ij} and d_i are the numbers of branches of bank *i* in market *j* and the total number of branches of bank *i*, respectively.	±
INDIV	Income diversification	The ratio of non-interest income to total net income	±
INBCVRS	Technical inefficiency	$1-\widehat{\theta}_{DEA}$ where $\widehat{\theta}_{DEA}$ is bias-corrected technical efficiency derived from the bootstrap DEA under variable returns to scale assumption	-
LNTA	Bank size	The natural logarithm of total assets	±
LATA	Liquidity risk	The ratio of liquid assets to total assets	±
OWNER	State ownership	A dummy variable takes a value of 1 for a state-owned commercial bank, 0 otherwise.	±
LISTED	Public bank	A dummy variable takes a value of 1 for a listed commercial bank, 0 otherwise.	±
FOREIGN	Foreign ownership	The actual percentage of foreign ownership over the capital of a local bank	±
MERGER	Bank consolidation	This variable takes a value of 1 for a newly-combined bank, 0 otherwise	±

(*Continued*)

Table 1. (*Continued*)

Variable		Definition	Expected sign
HHI	Market concentration	The Herfindahl-Hirschman index in terms of total assets	-
RF	The restructuring program	A dummy variable that takes a value of 1 for the restructuring period, 0 otherwise	+

Table 2. Descriptive statistics of variables used in the system GMM

	OBS	Mean	SD	Min	Max
Z-score	319	2.948	0.633	0.995	5.483
GEO	319	0.095	0.038	0.042	0.26
INDIV	319	0.251	0.676	−0.585	11.65
INBCVRS	319	0.123	0.081	0.029	0.467
LNTA	319	17.616	1.403	13.135	20.589
LATA	319	0.351	0.141	0.062	0.816
OWNER	319	0.153	0.361	0	1
LISTED	319	0.194	0.396	0	1
FOREIGN	319	0.057	0.079	0	0.3
MERGER	319	0.041	0.198	0	1
HHI	319	0.082	0.021	0.062	0.139
RF	319	0.514	0.501	0	1

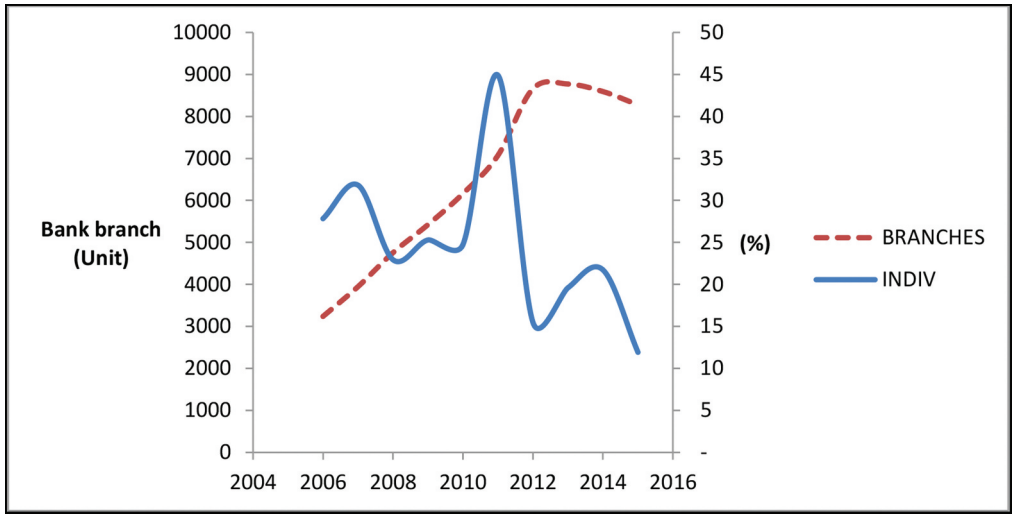

Figure 1. The development of income diversification and bank branches in Vietnam, 2006–2015.

utilize additional managerial efforts and additional resources to address these problems. This thus may increase banks' inefficiency. The ownership may be also endogenous since investors may decide to invest in riskier banks to maximize their expected utility (Gugler & Weigand, 2003).

Another critical issue is unobservable heterogeneity across banks, which could be very large in the Vietnamese banking system given differences in their corporate governance, which cannot be well-measured. Finally, bank risk may be persistent for Vietnamese banks because of political interference.[12]

To deal with three potential problems together, we employ the Generalized Method of Moments (GMM) system proposed by Arellano and Bover (1995) which moves beyond the methodology currently as used in the current literature on bank risk, mainly the pooled ordinary least square.[13] This method accounts for endogeneity by using the lagged values of the dependent variable and the lagged value of other regressors that are potentially suffering from endogeneity as instruments. We instrument for all regressors except for those which are exogenous.[14] It is noted that the variables treated as endogenous in our models are presented in italics in the tables of results below. The GMM system also controls for unobserved heterogeneity and the persistence

of the dependent variable. All in all, this estimator yields consistent estimations of the parameters. The estimated coefficients are also more efficient using an ampler set of instruments.

The above arguments suggest the application of a dynamic model that takes the following form:

$$\begin{aligned} z-score_{i,t} = {} & \alpha_0 + \alpha_1 Z-score_{i,t} + \alpha_2 GEO_{i,t} + \alpha_3 INDIV_{i,t} + \alpha_4 INBCVRS_{i,t} + \alpha_5 LNTA_{i,t} \\ & + \alpha_6 LATA_{i,t} + \alpha_7 OWNER_{i,t} + \alpha_8 LISTED_{i,t} + \alpha_9 FOREIGN_{i,t} + \alpha_{10} MERGER_{i,t} \\ & + \alpha_{11} HHI_t + \alpha_{12} RF + \varepsilon_{i,t} \end{aligned} \quad (1)$$

When estimating bank risk, few measures can be used in the literature such as the ratio of loan loss provision to total loans (J. Williams, 2004); the ratio of loan loss reserves (Altunbas et al., 2007; Le, 2018); the ratio of non-performing loans to total loans (Berger et al., 2009), one or five-year expected default frequency (Fiordelisi et al., 2011) and the Z-score (Demirgüç-Kunt & Huizinga, 2010; Fu et al., 2015). The first three measures are subject to managerial discretion and capture only credit risks.[15] The expected default frequency requires data on stock prices, but many Vietnamese banks do not hold publicly traded securities. Subsequently, this study uses the Z-score[16] as an inverse measure of overall bank risk. A larger value of the Z-score implies a greater bank's stability and less overall bank risk.

Following Lepetit and Strobel (2013) and Le et al. (2019), the Z-score of a bank is measured as

$$Z-score_{i,t} = \frac{\overline{ROA}_{i,} + EQUITY_{i,t}}{\sigma_{ROA_i}}$$

where $\overline{ROA}$, the mean of ROA over the sample period; EQUITY, the ratio of total equity to total assets; σ_{ROA}, the standard deviation of ROA is calculated based on the observations of ROA over the examined period. Since the distribution of Z-scores is highly skewed, the natural logarithm of Z-scores is used to mitigate this issue. For brevity, we still use the label, "Z-score", to represent the natural logarithm of the Z-score in the remainder of this study.

Following Kasman and Kasman (2016), $GEO_i = \sum_{j \in m} HHI_j(\frac{d_{ij}}{d_i})$ where *j*, a market (province) from the set of market, *m*, in which bank *i* is active. HHI_j is the Herfindahl—Hirschman Index in market *j* and d_{ij} and d_i are the numbers of branches of bank *i* in market *j* and the total number of branches of bank *i*, respectively. GEO_i ranges from 0 to 1 and is equal to 1 if a bank is geographically diversified. In this study, the province is considered as the local market. More specifically, there are 63 provinces in Vietnam. Additionally, the quadratic term of GEO *(SQRGEO)* is also used to account for whether the U-shaped relationship between geographic expansion and bank stability may exist. In our model, we also control for the level of concentration by including the standard Herfindahl Index (*HHI*) calculated based on total assets. *INDIV*, as measured by the ratio of non-interest income to total net income is used to control for income diversification effects (Le, 2017b). We further include *GEO*INDIV* in the following model to investigate the effect of interaction between geographic expansion and income diversification.

$$\begin{aligned} Z-score_{i,t} = {} & \alpha_0 + \alpha_1 Z-score_{i,t-1} + \alpha_2 GEO_{i,t} + \alpha_3 INDIV_{i,t} + \alpha_4 GEO_{i,t^*} INDIV_{i,t} + \alpha_5 INBCVRS_{i,t} \\ & + \alpha_6 LNTA_{i,t} + \alpha_7 LATA_{i,t} + \alpha_8 OWNER_{i,t} + \alpha_9 LISTED_{i,t} + \alpha_{10} FOREGIN_{i,t} \\ & + \alpha_{11} MERGER_{i,t} + \alpha_{12} HHI + \alpha_{13} RF + \varepsilon_{i,t} \end{aligned} \quad (2)$$

Following prior studies such as Le et al. (2019), Le (2020b) and among others, we use *INBCVRS*, technical inefficiency as derived from the bootstrap DEA under variable returns to scale assumption to test the efficiency channel. This approach measures how well the observed bank manages its costs to the best-practice bank in the sample. We calculate *INBCVRS* as follows: $1 - \widehat{\theta}_{DEA}$ where $\widehat{\theta}_{DEA}$ is bias-corrected technical efficiency following the bootstrap procedure as proposed by Simar and Wilson (1998, 2000)).[17] The procedure is described in Appendix 1. *LNTA*, the natural logarithm of total assets, is used to control for bank size. Bank liquidity is proxied by the ratio of liquid assets to total assets *(LATA)*.

Bank stability is also affected by bank ownership. Following Le (2020c) and Le et al. (Forthcoming), *OWNER*, a dummy variable that takes a value of 1 for SOCB and 0 otherwise, is used to control for the effect of bank ownership. Additionally, the increasing role of privatization, and in particular diffused ownership, is investigated by incorporating *LISTED* in the model, a dummy variable that takes a value of 1 for a listed bank in the stock market and 0 otherwise. *FOREIGN*, the actual percentage of foreign ownership over the capital of a local bank is used to control for the effect of foreign ownership.[18] *MERGER*, a dummy variable that takes a value of 1 for a newly-combined bank and 0 otherwise is used to control for bank consolidation. We further examine whether the effect of diversification (both measures) on bank stability varies among bank ownership by including the interaction terms.[19]

Finally, a market-specific variable used in the regression is the Herfindahl-Hirschman index (*HHI*) in terms of total assets. *RF*, a dummy variable that takes a value of 1 for the restructuring period, and 0 otherwise, is used to control for the effects of the restructuring program.

4. Empirical analysis

4.1. The base models

For ease of exposition, we focus on the general interpretation of key variables. In general, geographic expansion and income diversification are positively correlated with bank stability shown in Table 3. Also, there appear no high correlations among independent variables used. Because of the high potential endogeneity between variables used as explained above, the system GMM should be employed.

Table 4 indicates the results of the determinants of bank stability in the Vietnamese banking system between 2006 and 2015 using the system GMM.[20] The result of the Hansen test is also reported to investigate the validity of the dynamic panel model. Since the *p*-value of the Hansen test is statistically not significant in any of the models, the null hypothesis cannot be rejected.[21] Therefore, there is no evidence of over-identifying restrictions, which means that all conditions for the moments are satisfied and the instruments are accepted. Furthermore, the hypothesis of the non-existence of the first-order autocorrelation between the first residual differences is rejected. This, however, does not imply that estimates are inconsistent. Inconsistency would be concluded if the second-order autocorrelation is present (Arellano & Bond, 1991). Since *p*-values of AR2 in our all models are statistically not significant, this suggests that the moment conditions of the model are met.[22] As a result, we conclude that the estimated model meets diagnostic tests.

A number of regression models are run. Note that Model 1 is our base model. Nonetheless, Table 4 indicates that the coefficient of *Z-score* $_{t-1}$ is positive and significant in all models, suggesting the persistence in bank stability. Besides, *GEO* is positively and significantly related to *Z-score* in most models, suggesting that geographic expansion improves bank stability. This can be explained by the fact that more geographically diversified banks can increase loan portfolio diversification across different industries and markets, which ultimately alleviates banks' realized risk. This is

Table 3. Correlation matrix of variables used in this study

	Z-score	GEO	INDIV	BCVRS	LNTA	LATA	HHI
Z-score	1						
GEO	0.077	1					
INDIV	0.048	−0.042	1				
INBCVRS	0.073	−0.102	0.081	1			
LNTA	−0.218	0.4972	0.05	−0.096	1		
LATA	−0.02	−0.207	0.026	−0.124	−0.053	1	
HHI	0.093	0.295	0.207	0.133	−0.354	−0.043	1

Table 4. The results of the impact of multimarket contacts on bank stability in Vietnam

Z-score	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Z-score $_{t-1}$	0.689*** (0.046)	0.665*** (0.084)	0.346*** (0.079)	0.268* (0135)	0.487*** (0.105)	0.597*** (0.065)	0.562*** (0.071)
GEO	3.889*** (0.913)	6.533*** (1.35)	4.061** (1.89)	1.892 (2.303)	5.736*** (1.138)	4.064*** (0.955)	2.456*** (0.914)
SQRGEO			−5.173 (8.532)				
INDIV	−0.001*** (0.0002)	0.001 (0.001)	−0.0003** (0.0002)	0.0003 (0.0003)	−0.001 (0.0004)	0.0001 (0.0001)	−0.0004* (0.0002)
INBCVRS	0.291* (0.163)	0.024 (0.222)	0.682*** (0.148)	−0.153 (0.186)	0.07 (0.226)	0.294 (0.244)	0.361* (0.194)
LNTA	−0.192*** (0.03)	−0.229*** (0.037)	−0.164*** (0.045)	−0.319*** (0.059)	0.248*** (0.054)	−0.218*** (0.028)	−0.207*** (0.029)
LATA	−0.669*** (0.137)	−0.657*** (0.125)	−0.764*** (0.109)	−0.501** (0.189)	−0.414** (0.162)	−0.392*** (0.145)	−0.422*** (0.13)
OWNER	0.329*** (0.098)	0.546** (0.242)	0.796*** (0.177)	1.108*** (0.278)	1.273*** (0.385)	0.846*** (0.163)	0.757*** (0.17)
LISTED	−0.004 (0.095)	−0.025 (0.097)	−0.157 (0.119)	−0.367 (0.434)	−0.202 (0.173)	−0.077 (0.088)	−0.124 (0.095)
FOREIGN	2.036* (1.095)	2.132* (1.107)	4.019*** (1.138)	0.63 (2.418)	−0.38 (1.252)	0.204 (1.075)	0.065 (0.986)
MERGER	−0.004 (0.046)	0.02 (0.059)	0.011 (0.085)	0.206 (0.718)	−0.137 (0.246)	−0.034 (0.062)	0.045 (0.069)
HHI	−5.196*** (0.889)	−5.318*** (0.706)	−4.994*** (1.274)	−5.714*** (1.854)	−4.732*** (1.416)	−3.946*** (1.033)	−4.031*** (0.936)
RF	−0.037 (0.039)	−0.023 (0.041)	−0.09 (0.086)	0.119* (0.066)	0.06 (0.046)	0.052 (0.041)	0.042 (0.038)
GEO*INDIV		−0.011* (0.007)					
GEO*OWNER				4.548** (2.172)			

(*Continued*)

Table 4. (*Continued*)

Z-score	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
GEO*INDIV *OWNER						−0.012*** (0.003)	
GEO*LISTED				2.371 (3.355)			
GEO*FOREIGN				−1.589 (24.861)			
GEO*MERGER				−6.011 (7.462)			
INDIV*OWNER					−0.002 (0.001)		
INDIV*LISTED					−0.0002 (0.0003)		
INDIV*FOREIGN					0.006*** (0.001)		
GEO*INDIV*FOREIGN							0.045*** (0.015)
INDIV*MERGER					0.001 (0.001)		
Constant	4.445*** (0.485)	4.92*** (0.86)	4.781*** (0.898)	7.83*** (1.325)	5.844*** (1.12)	4.926*** (0.514)	4.996*** (0.497)
No. Obs	277	277	277	277	277	277	277
No. Groups	41	41	41	41	41	41	41
AR1 (p-value)	0.007	0.007	0.008	0.051	0.012	0.010	0.008
AR2 (p-value)	0.068	0.066	0.148	0.154	0.062	0.069	0.069
Hansen test (p-value)	0.772	0.776	0.972	0.997	0.948	0.800	0.912

Notes: The table contains the results estimated using the system GMM estimator. Variables in italics are instrumented through the GMM procedure following Arellano and Bover (1995). Robust standard errors are in parentheses. *, **, ***Significant at 10, 5, and 1 per cent levels, respectively.

comparable with the findings of Goetz et al. (2016) in the U.S. When including squared *GEO* in the model, we do not find any evidence of the U-shape relationship between geographic expansion and bank stability.

The coefficient of *INDIV* is generally negative and significant in 3 models, implying that income diversification may enhance bank risk. This can be explained by the following reasons. The shift towards non-traditional activities may require banks to make additional investments in technology and human resources, thus increasing operating leverage. This may increase bank earnings' volatility. Some fee-based activities may induce a high degree of financial leverage, thus contributing to higher volatility of bank income. Altogether, these may reduce bank stability. This supports the early finding of Le (2017b) who found that Vietnamese banks may use the non-interest income to expand leverage and herd by coordinating their diversification strategies during economic downturns, thus resulting in the risk-return trade deterioration. When examining the effect of interaction between geographic expansion and income diversification, the coefficient of *GEO*INDIV* is negative and significant, suggesting that more income-diversified banks with greater branch networks tend to face more insolvency risk. This finding somewhat supports those of Batten and Vo (2016), Le (2018), and Le (2017b) in Vietnam who suggest that the specialization in a single line of business or a local market tends to increase bank stability.

A positive relationship between *INBCVRS* and *Z-score* suggests that banks with high-quality management are more flexible to invest in risky assets. This is in line with the findings of Hughes and Mester (1998) and Le (2018) who found that higher risk is positively associated with more efficient banks. *LNTA* affects bank stability negatively, thus supporting the 'too-big-to-fail" effect. This implies that large banks have more incentives to invest more in risky assets. This finding is comparable with those of Beck et al. (2006) and Le et al. (2019). *LATA* is in general negatively and significantly related to Z-score in all models, implying that liquid banks seem to be more risk-taking. This can be explained by the fact that banks with a higher level of liquid assets (with a lower rate of returns) tend to generate lower-income, thus may face greater risk. Regarding bank property, a positive relationship between *OWNER* and *Z-score* suggests that SOCBs are generally more stable than POCBs. Because SOCBs are considered safe banks due to the government ownership, depositors are willing to accept lower deposit interest rates offered by them, thus enhancing their profitability and reducing their risk (Le et al., 2019). The same is true for the case of foreign-owned banks, thus suggesting that foreign ownership seems to reduce bank risk. We do not find any evidence on the effect of bank consolidation and listing activity.

When examining the effect of interaction between bank ownership and diversification, the coefficient of *GEO*OWNER* is positive and significant, suggesting that SOCBs with greater geographic expansion are more stable. When aggressively pursuing both geographic expansion and income diversification (*GEO*INDIV*OWNER*) SOCBs, however, tend to expose more insolvency risk. Although SOCBs are protected by implicit government guarantees, inefficient managers may utilize resources to pursue their own goals via massively expanding branch networks and shifting more toward non-traditional activities where they lack experience and competence. This, therefore, may result in additional costs for banks and induce greater risk-taking.

Regarding foreign ownership, the coefficients of *GEO*FOREIGN* and *GEO*INDIV*FOREIGN* are positive and significant, implying that more diversified foreign-owned banks are more stable. Foreign banks can transfer knowledge and better managerial skills to local partners as domestic banks are required to adopt Basel II, especially improving capital adequacy and internal risk assessment. This may suggest that the government should increase the share of foreign ownership in a local bank instead of imposing a maximum of 30% at present. Nonetheless, this finding is comparable with those of ElBannan (2015) in Egypt; Tacneng (2015) in the Philippines, and Le (2020a) in Vietnam.

Last, the findings show that *HHI* is negatively and significantly in all equations, thus supporting the view of the "competition-stability" that a less concentrated market reduces bank risk. This further supports the early findings of Le et al. (2020) and Le and Ngo (2020) using cross-country data. There also appears an increase in bank stability during the restructuring period (*RF*) although the coefficient of *RF* is relatively weak and significant in one model. Nonetheless, this somewhat reflects the effectiveness of the restructuring program where banks were required to strict their lending procedure and increase their capital to meet minimum charter capital requirements.

4.2. Robust checks

To provide additional empirical support to our findings, several robustness checks are run. Following Chiorazzo et al. (2008) and Stiroh and Rumble (2006), we first use the alternative of income diversification (HHI_{INDIV}) which is measured as$HHI_{INDIV} = 1 - \left(\left(\frac{interest\ income}{total\ net\ income}\right)^2 + \left(\frac{non-interest\ income}{total\ net\ income}\right)^2\right)$. HHI_{INDIV} ranges in value from zero to one, with higher values implying greater funding diversity. Following Le et al. (2020), and Le (2020d), we test whether geographic expansion and income diversification have any impact on bank profitability. Third, the above findings show a negative impact of bank size on bank stability. Following Le et al. (2019), we further examine whether the impact of diversification on bank stability may differ between small and large banks.

The data shown in Models 8–9 of Table 5 indicates the coefficients of HHI_{INDIV} and *GEO** HHI_{INDIV} are negative and significant, respectively thus confirming our main findings as above. When considering the impact of bank profitability, there appears that geographic expansion only affects RAR_{ROE} positively as indicated in Model 11. Nonetheless, this suggests the benefits of geographic expansion in the context of the Vietnamese banking system.

Following Le (2019) and Le et al. (2019), large and small banks are defined as those with total assets above and below the median, respectively. Then, *LARGE*, a dummy variable that takes a value of 1 for a large bank and 0 otherwise is used due to the small sample size.

The coefficient of *INDIV*LARGE* is negative and significant as shown in Model 10, suggesting that large banks with greater income diversification tend to expose greater instability. Large banks that choose to engage more in non-traditional activities seem to face increased complexity or agency costs, which in turn raises firm-specific risk or differences in operational focus. Alternatively, this increases risk-taking. Nonetheless, this supports the early suggestion of Stiroh (2005) and is partly consistent with the findings of Stiroh and Rumble (2006). Additionally, the findings show that the coefficient of *GEO*LARGE* is positive but not significant. Hence, we do not find any evidence that large banks with greater geographic expansion have greater bank stability.

5. Conclusion

This study investigated the impact of geographic expansion and income diversification on bank stability in Vietnam between 2006 and 2015 using the system GMM. The findings show that bank stability is positively associated with geographic expansion while income diversification tends to increase insolvency risk. This suggests that the State Bank of Vietnam should further remove restrictions on the opening of new branches—thus, improving the competitiveness of Vietnamese banks. The findings also suggest that banks in general should be cautious to pursue income diversification aggressively. The results of robust checks confirm our main findings.

The findings also indicate an improvement in banking efficiency precedes an increase in bank risk, supporting the skimping costs hypothesis. This suggests that bank managers must pay special attention to the bank's internal credit control procedures (i.e. loan monitoring and review, collateral valuing). The same conclusion is true for large banks, and banks with higher liquid assets. State-owned commercial banks are more stable when pursuing geographic diversification but not both strategies. Furthermore, a positive relationship between foreign ownership and bank stability

Table 5. The results of the robust checks

π	Z-score (Model 8)	Z-score (Model 9)	Z-score (Model 10)	RAR_{ROE} (Model 11)	RAR_{ROA} (Model 12)
π_{t-1}	0.581*** (0.06)	0.653*** (0.053)	0.393*** (0.075)	0.479** (0.211)	0.664*** (0.071)
GEO	4.425*** (1.397)	8.437*** (2.132)	1.718 (2.532)	24.369* (14.073)	3.406 (4.015)
INDIV			0.001 (0.001)	0.001 (0.004)	0.001 (0.001)
HHI_{INDIV}	−0.0004** (0.0001)	0.001 (0.001)			
$GEO*HHI_{INDIV}$		−0.02* (0.01)			
INBCVRS	−0.007 (0.183)	−0.014 (0.175)	1.057*** (0.245)	−8.747* (4.812)	−2.985*** (0.695)
LARGE			0.382 (0.297)		
GEO*LARGE			0.632 (2.324)		
INDIV*LARGE			−0.003*** (0.001)		
LNTA	−0.264*** (0.05)	−0.214*** (0.045)		−1.191 (0.911)	−0.23 (0.192)
LATA	−0.429*** (0.115)	−0.224* (0.126)	−0.306** (0.135)	4.339 (3.647)	0.252 (0.77)
OWNER	0.591*** (0.139)	0.476*** (0.128)	0.31 (0.195)	2.237 (3.103)	0.379 (0.916)
LISTED	0.151 (0.127)	0.127 (0.122)	−0.061 (0.105)	−2.045 (2.256)	−0.195 (0.473)
FOREIGN	2.482*** (0.908)	2.482** (1.026)	3.036*** (1.003)	31.239 (32.783)	3.524 (7.361)
MERGER	−0.068 (0.1)	−0.079 (0.126)	−0.54** (0.265)	−3.711 (4.439)	−0.895* (0.517)
HHI	−5.156*** (1.014)	−4.592*** (1.401)	−0.624 (1.57)	−43.427** (19.649)	−9.463** (4.235
RF	−0.027 (0.047)	−0.059 (0.056)	0.105*** (0.034)	0.08 (0.577)	−0.353*** (0.122)
Constant	5.788*** (0.924)	4.317*** (0.824)	1.318*** (0.303)	20.907 (13.698)	5.085 (3.807)
No. Obs	277	277	277	277	277
No. Groups	41	41	41	41	41
AR1 (p-value)	0.006	0.008	0.015	0.008	0.000
AR2 (p-value)	0.066	0.067	0.073	0.734	0.062
Hansen test (p-value)	0.882	0.815	0.838	0.795	0.954

Notes: The table contains the results estimated using the system GMM estimator. Variables in italics are instrumented through the GMM procedure following Arellano and Bover (1995). Robust standard errors are in parentheses. *, **, ***Significant at 10, 5, and 1 per cent levels, respectively.

when considering the effect of both geographic and income diversification may suggest that the Vietnamese authorities should gradually remove restrictions on foreign investments in the banking system. Finally, our findings demonstrate that a more competitive market can enhance bank stability, suggesting that future mergers and acquisitions in Vietnam, especially with the participation of large banks should be approached with caution.

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Author details
Tu DQ Le[1,2]
E-mail: tuldq@uel.edu.vn
[1] Institute for Development and Research in Banking Technology, University of Economics and Law, Ho Chi Minh, Vietnam, 700,000.
[2] Vietnam National University, Ho Chi Minh, Vietnam, 700,000.

The author statement
Dr. Tu Le is a researcher at the Institute for Development & Research in Banking Technology, University of Economics and Law, Vietnam. He is currently working on several projects in the emerging markets in several fields – including banking and finance, manufacturing sector, e-commerce, and Fintech. This paper is under the project entitled "what we know about the Vietnamese banking system". Several papers related to this project have been published in Managerial Finance, International Journal of Managerial Finance, Australasian Accounting Business and Finance Journal, Cogent Economics & Finance, Cogent Business & Management. In contrast, the current research is looking at the different issue named "geographic expansion, income diversification and bank stability".

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Notes

1. For further discussion, please see DeYoung et al. (2009) and Frame and White (2004).
2. The average annual economic growth of approximately 6.2% over the examined period, just behind China (WB, 2016).
3. The stock market has been only serving a limited number of companies that are favoured by the government.
4. Several wholly foreign-owned banks were established in 2009 and became strong competitors for local banks since they can fund local assets using internationally sourced funds at lower costs than their domestic counterparts. Also, this is due to the growing number of non-bank institutions in the financial sector.
5. Please see Le (2017a) for more details.
6. Please see Stein (2002) and Diamond (1984).
7. Unfortunately, the Global Bank Focus does not provide the data on bank branches. Since 2016, there have been substantial missing data on bank branches in each market. Therefore, we could not calculate the *GEO* values of the individual bank from the year 2016 and onward.
8. This exclusion from the sample is necessary to ensure the homogeneity of the sample when estimating relative bank efficiency using the bootstrap DEA. More importantly, the data of these banks are mostly unavailable.
9. They include Bank for Investment and Development, Foreign Trade Bank, Bank of Industry and Trade, Housing Bank of Mekong Delta, Agriculture and Rural Development Bank.
10. They include An Binh Bank, Asia Bank, Bao Viet Bank, Construction Bank, Dong A Bank, First Bank, Global Petrolimex Bank, Great Asia Bank, Hanoi Building Bank, HCM Development Bank, Kienlong Bank, Lien Viet Post Bank, Mekong Development Bank, Military Bank, Nam A Bank, National Citizen Bank, Ocean Bank, Orient Bank, Petrolimex Group Bank, Saigon-Hanoi Bank, Saigon Bank for Industry and Trade, Saigon Commercial Bank, Saigon Thuong Tin Bank, South-East Asia Bank, Southern Bank, TienPhong Bank, Viet A Bank, Technological Bank, Bank for Private Enterprise, Export-Import Bank, Vietnam International Bank, Maritime Bank, Tin Nghia Bank, Western Bank.
11. To test the endogeneity of *GEO*, we use the Durbin-Wu-Hausman test although the table of results could not be presented here due to the length restriction. The results show the small p-value of 0.03 indicates that OLS is not consistent.
12. Apart from the efforts of bank managers, banking reforms released by the State Bank of Vietnam are generally implemented to improve the banks' stability over time.
13. This method has been used in Tacneng (2015) and ElBannan (2015).
14. It is assumed that strictly exogenous variables are not correlated to the individual effects while the endogenous variables are predetermined.
15. There is substantial missing data on non-performing loans of banks in the sample.
16. For further discussions on the measures of Z-score, please see Lepetit and Strobel (2013) and Lepetit and Strobel (2015).
17. According to the intermediation approach in which banks act as intermediaries between depositors and borrowers, a 3 × 2 set of inputs and outputs is used. Following prior studies such as Le (2017a), Le et al. (2019) inputs include fixed assets, operating expenses, and loanable funds while outputs include loans and other earning assets. Because of the unavailability of data on either a number of employees or labor expenses in many banks in the sample, operating expenses are used to proxy for labor costs.
18. To provide robust checks, we also use a dummy variable that takes a value of 1 for a local bank that has foreign participation in its capital and 0 otherwise, independently of how large it is. Similar findings are obtained although it cannot be presented here due to length restrictions.
19. The models include these interaction terms can be formed in the same way as model 2.
20. We also conduct robustness checks with more rudimentary approaches for panel data using fixed effects. The results confirm our main findings and are available upon request.
21. Cameron and Pravin (2010) suggest that the value of the Hansen test for over-identifying restrictions should exceed 0.05, thus the null hypothesis cannot be rejected. Alternatively, there is no correlation between the instrument variables and the residuals.
22. Arellano and Bond (1991) demonstrate p-values of AR2 above 0.05 that instruments are still valid.

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Appendix 1

Given a bank with a set of input p and a set of output q, a production set Ψ can be defined in the Euclidean space R_+^{p+q} as: $\Psi = \{(x,y)|x \in R_+^p, y \in R_+^q, (x,y) is feasible\}$ (1)

Assume that cost efficiency is the primary objective of Vietnam commercial banks. Following Farrell (1957) concept, the input-oriented efficiency score of a bank operating at the level is estimated as

$$\theta(x_0,y_0) = \inf\{\theta|\theta x_0 \in C(y_0)\} = \inf\{\theta|(\theta x_0,y_0) \in \Psi\} \quad (2)$$

Thereafter, the following DEA estimator under the variable returns to scale (VRS) assumption proposed by Banker et al. (1984) is measured as:

$$\hat{\theta}_{DEA}(x_0,y_0) = \min\left\{ \theta \middle| y_0 \le \sum_{i=1}^{n} \gamma_i Y_i; \theta x_0 \ge \sum_{i=1}^{n} \gamma_i X_i; \theta \right\rangle 0; \sum_{i=1}^{n} \gamma_i = 1; \gamma_i \ge 0, i = 1,\ldots,n \Bigg\} \quad (3)$$

The value of $\hat{\theta}_{DEA}(x_0,y_0)$ will be bounded by 0 and 1. A bank that obtains a score of 1 is considered as technically efficient since it operates on the boundary of its production set.

However, DEA measure is often criticized as lacking a statistical basis (Assaf et al., 2011). Therefore, a bootstrap DEA is introduced to overcome this issue. The procedure has been described in detail by Simar and Wilson (1998, 2000)) and is not repeated here for want of space. Accordingly, this procedure can produce confidence limits on the efficiencies of the units to capture the true efficiency frontier within the specified interval (Dyson & Shale, 2010).

The bootstrap bias estimate for the original DEA estimator $\hat{\theta}_{DEA}(x_o,y_0)$ is computed as: $\widehat{BIAS}_B(\hat{\theta}_{DEA}(x_o,y_0)) = \frac{1}{B}\sum_{b=1}^{B} \hat{\theta}^*_{DEA,b}(x_0,y_0) - \hat{\theta}_{DEA}(x_0,y_0)$ (4)

The bias-corrected estimator of $\theta(x_0,y_0)$ is estimated as:

$\hat{\hat{\theta}}_{DEA}(x_0,y_0) = \hat{\theta}_{DEA}(x_0,y_0) - \widehat{BIAS}_B(\hat{\theta}_{DEA}(x_0,y_0)) = 2\hat{\theta}_{DEA}(x_0,y_0) - \frac{1}{B}\sum_{b=1}^{B} \hat{\theta}^*_{DEA,b}(x_0,y_0)$ $\hat{\theta}^*_{DEA,b}(x_0,y_0)$ is a bootstrapped value; B is 2,000 replications (5)

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