Article:

Zhao, B., Kenjegalieva, K., Wood, J. et al. (1 more author) (2020) A spatial production analysis of Chinese regional banks: case of urban commercial banks. International Transactions in Operational Research, 27 (4). pp. 2021-2044. ISSN 0969-6016

https://doi.org/10.1111/itor.12732

A Spatial Production Analysis of Chinese Regional Banks: Case of Urban Commercial Banks

Abstract

Urban commercial banks are regional banks which have gained tremendous importance in the last two decades in China. There is, however, a lack of research on regional banking, especially on the Chinese regional banking industry. Therefore, using an innovative spatial approach, this paper investigates the efficiency of 65 Chinese urban commercial banks across 26 regions during 2013 to 2017. A Key finding for our sample is the significant spatial dependence of loans of Chinese urban commercial banks with their neighbouring regions' banks. Short-run efficiency is increasing during the research period. For regions with less than three urban commercial banks, the average efficiencies are stable and relatively high. However, regions with more banks have both the highest and lowest efficient banks existing at same time. These interesting results fit with the development process of Chinese urban commercial banking, which the market restructure has contributed to banks' efficiency.

Keywords: Regional Banking, Spatial Analysis, Banking Efficiency, Chinese Urban Commercial Banks

1. Introduction

With China's total GDP of 82,075.4 billion RMB[1] in 2017 and the total assets of the Chinese banking industry being 252,404 billion RMB in the same year, the Chinese banking industry plays a vital role in the economy. As second largest economy, the mainland China has 31 administrative regions and it covers 9.6 million square kilometres[2]. There is unbalanced economic development among those regions. The different levels of regional economy require various financial services.

Regional banks are financial institutions which serve small- and medium-sized local companies and individuals. In China, urban commercial banks are a type of regional bank, and the industry has grown tremendously in the last two decades. The total assets of overall urban commercial banks have grown from 1,462 billion RMB to 31,722 billion RMB during 2003 to 2017, constituting a 12.57 per cent of Chinese banking total assets in 2017 up from 5.29 per cent in 2013[3]. Now the third largest type of bank in China, urban commercial banks are an essential part of the economy and a crucial research area.

The urban credit cooperatives are initially founded to provide financial service for local requirements. However, because of poor risk-management they generate a large number of non-performing loans. To deal with the problem, the market restructure started in the 1990s and finished in 2012 and transformed urban credit cooperatives into urban commercial banks. Based on the annual report of China Banking Regulatory Commission, there are 133 urban commercial banks. It is therefore valuable to find the impact of the market restructure on the efficiency of urban commercial banks.

Although the literature in banking production and efficiency is well established (e.g., Berger and Mester, 1997; Berger and Humphrey, 1997; Bonin et al., 2005; Boubakri et al., 2005; Delis et al., 2017; Konara et al., 2019), there is a lack of research in regional banking, and particularly in Chinese urban commercial banks. To the authors' best knowledge, there are only three papers that study the efficiency of Chinese urban commercial banks; however, there are some limitations to the existing research. Ferri (2009) only presents the performance of 20 banks within three regions and does not provide frontier efficiency analysis. The research period of other two papers does not cover the time after the market restructure. Zhang et al. (2012) studies 133 urban commercial banks' efficiency with a distance function approach from 1999 to 2008. Sun et al. (2013) employs data envelopment analysis of 72 urban commercial banks during 2002 to 2010. None of these papers attempt to analyse spatial dependence among urban commercial banks. Based on the

[1] RMB is official currency of China, data source from National Bureau of Statistics of China.
[2] Source from website of the central government of China http://www.gov.cn/test/2005-05/25/content_17358.htm.
[3] Source from Chinese Banking Regulatory Commission annual report 2018 and detail display in Table 1.

geographical characteristic of urban commercial banks, whose main purpose is to provide business for local markets), it is worthwhile to investigate their spatial relationship. We extend the existing research on efficiency analysis of Chinese urban commercial banks. Our paper focuses on the post-market restructure period from 2013 to 2017. We identify the impact of market restructure on bank efficiency and analyse the spatial relationship between Chinese adjacent regions' banks via a spatial production function. Therefore, by adding a spatial parameter into the modelling, our results provide a more accurate efficiency estimation.

This paper investigates the efficiency of 65 Chinese urban commercial banks across 18 Chinese provinces, four municipalities, and four autonomous regions[4] (a total of 26 regions) during 2013 to 2017. We utilise a Spatial Durbin Production Frontier with random effects model to estimate our results. Contributing to the existing literature, we address the relationship of Chinese urban commercial banks' output loans around neighbouring regions and include the effect of the regional market environment on bank performance. The model estimation parameters indicate that, compared to other input variables, deposits have the greatest influence on output loans. Moreover, the results provide evidence that loans of urban commercial banks have positive spatial relationships with the bank loans of their neighbouring regions. In addition, banks from contiguous regions have similar efficiency results. We also find that the regional market environment has an influence on the performance of local banks, though the results are mixed: for regions with less than three urban commercial banks, they have stable and relatively high average efficiency scores; for regions with more banks, there exist both higher and lower efficiency banks.

The rest of this paper is organised as follows. Section 2 provides the background of the development to Chinese urban commercial banks; section 3 is the literature review of regional banking, which looks at regional banking both outside and inside China's banking industry. We describe our sample dataset and methodology in section 4 and provide model estimation results in section 5. Section 6 concludes.

2. Background of Chinese urban commercial bank development

Chinese urban commercial banks were transformed from urban credit cooperatives, which were established following the Chinese economic opening-up policy in 1979. With fast growth of the national economy, they aimed to provide financial services to local small- and medium-sized businesses and individuals. Due to inadequate regulation and restrictions,

[4] They are same level administrative areas which have no overlap between each other.

urban credit cooperatives expanded rapidly especially from 1987 to 1988 and from 1991 to 1995. Figure 1 is the number of urban credit cooperatives from 1987 to 2003.

The first urban credit cooperative was founded in 1979, and by 1987 there were 1,615 urban credit cooperatives in China. In 1986, the state council issued provisional banking regulation rules to supervise urban credit cooperative activities, and the central bank issued provisional urban credit cooperative regulation rules to define the business area and property of urban credit cooperatives, as well as the standard to establish credit cooperatives. However, just over one year later, in 1988 the number of urban credit cooperatives rocketed to 3,265 with high-risk operating and a lack of self-monitoring. Most of the urban credit cooperatives contained a high volume of non-performing loans at that time. The central bank noticed the problem and agreed to increase the registered capital from 0.1 million to 0.5 million RMB (Men, 2011). The number of urban credit cooperatives remained stable at 3,518 in 1991. However, there was rapid growth of the economy in the following years and the GDP of China rose from 2,201 to 6,134 billion RMB during the period from 1991 to 1995. As a result, the number of urban credit cooperatives increased again to 5,217 in 1995. Figure 2 provides the GDP of China from 1986 to 1995.

Despite their rapid growth, due to the lack of supervision and an undeveloped financial system, the urban credit cooperatives faced a large number of non-performing loans and payment crises. To overcome those risks, the central bank stopped issuing licences to establish new urban credit cooperatives. The state council merged urban credit cooperatives with some rural credit cooperatives and local financial institutions, founding the earliest urban cooperative bank in 1995. After that, all the urban credit cooperatives were restructured into urban cooperative banks, and the central bank changed the name of urban cooperative banks into urban commercial banks in 1998 (Li, 2009).

By undertaking business from credit cooperatives, the urban commercial banks are still designed to provide service to small- and medium-sized local companies and individuals. The new format gives institutions unified standards, new governance and strong regulation. However, urban commercial banks were founded in provincial capital cities or prefecture level cities, and they could only operate within their administrative regions (Sun et al., 2013). After 2003, the China Banking Regulatory Commission undertook the duty of banking regulation and supervision; it encouraged the urban commercial banks to exploit cross-regionally. In 2005, the Bank of Shanghai and Bank of Beijing established branches in other provinces (Li, 2009). However, some urban commercial banks are too small in size to take the risk of transforming from urban credit cooperatives into urban commercial banks. Therefore, those banks within the same province have merged into one bank. For example, 10 urban commercial banks in Jiangsu province were combined into the Bank of Jiangsu in 2006 (Li, 2009).

To improve self-management and governance, urban commercial banks attracted foreign strategic investors. The first case was when the International Finance Corporation received 5 per cent in stock rights for the Bank of Shanghai in 1998 (Xie and Zhu, 2009). After that, many overseas investments flowed into Chinese urban commercial banks. As new investors joined urban commercial banks, they required that the banks change the governance to an international standard, which improved the bank management. With expansion, urban commercial banks started to list on the stock market in order to raise capital. The Bank of Beijing, Nanjing, and Ningbo first issued IPOs on the Shanghai Stock Exchange in 2007 (Xie and Zhu, 2009). By 2007 all urban commercial banks disclosed their annual reports to the public, with the banking regulatory commission requiring all of them to use new accounting standards for financial reporting[5]. Going public attracts more and more private capital to join the market; in 2010 the private capital accounted for 42.59 per cent of urban commercial banks' total capital and in 2014 it increased to 57.42 per cent[6]. Also, there are two urban commercial banks that set up representative offices overseas in 2010（Bank of Beijing and Fudian Bank[7]）.

By 2012, all of the urban credit cooperatives had transformed into urban commercial banks; and by 2015, there were 133 urban commercial banks in the Chinese banking industry. They became a vital part of the Chinese banking industry[8], with the total assets of urban commercial banks increasing from 1,462 billion RMB to 22,680 billion RMB from 2003 to 2015. In the meantime, the percentage of urban commercial banks to the entire market total assets increased from 5.29 per cent to 11.38 per cent. Table 1 provides details of total assets of urban commercial banks from 2003 to 2015.

According to the administrative divisions of China, there are four direct-control municipalities, 22 provinces, and five autonomous regions in mainland China[9]. Each province or autonomous region has one capital city. Therefore, most urban commercial banks set up headquarters in those capital cities. However, due to the different degrees of regional development, some provinces have more than 10 city commercial banks and some provinces just have two. Table 2 provides details of different provinces' GDP, population, and number of urban

[5] From the China Banking Regulatory Commission annual report 2007.
[6] From the China Banking Regulatory Commission annual report 2010-2014.
[7] Information from China Banking Regulatory Commission annual report 2010.
[8] The Banking Regulatory Commission even pays more attention to urban commercial banks. In 2015, it set up an individual urban commercial bank supervision department to monitor them.
[9] Reference from Chinese government websitehttp://www.gov.cn/test/2005-06/15/content_18253.htm

commercial banks for each region.

The nature of how fundamental and widespread urban commercial banks have become to the Chinese banking system as a whole makes further research in this area worthwhile, and investigation into their performance and comparison of their efficiency across regions crucial.

3. Literature review

Most research on banking investigates the European and US banking industries. For example, Vander Vennet (2002) works on cost and profit efficiency in the European banking system. However, recently more and more literature focus on developing countries (Bonin et al., 2005; Boubakri et al., 2005; Clarke et al., 2005) with some studies focusing on banking in China (Fu and Heffernan, 2009; Xiaogang et al., 2005; Lin and Zhang, 2009).

3.1 Literature outside of the Chinese banking industry

Considering research that examines bank industries outside of the Chinese market, most focus on how ownership influences banking performance. Altunbas et al. (2001) report that private commercial banks are more efficient than public saving and mutual cooperative banks in the German banking industry, even though all sizes of public and mutual banks have slight cost and profit advantages over private banks. Bonin et al. (2005) find that foreign banks have more efficiency than other banks in transition countries. The foreign investor provides a better service and has a positive impact on banks' profit efficiency. A similar result is found in Boubakri et al. (2005), which find that long term privatisation can improve economic efficiency and reduce credit risk exposure to developing countries' banks. However, newly privatised banks, which are controlled by local industrial groups, have more opportunities to suffer credit risk and interest rate risk. Clarke et al. (2005) show that privatisation improves banking performance and competition. But there are many potential problems with banking privatisation such as a minority share of state ownership in those banks, some governments restrict the privatisation, foreign investors cannot participate in the privatisation process, and private share offering instead of direct sale to strategic investors. By comparing efficiency between foreign and domestic banks, Lensink et al. (2008) states that it is important to look at the quality of institutions in both of the home and the host countries; if the governance distance of institution's host and home countries becomes smaller, the foreign banks are more efficient than domestic banks. In contrast, Staub et al. (2010) find that state-owned banks are more cost efficient than foreign and foreign participation banks in Brazil. Konara et al. (2019) exam the effect of foreign direct investment to efficiency measurement. Their results present that foreign competition has benefits to overall technical efficiency and scale efficiency, but has no benefit to pure technical efficiency, cost efficiency, and revenue efficiency.

Besides ownership, some literature focuses on political effects on banking efficiency. Boehmer et al. (2005) research 101 developing countries' banks from 1982 to 2000 and report that political factors have a significant effect on banking privatisation. The state-owned banks privatisation is related to political conditions and has a higher opportunity to privatise if the government has greater accountability to voters. Also bank size is another factor for influencing banking efficiency. While Vander Vennet (2002) finds that financial conglomerates are more revenue efficient than specialised banks in non-traditional banking business and that universal banks have higher cost and profit efficiency than non-universal banks. They conclude that de-specialisation of banking might lead to a more efficient European banking system. Similarly, Berger and DeYoung (2001) finds that nationwide banks are more efficient than very small banks. Altunbas et al. (2000) investigate the scale economy and efficiency of Japanese banking, and their results suggest that the largest banks can be more efficient by decreasing output to reduce cost rather than improving X-efficiency. Regarding to economy environment factors, Kenjegalieva et al. (2009) employ a bootstrapped regression approach to study the effect of macroeconomic environment to the efficiency of transition banks. Their results state that the level of inefficiency of banks have been steadily increasing during the European Union negotiation period. In their earlier stages of the European Union negotiation period, the macroeconomic factors have a significant effect on the banking inefficiency in transition countries. Also, Kazakh's banks increased a huge number of bad loans during the world financial crisis. It has a serious influence on the banks' cost, input distance and revenue frontiers (Glass and Kenjegalieva, 2014a). Tabak et al. (2013) notice that local environment and constraints are also affecting the performance of banks. They prove that geographical distance has the effect of technical efficiency by estimating a geographically weighted cost function. In considering risk into banking performance, Fiordelisi et al. (2011) investigate relationship of efficiency, risk and capital in European banking. They demonstrate negative relationship between efficiency and risk; and positive relationship between efficiency and capital. Delis et al. (2017) confirm the negative relationship between risk and efficiency in U.S.; and they also find that efficiency results are depending on whether the model including or not including risk component.

By looking at the regional banking industry, Berger and DeYoung (2001) investigate 7,000 US banks from 1993 to 1998. They find that the geographic scope has an impact on bank efficiency[10]. If a bank expands into a close regional area, its efficiency will increase. On the other hand, if a bank affiliate

[10] The definition of banking efficiency is that how successes of banks allocate their input to produce output to achieve their missions (Kumbhakar and Lovell, 2000).

moves further away from the origin, its efficiency will decrease. Collender and Shaffer (2003) provide information about why local banks behave differently from national banks; they have different levels of access to local information, of commitment to local prosperity, of technology in risk management and of bank size. When comparing local and national banks from a customer perspective, local banks receive more positive evaluations on extra services, bank's image and convenience in the US (Kaynak and Harcar, 2005). Hasan et al. (2009) find that there is a positive relationship between banking quality and economic growth across regions in 11 European countries, while Bos and Kool (2006) support that local market conditions as environmental factor influences bank efficiency. Aside from the regional factors affecting bank efficiency, banks also have an influence on the local economy. Collender and Shaffer (2003) state that in the short run bank liberalisation affects local economic growth, and out of market banks mergers or acquisitions, will not impair local economies; they will instead benefit the rural market. Moreover, Goodfriend (1999) finds that regional banks can facilitate central bank communications with the public. Beyond impaction factors of efficiency studies, some literature looks at research methodology; Wu et al. (2006) provide fuzzy logic into Data Envelopment Analysis which enables cross regional comparison.

3.2 Literature for the Chinese banking industry

When it comes to the Chinese banking industry, most literature studies the top-ranking banks such as the big five state-owned commercial and 12 joint-stock commercial banks, with most research analysing the relationship between ownership and efficiency. Fu and Heffernan (2009) demonstrates that joint-stock banks had more x-efficiency[11] than state-owned banks from 1985 to 2002, while Lin and Zhang (2009) support that state-owned banks have less efficiency. The authors find that foreign shares or public listings can help to improve the performance. A similar result is presented in Ariff and Can (2006), which find that joint-stock banks have more efficacy than stated owned banks by looking at data from 1995 to 2004. On the other hand, Chen et al. (2005) find that state-owned banks are more efficient than medium banks. A few aspects on which most research agrees are that privatisation and foreign investors can improve banking performance in developing countries[12].

Wang et al. (2014) study Chinese banking performance during third round banking reform period and find that overall efficiency is increasing. However, they find the state-owned commercial banks are more efficient than the joint-stock commercial banks in pre-reform period. Their results are inconsistent with other literature on Chinese banking. There are more foreign investments involved in the Chinese financial market after China joined WTO.

---

[11] Definition of X-efficiency is that ratio of minimum cost of best-practice bank from sample with same exogenous variable to actual cost (Berger and Mester 1997).

[12] For example, Boehmer et al. (2005), Boubakri et al. (2005), and Clarke et al. (2005).

Berger et al. (2009) compare the efficiency of foreign and domestic banks, and foreign banks were found to be the most efficient. The results indicate that Chinese banks can improve efficiency by acquiring foreign ownership. Jiang et al. (2009) support the view that foreign acquisition can improve efficiency of Chinese domestic banks in the long-term. Barros et al. (2011) indicate that the overall banking efficiency is improved after China entered the WTO, and the economic environment and policy also have an effect on the banking performance. Tan and Floros (2013) find that the risk and technical efficiency have a positive relationship; and there is negative relationship between risk and level of capitalisation in the Chinese banking industry in the post-WTO period.

Besides ownership, there is also research which discusses bank size and the Chinese banking development process. Chen et al. (2005) state that smaller banks are more efficient than medium-sized banks. But other literature, such as Ariff and Can (2006), suggest that the medium-sized banks are more efficient than small- and large-sized banks. Dobson and Kashyap (2006) discuss the advantages and disadvantages of Chinese banking reform. They state that there is a substantial process of Chinese banking reform, but the tensions of banking efficiency and social stability has remained and contributed to the distortions. Ariff and Can (2006) argue that open markets, risk management and reduction of government capital can improve Chinese banking efficiency.

Drake et al. (2006) state that the Hong Kong banking system had been affected by macroeconomic factors such as financial deregulation and 1978/79 South East Asian financial crisis, but to varying degrees based on different sizes of banks and different institutional sectors. Shyu et al. (2015) investigate banking efficiency in Taiwan, Hong Kong and Mainland China; they conclude that environmental conditions have significant impact on efficiency measurement. There is some literature working on Chinese banking productivity; Kumbhakar and Wang (2007) analyse the impact of banking reform to banking productivity and they find that the productivity increases during 1993 to 2002. Similar to the result of efficiency, productivity improvement of joint-stock commercial banks is better than state-owned commercial banks. Change et al. (2012) continue work on Chinese banking productivity and find similar results that productivity of Chinese banking is increasing from 2002 to 2009; in addition, joint-stock commercial banks have higher productivity growth rates compare to state-owned commercial banks.

With regard to Chinese regional banking research, there is limited literature in this area related to banking efficiency. Ferri (2009) provides information about geographical and ownership factors, finding that city commercial banks in the east of China have better performance and that banks controlled by the state-owned enterprises show less performance. Zhang et al. (2012) study 133 Chinese city commercial banks' relationships of law enforcement to the bank risk taking and bank efficiency from 1999 to 2008. The results show that stronger law enforcement increases the bank risk-taking in the region and a better legal environment, such as protection of intellectual property rights, can improve bank efficiency. In recent literature, Sun et al.'s (2013) research examines the relationship between strategic investors to city commercial banks' efficiency. They find that strategic investors can improve the city commercial banks' efficiency but that there is a negative relationship between strategic investors and the level of regional economic development. There is also some literature that compiles regional banks with state-owned and joint-stock banks together as one Chinese banking market for analysis (Ariff and Can, 2008; Chen et al., 2005; Lin and Zhang, 2009). Research on the ownership factor in Chinese bank efficiency is examined in Berger et al. (2009) and Jiang et al. (2009).

In addition to regional banking, there is a lot of literature focusing on the Chinese regional economy. Jin et al. (2005) manifest the relationship between local governments and the local markets' development and finds that the provincial government's strong fiscal incentive has a positive impact on the local economy, development and reform. Chen et al. (2005) show that the Chinese central government links the local official's turnover to the local economic growth in order to incentivise the regional economy's development. Comparing the federalism between China and Russia, Blanchard and Shleifer (2001) argue that Chinese local governments must support new companies energetically, and that federalism has an important function on Chinese economy growth. Jin et al. (2005) also show evidence of support that Chinese federalism provides fiscal incentives for local governments, which contribute to market development.

3.3 Literature of modelling

The method of frontier efficiency analysis can be separated into non-parametric and parametric approaches. Data envelopment analysis (DEA), as a non-parametric approach, is developed by Charnes et al. (1978) and wildly applied in efficiency measurement. However, the drawback of DEA is it does not account for economic inputs and outputs; moreover, DEA does not deal with random errors in the model estimation (Berger and Mester, 1997). On the contrary, stochastic frontier approach (SFA) allows economic variables and random error in the model. SFA is a parametric approach which was proposed by Aigner et al. (1977) and Meeusen and van den Broeck (1977). But compared to DEA, SFA requires the assumption of inefficiency distribution (Berger and Humphrey, 1997).

Traditional DEA and SFA cannot deal with spatial dependence of variables, and the result might lead to bias if spatial dependence exists within the research target. There is emerging literature on spatial stochastic frontier modelling which combine spatial econometrics with SFA. It began with adding a spatial parameter into frontier efficiency analysis with a distribution free approach. Druska and Horrace (2004) extend the cross-sectional model of Kelejian and Prucha (1999) by adding spatial correlation parameters into frontier framework with a fixed-effect model and measure time-invariant efficiency of Indonesian rice farms. Glass et al. (2013, 2014b) employ a similar model but measure time-varying efficiency under SFA following Cornwell et al. (1990).

Later, Glass et al. (2016a) (GKS from hereon) combine SFA with spatial econometrics as a spatial autoregressive stochastic frontier and spatial Durbin stochastic frontier for panel data. The spatial autoregressive stochastic frontier account for spatial lag of dependent variables, and the spatial Durbin stochastic frontier account for both spatial lag of dependent and independent variables. They calculate efficiency by assuming a half-normal distribution of inefficiency component and following Schmidt and Sickles (1984) obtain time-varying direct, asymmetric indirect and asymmetric total efficiencies. Glass et al. (2016b) develop the GKS model of latent heterogeneity by estimating a four error structure; they also introduce a spatial efficiency multiplier which separates asymmetric system efficiency from its own efficiency and asymmetric efficiency spillover from other units. At the same time, Tsionas and Michaelides (2016) also employ a spatial inefficiency model and the inefficiency term is spatial autoregressive in the Bayesian econometrics. Kutlu (2018) follows GKS model and provide another way to measure efficiency under spatial autoregressive stochastic frontier. The advantages of GKS model are allowing spatial lag of dependent and independent variables in model estimation, and it can capture spatial relationship and spillover within spatial context.

To summarise, recently research has paid more attention to banking in developing countries, especially China, instead of the European and US markets. Most of the literature surrounding Chinese banking industry looks at environmental factors' (ownership and size) impact on efficiency of top-ranking banks (state-owned and joint–stock commercial banks) and there is less work on regional banking. With the fast growth of regional industry, it is worth investigating the Chinese regional banking industry in much greater detail. The model proposed by Glass et al. (2016a, 2016b) can measure spatial relationship, and spillover for research targets which carry with spatial dependence. Therefore, the model is suitable for regional banking analysis.

4. Data and methodology

4.1 Sample of variables

Our data sample consists of 65 Chinese urban commercial banks. These banks operate in 18 Chinese provinces, four municipalities and four autonomous regions which cover the majority of mainland China. However, due to the data availability we exclude banks from the five provinces[13]. The dataset consists of a balanced panel with a time span of 2013-2017 obtained from Orbis Bank Focus[14]. Our model requires a balanced dataset, but there are some merger and initial public offering activities during our research period which causing missing data. Therefore, this is biggest dataset we can collect. The choice of output and input variables is guided by the well-established intermediation approach to banking (Sealey and Lindley, 1977) which treats banks as fund intermediaries. The three inputs in our model specification are deposits, labour and fixed assets. The single output variable is loans. The deposits variable is measured in monetary value. We use the staff expenses as labour variable in the modelling. However, some of the data on staff expenses are missing for one year. For those banks we calculate annual staff expenses growth rate by using four years of other data. We fill the dataset by last year's data multiplied by one plus the growth rate or discount back next year's data. The fixed assets are measured as long-term tangible pieces of property that banks own and use during their production process. The loans are the lending money from a bank to another party in return for future repayment of the principal amount and interest. We use mean-adjusted variables so that model coefficient results can be explained as elasticities at the sample mean. See Table 3 for detailed descriptions of the output and input variables and their summary statistics.

4.2 Spatial Production function

Instead of a traditional production function, we use spatial production function (following Glass et al., 2016a, 2016b) to measure the relationship between inputs and output(s). The reason we employ a production function is the nature of urban commercial banks. As emerging banks, they mainly focus on traditional banking business which transfers deposits into loans. The other operating income of urban commercial banks is 1.5 billion RMB compared to total loans of 112 billion RMB, which is only 1.3 per cent[15]. We also look at the spatial relationship between the different regions. The general production function can be written as:

$$y_{it} = f\left(x_{it};\beta\right) * TE_{it} \quad (1)$$

[13] These five provinces are Hainan, Guizhou, Tibet, Shaanxi, and Qinghai.

[14] Orbis Bank Focus is a worldwide database for 42,000 financial institutions information sourced by Bureau van Dijk. http://www.bvdinfo.com/en-gb/our-products/company-information/international-products/orbis-banks.

[15] Data from Orbis Bank Focus.

In this function, y_{it} is vector of the produced output from total N observed banks i, i = 1,…, N, at time period T, t = 1,…, T, x_{it} is vector of inputs which producer i used for process during time t, $f(x_{it};\beta)$ is the production frontier, β is a technology parameter to be estimated, and TE_{it} represents the output-oriented technical efficiency for each bank i over time t. In order to capture the effect of a random shock or idiosyncratic error, the function can be rewritten as:

$$y_{it} = f(x_{it};\beta) * exp\{v_{it}\} * TE_{it} \quad (2)$$

where $exp\{v_{it}\}$ represents the idiosyncratic error. As we know $TE_{it} = exp\{-\mu_{it}\}$ and we can re-write the production function as:

$$y_{it} = f(x_{it};\beta) * exp\{v_{it}\} * \exp\{\mu_{it}\} \quad (3)$$

Then we take $f(x_{it};\beta)$ into translog form (Christensen et al., 1973) so that the function is represented as:

$$\ln y_{it} = \alpha + \beta \sum_{h=1}^{H} \sum_{i=1}^{N} \ln x_{hit} + \tfrac{1}{2} \rho \sum_{h=1}^{H} \sum_{i=1}^{N} (\ln x_{hit})^2 + \lambda \sum_{h=1}^{H} \sum_{i=1}^{N} \ln x_{hit} \ln x_{(h+1)it} + v_{it} - \mu_{it} \quad (4)$$

where the random error is $\varepsilon_{it} = v_{it} - \mu_{it}$, v_{it} the random noise component, and μ_{it} is the technical inefficiency component. It requires that $\mu \geq 0$, then we can have $TE_{it} = \exp\{-\mu\} \leq 1$. The random noise component v_{it} assumed to be i.i.d. and symmetric and independently distributed with μ_{it}, therefore the random error ε_{it} is asymmetric. The vectors α , β , ρ , and λ are regression parameters which describe the relationship between inputs and outputs, h of x_{hit} indicate the different input variables h = 1,…,H, for each bank i during time t. For the spatial production function, we add spatial lags of the independent and dependent variables into the traditional production function. Therefore, we can investigate the relationship of a bank's input and output variables relative to the banks operating in contiguous regions. For the spatial analysis, we create a spatial contiguity matrix which covers all of our data regions. We give equal weights (which sum to one) for each regions' neighbour and give zero value for the region itself and the non-neighbouring provinces.

4.3 Model

For the spatial stochastic production frontier estimation, we applied Spatial Durbin Production Frontier with random effects model by adding spatial lags of the dependent variables and lags of dependent and independent variables into function (4). We can rewrite function (4) as:

$$\ln y_{\mathrm{it}} = \alpha + \beta \sum_{h=1}^{H} \sum_{i=1}^{N} \ln \mathrm{x}_{\mathrm{hit}} + \tfrac{1}{2} \rho \sum_{h=1}^{H} \sum_{i=1}^{N} (\ln x_{\mathrm{hit}})^2 + \lambda \sum_{h=1}^{H} \sum_{i=1}^{N} \ln x_{\mathrm{hit}} \ln x_{\mathrm{(h+1)it}} + \delta \sum_{\mathrm{k}=1}^{\mathrm{N}} \sum_{i=1}^{N} w_{ik} y_{kt} + \phi \sum_{j=1}^{N} \sum_{i=1}^{N} \sum_{h=1}^{H} w_{ij} x_{\mathrm{h}jt} + v_{\mathrm{it}} + \kappa_{\mathrm{i}} - \mu_{\mathrm{it}} - \eta_i \quad (5)$$

Where $\delta \sum_{\mathrm{k}=1}^{\mathrm{N}} \sum_{i=1}^{N} w_{ik} y_{kt}$ is the spatial lag of the dependent variable, δ is the spatial parameter need to be estimated, w_{ik} indicates the spatial arrangement of each individual bank where $i \neq \mathrm{k}$. $\phi \sum_{j=1}^{N} \sum_{i=1}^{N} \sum_{h=1}^{H} w_{ij} x_{\mathrm{h}jt}$ is the spatial lag of independent variables, vector ϕ is spatial parameter, and w_{ij} indicates the spatial arrangement of each individual bank where $i \neq \mathrm{j}$.

Our spatial models include a four error component which is $\varepsilon^*_{\mathrm{it}} = \varepsilon_{it} + \varepsilon_i = v_{\mathrm{it}} + \kappa_{\mathrm{i}} - \mu_{\mathrm{it}} - \eta_i$ where $\varepsilon_{it} = v_{\mathrm{it}} - \mu_{\mathrm{it}}$ is the time variant component and $\varepsilon_i = \kappa_{\mathrm{i}} - \eta_i$ is the time invariant component. To deal with the distributional assumption of the four error component, we use random effects. Within equation (5), v_{it} is the standard idiosyncratic error based on unobserved heterogeneity of random effects. κ_i is time invariant random error of unit specific effects. μ_{it} is net time variant inefficiency (NVI) and η_i is net time invariant inefficiency (NII). Both of these two inefficiencies are assumed to be half-normally distributed. Then we compute gross inefficiency (GVI) by combining these two inefficiencies, $\text{GVI=NVI*NII=}\mu_{it} * \eta_i$. The resulting inefficiency measure GVI is time variant inefficiency (Glass and Kenjegalieva, 2018). By separate inefficiency into NVI and NII components, we can observe any effects based on market restructure to short-run and persistent efficiency.

4.4 Elasticities of spatial production model

It has been well-established that the fitted parameters for the exogenous repressors are not elasticities for a model which contains a spatial autoregressive variable. To deal with the effect of the spatial autoregressive variable for exogenous regressors, we provide direct, indirect and total elasticities by using the fitted parameters from our model. The direct elasticity contains the effects of feedback from a spatial matrix. It is measured the same way as non-spatial model elasticity.

There are two explanations of indirect elasticity: 1) average change of the dependent variable from remaining units in the sample following a change of an independent variable from one observed unit; 2) average change of the dependent variable from one observed unit following a change of an independent variable from remaining units in the sample. The sum of direct and indirect elasticities is total elasticity.

5. Results and discussion

5.1 OLS residual skewness test

To begin our analysis, we first run OLS residual skewness test (Schmidt and Lin, 1984) for the validity of our model's stochastic frontier specification. Based on the production function, we expect the residual should skew to the left which indicates that the skewness test result should be negative. We run the pooled OLS first to get results for residual skewness check. The residuals result shows that we have expected negative result (-0.73) for our skewness. Thus, we can reject the null hypothesis of non-skewness of OLS residual.

5.2 Model results

Table 4 provides details of our model estimated results. Based on the monotonicity property of the production function (Kumbhakar and Lovell, 2003), an increase of inputs should lead to an increase in output. The output should be convex with respect to inputs. Therefore, we expect a positive relationship between input variables and the output variable.

The three inputs variables denoted as lx1, lx2, and lx3, are deposits, labour, and fixed assets, respectively. The model results report positive and significant results for all input variables coefficients. This result supports the monotonicity properties of the production function at the sample mean. Among input variables, deposits have the most impact on the banking production of output loans compared to the other two inputs. The parameter of the spatial lag of the dependent variable δ has a significant and positive coefficient in the model estimation. It describes the spatial autoregressive dependence of loans across the 65 urban commercial banks. However, there is no significant relationship of the spatial lag of independent variables. The details of direct, indirect, and total elasticities are presented in table 5. All direct and some of total elasticities are positive and significant. There are non-significant results from indirect elasticities under the Spatial Durbin Production Frontier model. Therefore, the significant result from the total elasticities were contributed to by the direct input elasticities.

5.3 Net and gross efficiency results

Based on the model estimation results, we have three efficiency results：Net Time-Variant Efficiency (NVE), Net Time-Invariant Efficiency (NIE) and Gross Time-Variant Efficiency (GVE). Table 6 provides a summary of the efficiency results.

According to the efficiency sources, NIE and GVE provide a much wider range of results compared to NVE. Figures 3 to 5 display the histogram of the three efficiency scores and the geographical distribution of the efficiency scores are illustrated in Figures 6. Most of Chinese urban commercial banks achieved NVE close to 95 per cent, NIE close to 87 per cent and GVE close to 82 per cent. The efficiency scores are widely distributed for NIE and GVE results. By looking at efficiency sources over time, the overall efficiency is nearly unchanged based on GVE results. However, the average results of NVE present an increasing status of efficiency from 93.99 per cent to 94.77 per cent. The lowest efficient banks have improvement of their efficiency from 2013 to 2017 and highest efficient banks remain have efficiency scores that are unchanged. The results imply that the market restructure has contributed to the short-run efficiency of urban commercial banks. Table 7 and 8 provide results of NVE and GVE change over research period. Then we look at efficiency results for different regions. Table 9 to 11 give details of each type of efficiency within each region.

In our results we order the efficiency score from largest to smallest for mean, minimum and maximum and provide respective rankings. Because of the data availability, some regions only display one bank in our sample. However, they contain more than one but less than three urban commercial banks in their region, except Shanxi and Xinjiang. The rest of the regions have more than three urban commercial banks (except Heilongjiang, Hunan, Guangxi, and Chongqing). All results provide similar rankings for each region based on their mean efficiency. If regions only have one urban commercial bank in our sample, they achieve a higher average and minimum efficiency scores rather than regions which include more than one urban commercial bank. Bank of Beijing (which is the biggest urban commercial bank in China) has the highest mean efficiency in all three results. The next highest ranking (based on mean efficiency) of urban commercial bank regions is located in the west of China and does not have high level of GDP or high population such as Ningxia and Gansu. This is opposite to Ferri's (2009) result where they find east region banks to achieve higher efficiency. However, the regions which have more urban commercial banks receive the highest efficiency scores. For example, Zhejiang has 14 urban commercial banks and its highest GVE result ranking is the 2nd, but lowest result ranking is at 21th. A similar scenario for Jiangsu, where the highest result ranking is 4th but lowest result ranking is 16th. The same case also applies to the NVE and NIE results.

Regions which are located in the east of China have a faster developing economy compared to the western regions. Therefore, if regions have a relatively competitive environment, their urban commercial banks will achieve higher efficiency levels. This is in line with Bos and Kool (2006) where the authors find that the regional market environment has an impact on bank performance. The advances of the regional economy have no positive impact on their regional bank efficiency. For regions with less than three urban commercial banks, the efficiency results are stable during our sample years. This result matches with the current Chinese urban commercial bank industry problem. All of the Chinese urban commercial banks were transferred from urban credit cooperatives, which are non-profit institutions. There are a number of urban commercial banks that are less efficient and facing high risks. This has motivated the recent wave of mergers and restructuring of those banks in order to achieve efficiency and reduce risk. For example, Huishang Bank was founded by merging six urban commercial banks and seven urban credit cooperatives within their region Anhui province[16]. The highest GVE result of Huishang Bank ranks 3rd under our model results.

6. Conclusion

We extend the research on Chinese urban commercial banks with a particular focus on the post-market restructure period. We provide more accurate efficiency analysis by employing a Spatial Durbin Production Frontier model to measure efficiency levels of 65 urban commercial banks from 2013 to 2017. Our data sample covers most regions of mainland China and utilises three input variables (deposits, labour, and fixed assets) and one output (loans). Our

[16] Source from Huishang Bank official website http://www.hsbank.com.cn/Channel/312285.

models provide significant results which satisfy the monotonicity properties of the production function.

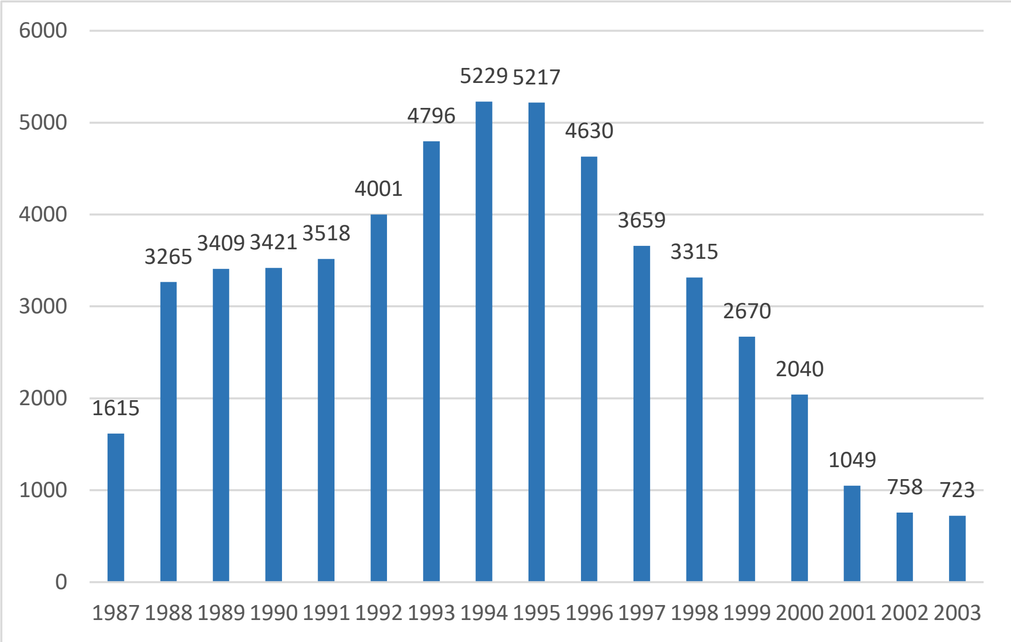
Our study addresses the relationship of Chinese urban commercial banks' output loans within the neighbouring regions and investigates the effect of regional market environment on bank performance. Among input variables, deposits have the most influence on output of loans of urban commercial banks. Most importantly, positive significant results on the spatial lag of the dependent variable indicate that output loans of Chinese urban commercial banks have a positive spatial relationship with other banks in their neighbouring regions. It can be simply interpreted that if one urban commercial bank increases its output, the outputs of other banks from its neighbouring regions should increase to a certain level as well.

The overall efficiency level of urban commercial banks is not changing from 2013 to 2017. However, the short-run average efficiency has slightly increased and the most inefficient banks have improved efficiency by 6.16 per cent. The results state that market restructures have contributed to short-run efficiency improvement of urban commercial banks. The western regions lack an economic advantage compared to eastern regions; but it is a surprise in our results that some underdeveloped regions have higher efficiency than more advanced regions. For regions with less than three urban commercial banks, the average efficiency is stable and relatively high. However, both the highest and lowest efficient banks exist in the regions which have more urban commercial banks. Thus, the regional market environment has an effect on performance of urban commercial banks. There are various reasons that can cause this situation; it could be a competitive environment or different local policy. This result matches the historical problem of Chinese urban commercial banks, which inherited high non-performing loans from the urban credit cooperatives. There are many urban commercial banks with lower efficiency results. These results fit with the development processes of Chinese urban commercial banks where mergers and restructures are taking place to increase efficiency. The regions with less than three urban commercial banks have stable banks with relatively higher efficiency scores. Those efficiency results confirm the achievement of Chinese urban commercial banks' development especially in the recent merger activities of market restructure. It indicates that lowest efficient urban commercial banks can improve their efficiency by mergers with other banks and financial institutions.

The limitation of this paper is the data scale. There are only five years data we can collect after the market restructure. Our model requires a balance dataset, and merger and stock listing activities caused missing data. The biggest dataset we can get only covers half of Chinese urban commercial banks. By identifying spatial dependence that exists among Chinese urban commercial banks, future research can work on spatial analysis of productivity, second stage analysis of efficiency, competition of each regions, risk measurement, impact of non-performing loans and merger activities.

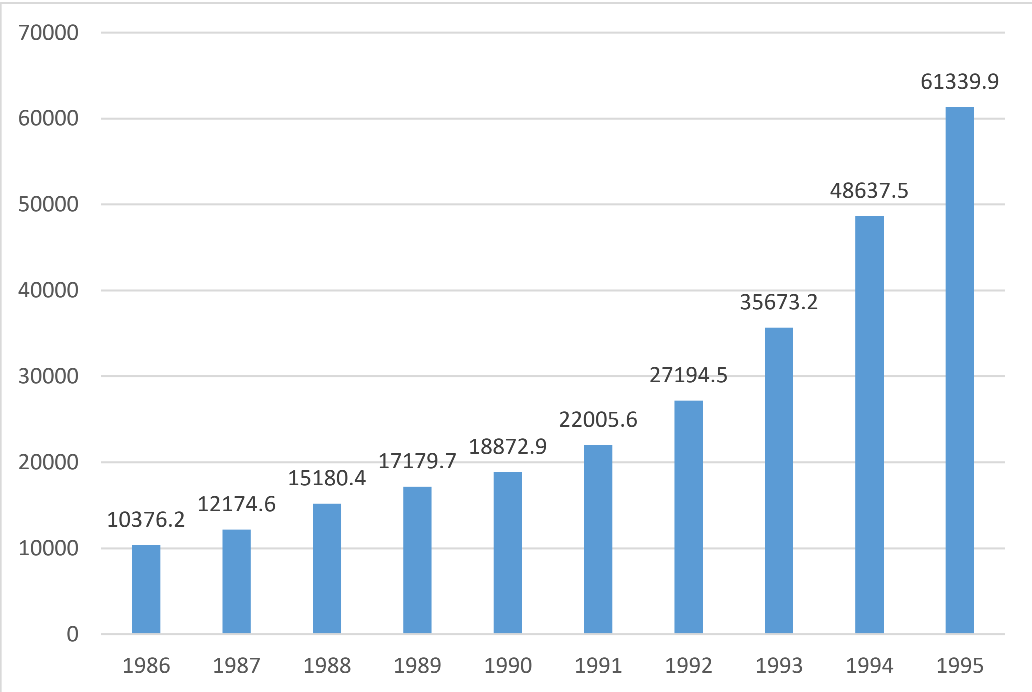
Acknowledgments
We would like to thank two anonymous referees and comments from of 6th International Workshop on "Efficiency in Education, Health and other Public Services" that improved the paper.

Figure 1 Number of urban credit cooperatives in China from 1987 to 2003



Source: 1987 - 2004 Almanac of China's Finance and Banking

Figure 2 Chinese national GDP from 1986 to 1995 (in million RMB)



Source: National Bureau of Statistics of China

Table 1 Total assets of urban commercial banks from 2003 to 2017

Years/Percentage	Urban commercial bank (in billion RMB)	Total banking industry (in billion RMB)
2003	1,462	27,658
%	5.29%	100%
2004	1,706	31,599
%	5.40%	100%
2005	2,037	37,470
%	5.44%	100%
2006	2,594	43,950
%	5.90%	100%
2007	3,341	53,116
%	6.29%	100%
2008	4,132	63,152
%	6.54%	100%
2009	5,680	79,515
%	7.14%	100%
2010	7,853	95,305
%	8.24%	100%
2011	9,985	113,287
%	8.81%	100%
2012	12,347	133,622
%	9.24%	100%
2013	15,178	151,355
%	10.03%	100%
2014	18,084	172,336
%	10.49%	100%
2015	22,680	199,345
%	11.38%	100%
2016	28,238	232,253
%	12.16%	100%
2017	31,722	252,404
%	12.57%	100%

Source: China Banking Regulatory Commission annual report 2018

Table 2 GDP, population, and number of urban commercial banks for different region in 2015

Region	GDP in billion RMB	Population in million	Number of UCB
Beijing	2,301	21.7	1
Tianjin	1,654	15.5	1
Hebei	2,981	74.3	11
Shanxi	1,277	36.6	6
Inner Mongolia	1,783	25.1	4
Liaoning	2,867	43.8	15
Jilin	1,406	27.5	1
Heilongjiang	1,508	38.1	2
Shanghai	2,512	24.2	1
Jiangsu	7,012	79.8	4
Zhejiang	4,289	55.4	14
Anhui	2,201	61.4	1
Fujian	2,598	38.4	4
Jiangxi	1,672	45.7	4
Shandong	6,300	98.5	14
Henan	3,700	94.8	5
Hubei	2,955	58.5	2
Hunan	2,890	67.8	2
Guangdong	7,281	108.5	5
Guangxi	1,680	48.0	3
Hainan	370	9.1	1
Chongqing	1,572	30.2	2
Sichuan	3,005	82.0	12
Guizhou	1,050	35.3	2
Yunnan	1,362	47.4	3
Tibet	103	3.2	1
Shaanxi	1,802	37.9	2
Gansu	679	26.0	2
Qinghai	242	5.9	1
Ningxia	291	6.7	2
Xinjiang	932	23.6	5

Source: National Bureau of Statistics of China and China Banking Regulatory Commission
Notice: UCB is urban commercial bank

Table 3 Statistics summary of all data variables

Variable	Model notation	Mean	Std. Dev.	Min	Max
Loans, in 100 million RMB	y	1060.00	1350.00	97.20	10400.00
Deposits, in 100 million RMB	x1	2450.00	3040.00	257.00	19500.00
Labour, in 100 million RMB	x2	17.31	18.66	0.65	116.00
Fixed assets, in 100 million RMB	x3	297.00	1750.00	1.37	24400.00

Table 4 Spatial Production Frontier model estimated results

Variables	Parameter	SDPF with Random Effect	Variables	Parameter	SDPF with Random Effect
lx1	β_1	0.652***	**wlx1**	ϕ_1	-0.143
lx2	β_2	0.155***	**wlx2**	ϕ_2	0.092
lx3	β_3	0.121***	**wlx3**	ϕ_3	-0.028
lx1x1	ρ_{11}	0.006	**wlx1x1**	ϕ_{11}	-0.069
lx2x2	ρ_{22}	-0.028***	**wlx2x2**	ϕ_{22}	-0.029
lx3x3	ρ_{33}	0.011	**wlx3x3**	ϕ_{33}	-0.009
lx1x2	λ_{12}	0.005	**wlx1x2**	ϕ_{12}	-0.015
lx1x3	λ_{13}	-0.015	**wlx1x3**	ϕ_{13}	0.046
lx2x3	λ_{23}	0.025*	**wlx2x3**	ϕ_{23}	-0.042
_cons	α	0.181**	**rho**	δ	0.190*

Note: ***, **, and * represent statistically significance at 1%, 5%, and 10% level.

Table 5 Direct, indirect, and total elasticities

	SDPF		
	Direct	Indirect	Total
lx1	0.652***	-0.031	0.621***
lx2	0.155***	0.166	0.321*
lx3	0.123***	-0.014	0.109
lx1x1	0.005	-0.088	-0.082
lx2x2	-0.028***	-0.045*	-0.073**
lx3x3	0.013	-0.006	0.006
lx1x2	0.005	-0.003	0.002
lx1x3	-0.016	0.050	0.034
lx2x3	0.025	-0.054	-0.029

Note: ***, **, and * represent statistically significance at 1%, 5%, and 10% level.

Table 6 Net and gross efficiency results summary

	Mean	Std. Dev.	Min	Max
NVE	94.31%	0.020	84.39%	97.71%
NIE	86.42%	0.061	67.85%	94.73%
GVE	81.52%	0.063	61.40%	91.22%

Figure 3 Net Time-Variant efficiency histogram result

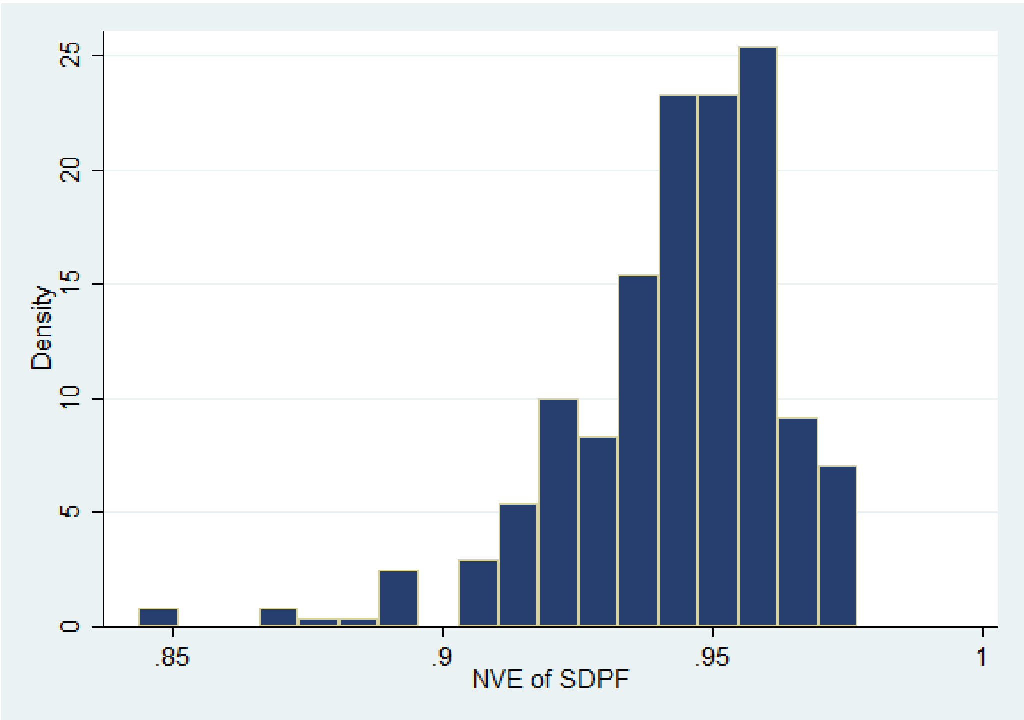


Figure 4 Net Time-Invariant efficiency histogram result

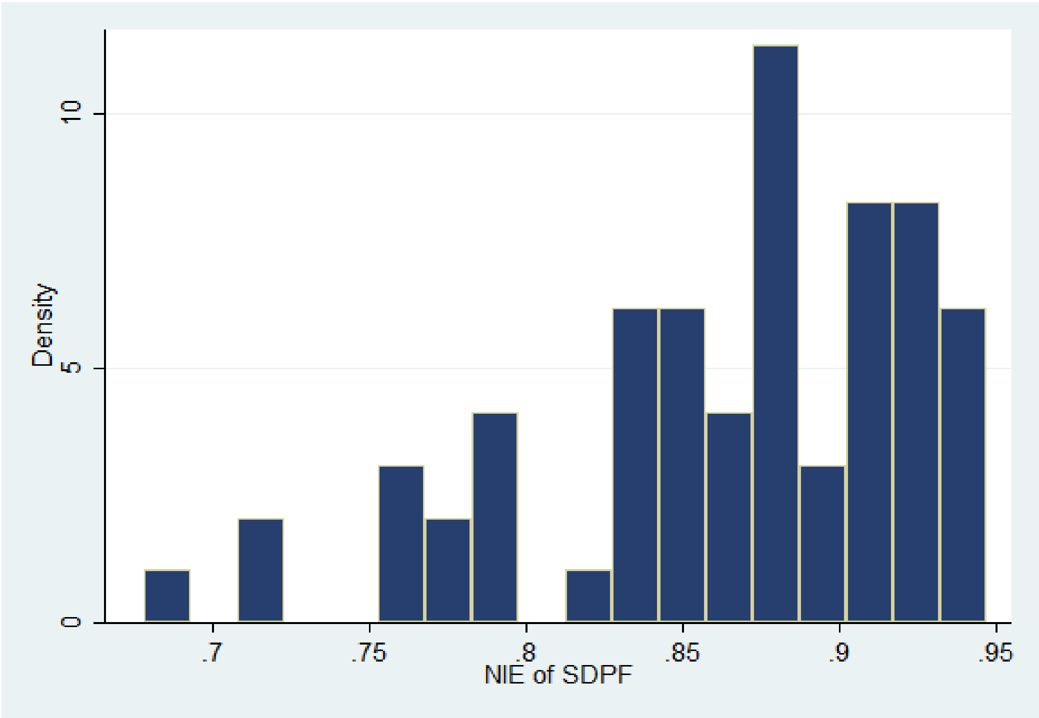


Figure 5 Gross Time-Variant efficiency histogram result

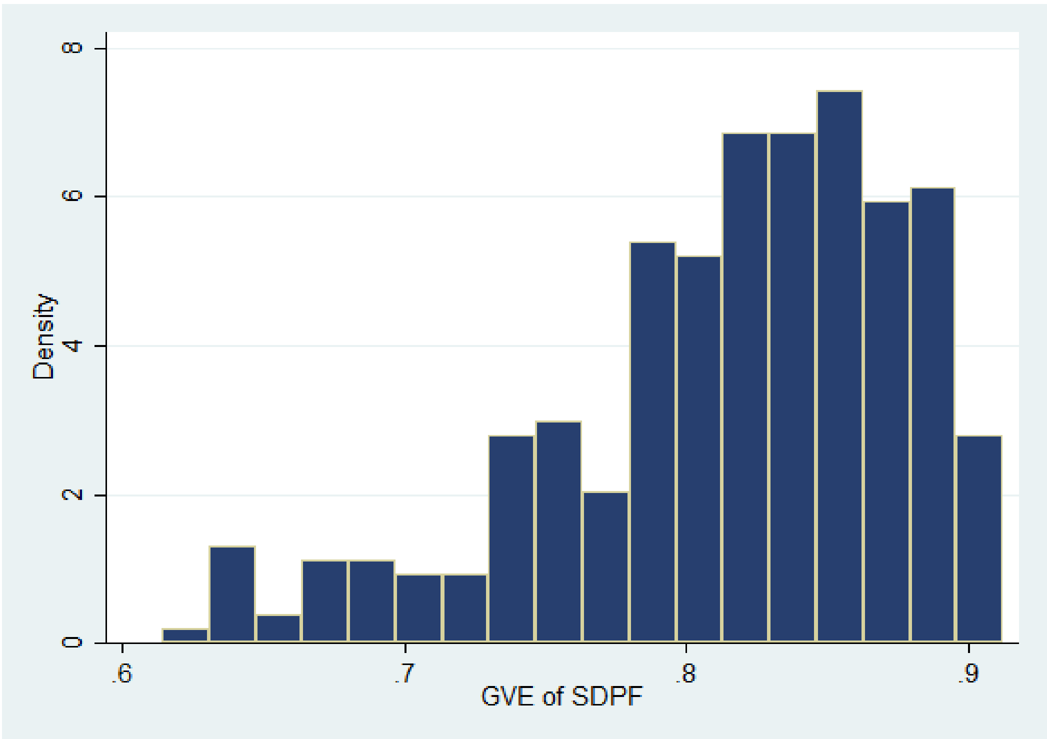


Figure 6 Geographical distribution of the Gross Time-Variant efficiency results

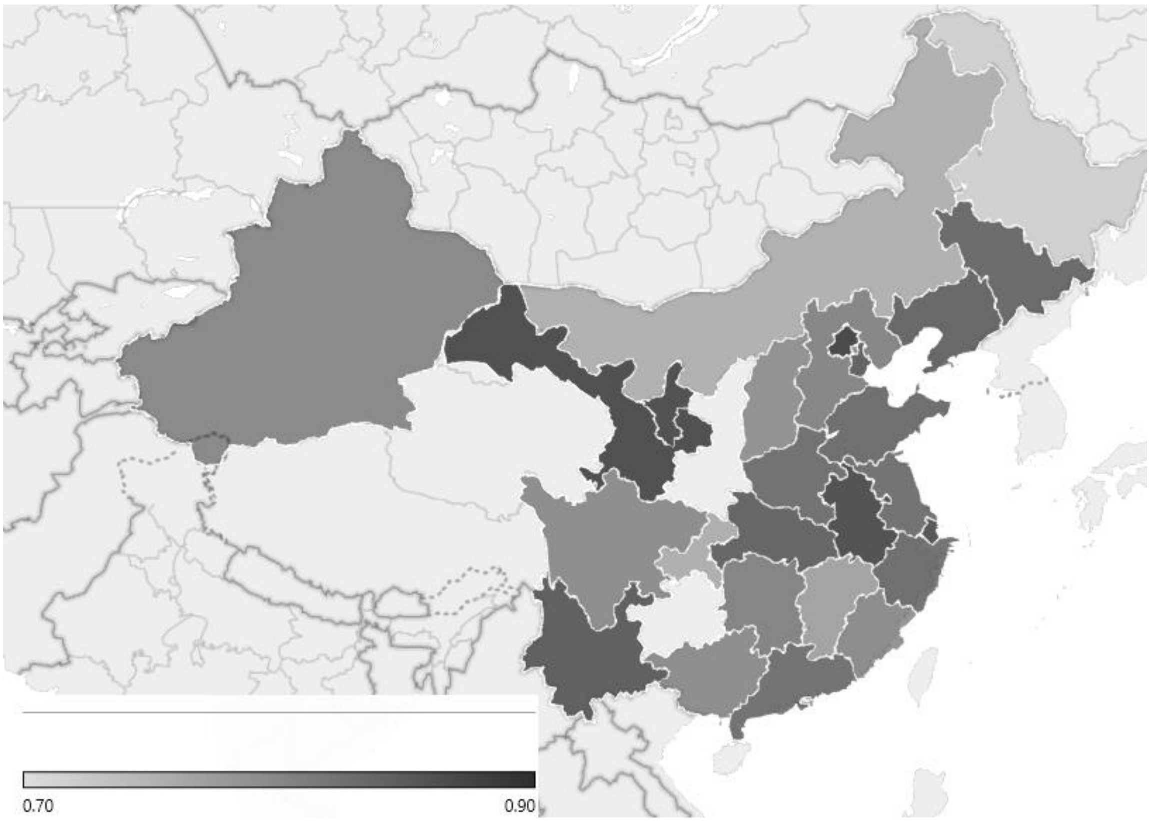


Table 7 Net time-variant efficiency over time

Year	Mean	Std. Dev.	Min	Max
2013	93.99%	0.031	84.39%	97.21%
2014	94.49%	0.018	88.55%	96.84%
2015	94.24%	0.013	91.02%	96.44%
2016	94.03%	0.016	90.50%	97.44%
2017	94.77%	0.020	90.56%	97.71%

Table 8 Gross time-variant efficiency over time

Year	Mean	Std. Dev.	Min	Max
2013	81.31%	0.074	64.39%	91.22%
2014	81.71%	0.066	63.44%	90.62%
2015	81.46%	0.061	63.34%	89.25%
2016	81.26%	0.059	61.40%	90.42%
2017	81.86%	0.056	63.09%	91.08%

Table 9 Net Time-Variant efficiency for each region

Region	No. of banks	Mean	Ranking	Min	Ranking	Max	Ranking
Beijing	<3	94.96%	1	93.73%	2	96.30%	18
Tianjin	<3	94.65%	5	87.07%	23	97.71%	1
Hebei	>3	94.32%	17	93.55%	3	96.32%	17
Shanxi	>3	94.36%	14	87.69%	22	97.36%	5
Inner Mongolia	>3	93.66%	25	94.34%	1	95.74%	26
Liaoning	>3	94.43%	12	92.24%	8	97.10%	10
Jilin	<3	94.58%	8	89.51%	18	97.51%	4
Heilongjiang	<3	93.47%	26	91.95%	10	96.62%	15
Shanghai	<3	94.74%	4	92.41%	7	95.83%	24
Jiangsu	>3	94.53%	10	91.18%	14	96.68%	14
Zhejiang	>3	94.42%	13	88.55%	21	97.26%	7
Anhui	<3	94.61%	7	92.81%	6	95.77%	25
Fujian	>3	94.14%	20	84.77%	25	97.62%	2
Jiangxi	>3	93.89%	23	91.50%	12	96.19%	22
Shandong	>3	94.57%	9	92.09%	9	96.27%	19
Henan	>3	94.36%	15	91.70%	11	96.73%	13
Hubei	<3	94.64%	6	90.73%	16	96.84%	12
Hunan	<3	94.08%	21	90.50%	17	96.38%	16
Guangdong	>3	94.17%	19	84.39%	26	97.35%	6
Guangxi	=3	93.81%	24	93.54%	4	95.91%	23
Chongqing	<3	94.06%	22	91.18%	13	96.23%	20
Sichuan	>3	94.34%	16	90.76%	15	97.21%	9
Yunnan	=3	94.46%	11	86.66%	24	97.22%	8
Gansu	<3	94.90%	3	89.41%	19	96.97%	11
Ningxia	<3	94.91%	2	93.41%	5	96.21%	21
Xinjiang	>3	94.20%	18	89.35%	20	97.62%	3

Table 10 Net Time-Invariant efficiency for each region

Region	No. of banks	Mean	Ranking	Min	Ranking	Max	Ranking
Beijing	<3	94.73%	1	94.73%	1	94.73%	1
Tianjin	<3	90.58%	7	90.58%	7	90.58%	15
Hebei	>3	84.75%	17	76.23%	22	91.95%	10
Shanxi	>3	82.52%	22	82.52%	17	82.52%	24
Inner Mongolia	>3	77.88%	25	76.78%	21	78.98%	25
Liaoning	>3	89.99%	9	87.80%	10	92.18%	9
Jilin	<3	89.22%	10	89.22%	9	89.22%	17
Heilongjiang	<3	74.68%	26	71.04%	25	78.32%	26
Shanghai	<3	92.65%	5	92.65%	5	92.65%	8
Jiangsu	>3	87.79%	15	83.55%	16	94.40%	3
Zhejiang	>3	88.77%	11	78.49%	19	94.53%	2
Anhui	<3	93.62%	3	93.62%	3	93.62%	5
Fujian	>3	83.88%	19	71.64%	24	91.62%	12
Jiangxi	>3	80.04%	23	77.75%	20	84.17%	23
Shandong	>3	88.47%	12	85.25%	12	93.11%	7
Henan	>3	88.24%	13	86.47%	11	90.70%	14
Hubei	<3	90.07%	8	90.07%	8	90.07%	16
Hunan	<3	85.32%	16	84.28%	14	86.37%	21
Guangdong	>3	88.23%	14	83.98%	15	91.76%	11
Guangxi	=3	83.87%	20	75.96%	23	88.36%	18
Chongqing	<3	77.93%	24	67.85%	26	88.01%	19
Sichuan	>3	83.57%	21	78.94%	18	87.84%	20
Yunnan	=3	91.30%	6	91.30%	6	91.30%	13
Gansu	<3	93.67%	2	93.67%	2	93.67%	4
Ningxia	<3	93.42%	4	93.42%	4	93.42%	6
Xinjiang	>3	84.34%	18	84.34%	13	84.34%	22

Table 11 Gross Time-Variant efficiency for each region

Region	No. of banks	Mean	Ranking	Min	Ranking	Max	Ranking
Beijing	<3	89.96%	1	88.79%	1	91.22%	1
Tianjin	<3	85.74%	7	84.62%	6	87.15%	14
Hebei	>3	79.96%	17	68.16%	20	89.16%	9
Shanxi	>3	77.87%	22	76.26%	15	79.08%	24
Inner Mongolia	>3	72.94%	25	66.85%	22	75.72%	26
Liaoning	>3	84.98%	9	79.66%	10	88.72%	10
Jilin	<3	84.39%	10	82.81%	9	85.44%	17
Heilongjiang	<3	69.80%	26	64.41%	23	76.37%	25
Shanghai	<3	87.78%	5	85.31%	5	89.19%	8
Jiangsu	>3	83.00%	15	76.19%	16	90.64%	4
Zhejiang	>3	83.83%	11	68.02%	21	91.08%	2
Anhui	<3	88.57%	4	86.36%	4	90.90%	3
Fujian	>3	79.01%	19	63.44%	25	87.92%	12
Jiangxi	>3	75.16%	23	68.18%	19	80.77%	23
Shandong	>3	83.67%	12	78.25%	12	90.06%	5
Henan	>3	83.27%	13	79.47%	11	87.12%	15
Hubei	<3	85.24%	8	84.25%	7	86.75%	16
Hunan	<3	80.27%	16	77.17%	14	84.31%	21
Guangdong	>3	83.09%	14	74.99%	17	88.65%	11
Guangxi	=3	78.73%	21	64.39%	24	84.83%	18
Chongqing	<3	73.34%	24	61.40%	26	84.66%	19
Sichuan	>3	78.84%	20	72.60%	18	84.44%	20
Yunnan	=3	86.24%	6	83.54%	8	87.82%	13
Gansu	<3	88.89%	2	87.62%	3	89.83%	6
Ningxia	<3	88.66%	3	88.13%	2	89.44%	7
Xinjiang	>3	79.45%	18	77.55%	13	81.49%	22

References

Aigner, D., Lovell, C. A. K. and Schmidt, P. (1977) 'Formulation and estimation of stochastic frontier production function models', Journal of Econometrics. North-Holland, 6(1), pp. 21–37. doi: 10.1016/0304-4076(77)90052-5.

Altunbas, Y., Evans, L. and Molyneux, P. (2001) 'Bank Ownership and Efficiency', Journal of Money, Credit and Banking, 33(4), p. 926. doi: 10.2307/2673929.

Altunbas, Y. et al. (2000) 'Efficiency and risk in Japanese banking', Journal of Banking & Finance, 24(10), pp. 1605–1628. doi: 10.1016/S0378-4266(99)00095-3.

ARIFF, M. and CAN, L. (2008) 'Cost and profit efficiency of Chinese banks: A non-parametric analysis', China Economic Review, 19(2), pp. 260–273. doi: 10.1016/j.chieco.2007.04.001.

Barros, C. P. et al. (2011) 'Technical efficiency in the Chinese banking sector', Economic Modelling, 28(5), pp. 2083–2089. doi: 10.1016/j.econmod.2011.04.003.

Berger, A. N. and DeYoung, R. (2001) 'The Effects of Geographic Expansion on Bank Efficiency', Journal of Financial Services Research, 19(2–3), pp. 163–184. doi: 10.1023/A:1011159405433.

Berger, A. N. et al. (2005) 'Corporate governance and bank performance: A joint analysis of the static, selection, and dynamic effects of domestic, foreign, and state ownership', Journal of Banking & Finance, 29(8-9 SPEC. ISS.), pp. 2179–2221. doi: 10.1016/j.jbankfin.2005.03.013.

Berger, A. N., Hasan, I. and Zhou, M. (2009) 'Bank ownership and efficiency in China: What will happen in the world's largest nation?', Journal of Banking & Finance. North-Holland, 33(1), pp. 113–130. doi: 10.1016/J.JBANKFIN.2007.05.016.

Berger, A. N. and Humphrey, D. B. (1997) 'Efficiency of financial institutions: International survey and directions for future research', European Journal of Operational Research. North-Holland, 98(2), pp. 175–212. doi: 10.1016/S0377-2217(96)00342-6.

Berger, A. N. and Mester, L. J. (1997) 'Inside the Black Box: What explanis Differences in the Efficiency of Financial Institutions', Journal of banking & Finance, 21, pp. 895–947.

Blanchard, O. and Shleifer, A. (2001) 'Federalism with and without political centralization: China versus Russia', IMF staff papers.

Boehmer, E., Nash, R. C. and Netter, J. M. (2005) 'Bank privatization in developing and developed countries: Cross-sectional evidence on the impact of economic and political factors', Journal of Banking & Finance. North-Holland, 29(8–9), pp. 1981–2013. doi: 0.1016/J.JBANKFIN.2005.03.004.

Bonin, J., Hasan, I. and Wachtel, P. (2005) 'Privatization matters: Bank efficiency in transition countries', Journal of Banking & Finance.

Bos, J. and Kool, C. (2006) 'Bank efficiency: The role of bank strategy and local market conditions', Journal of Banking & Finance.

Boubakri, N. et al. (2005) 'Privatization and bank performance in developing countries', Journal of Banking & Finance, 29(8-9 SPEC. ISS.), pp. 2015–2041. doi: 10.1016/j.jbankfin.2005.03.003.

Chang, T. P. et al. (2012) 'The sources of bank productivity growth in China during 2002-2009: A disaggregation view', Journal of Banking & Finance, 36(7), pp. 1997–2006. doi: 0.1016/j.jbankfin.2012.03.003.

Charnes, A., Cooper, W. W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', European Journal of Operational Research. North-Holland, 2(6), pp. 429–444. doi: 10.1016/0377-2217(78)90138-8.

CHEN, X., SKULLY, M. and BROWN, K. (2005) ‘Banking efficiency in China: Application of DEA to pre- and post-deregulation eras: 1993–2000’, China Economic Review. North-Holland, 16(3), pp. 229–245. doi: 10.1016/J.CHIECO.2005.02.001.
Chen, Y., Li, H. and Zhou, L. (2005) ‘Relative performance evaluation and the turnover of provincial leaders in China’, Economics Letters.
Christensen, L. R., Jorgenson, D. W. and Lau, L. J. (1973) ‘Transcendental Logarithmic Production Frontiers’, The Review of Economics and Statistics. The MIT Press, 55(1), p. 28. doi: 10.2307/1927992.
Clarke, G., Cull, R. and Shirley, M. (2005) ‘Bank privatization in developing countries: A summary of lessons and findings’, Journal of Banking & Finance.
Collender, R. and Shaffer, S. (2003) ‘Local bank office ownership, deposit control, market structure, and economic growth’, Journal of Banking & Finance.
Cornwell, C., Schmidt, P. and Sickles, R. C. (1990) ‘Production frontiers with cross-sectional and time-series variation in efficiency levels’, Journal of Econometrics. North-Holland, 46(1–2), pp. 185–200. doi: 10.1016/0304-4076(90)90054-W.
Delis, M., Iosifidi, M. and Tsionas, M. G. (2017) ‘Endogenous bank risk and efficiency’, European Journal of Operational Research. North-Holland, 260(1), pp. 376–387. doi: 10.1016/J.EJOR.2016.12.024.
Dobson, W. and Kashyap, A. (2006) ‘The contradiction in China’s gradualist banking reforms’, Brookings Papers on Economic Activity.
Drake, L., Hall, M. J. B. and Simper, R. (2006) ‘The impact of macroeconomic and regulatory factors on bank efficiency: A non-parametric analysis of Hong Kong’s banking system’, Journal of Banking & Finance, 30(5), pp. 1443–1466. doi: 10.1016/j.jbankfin.2005.03.022.
Druska, V. and Horrace, W. C. (2004) ‘Generalized Moments Estimation for Spatial Panel Data: Indonesian Rice Farming’, American Journal of Agricultural Economics. Narnia, 86(1), pp. 185–198. doi: 10.1111/j.0092-5853.2004.00571.x.
Ferri, G. (2009) ‘Are new tigers supplanting old mammoths in China’s banking system? Evidence from a sample of city commercial banks’, Journal of Banking & Finance.
Fiordelisi, F., Marques-Ibanez, D. and Molyneux, P. (2011) ‘Efficiency and risk in European banking’, Journal of Banking & Finance. North-Holland, 35(5), pp. 1315–1326. doi: 10.1016/J.JBANKFIN.2010.10.005.
Fu, X. and Heffernan, S. (2009) ‘The effects of reform on China’s bank structure and performance’, Journal of Banking & Finance.
Glass, A. J. and Kenjegalieva, K. (2019) ‘A spatial productivity index in the presence of efficiency spillovers: Evidence for U.S. banks, 1992–2015’, European Journal of Operational Research. North-Holland, 273(3), pp. 1165–1179. doi: 10.1016/j.ejor.2018.09.011.
Glass, A., Kenjegalieva, K. and Paez-Farrell, J. (2013) ‘Productivity growth decomposition using a spatial autoregressive frontier model’, Economics Letters, 119(3), pp. 291–295. doi: 10.1016/j.econlet.2013.03.002.
Glass, A., Kenjegalieva, K. and Sickles, R. C. (2014b) ‘Estimating efficiency spillovers with state level evidence for manufacturing in the US’, Economics Letters. North-Holland, 123(2), pp. 154–159. doi: 10.1016/J.ECONLET.2014.01.037.

Glass, A. J., Kenjegalieva, K. and Sickles, R. C. (2016a) 'A spatial autoregressive stochastic frontier model for panel data with asymmetric efficiency spillovers', Journal of Econometrics. North-Holland, 190(2), pp. 289–300. doi: 10.1016/J.JECONOM.2015.06.011.
Glass, A. J., Kenjegalieva, K. and Sickles, R. C. (2016b) 'The Spatial Efficiency Multiplier and Random Effects in Spatial Stochastic Frontier Models', SSRN Electronic Journal. doi: 10.2139/ssrn.2873520.
Glass, A. J., Kenjegalieva, K. and Weyman-Jones, T. (2014a) 'Bank performance and the financial crisis: Evidence from Kazakhstan', Applied Financial Economics, 24(2), pp. 121–138. doi: 10.1080/09603107.2013.868584.
Goodfriend, M. (1999) 'The Role of a Regional Bank in a System of Central Banks', SSRN Electronic Journal. doi: 10.2139/ssrn.2180958.
Hasan, I., Koetter, M. and Wedow, M. (2009) 'Regional growth and finance in Europe: Is there a quality effect of bank efficiency?', Journal of Banking & Finance
Jiang, C., Yao, S. and Zhang, Z. (2009) 'The effects of governance changes on bank efficiency in China: A stochastic distance function approach', China Economic Review, 20(4), pp. 717–731. doi: 10.1016/j.chieco.2009.05.005.
Jin, H., Qian, Y. and Weingast, B. (2005) 'Regional decentralization and fiscal incentives: Federalism, Chinese style', Journal of public economics.
Kaynak, E. and Harcar, T. (2005) 'American consumers' attitudes towards commercial banks: A comparison of local and national bank customers by use of geodemographic segmentation', International Journal of bank marketing.
Kelejian, H. H. and Prucha, I. R. (1999) 'A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model', International Economic Review. John Wiley & Sons, Ltd (10.1111), 40(2), pp. 509–533. doi: 10.1111/1468-2354.00027.
Kenjegalieva, K. A., Simper, R. and Weyman-Jones, T. G. (2009) 'Efficiency of transition banks: Inter-country banking industry trends', Applied Financial Economics, 19(19), pp. 1531–1546. doi: 10.1080/09603100902984343.
Konara, P., Tan, Y. and Johnes, J. (2019) 'FDI and heterogeneity in bank efficiency: Evidence from emerging markets', Research in International Business and Finance, 49, pp. 100–113. doi: 10.1016/j.ribaf.2019.02.008.
Kumbhakar, S. C. and Wang, D. (2007) 'Economic reforms, efficiency and productivity in Chinese banking', Journal of Regulatory Economics. Springer US, 32(2), pp. 105–129. doi: 10.1007/s11149-007-9028-x.
Kumbhakar, S. and Lovell, C. A. K. (2003) Stochastic frontier analysis. Cambridge University Press.Kutlu, L. (2018) 'Estimating efficiency in a spatial autoregressive stochastic frontier model', Economics Letters. North-Holland, 163, pp. 155–157. doi: 10.1016/J.ECONLET.2017.12.025.
Lensink, R., Meesters, A. and Naaborg, I. (2008) 'Bank efficiency and foreign ownership: Do good institutions matter?', Journal of Banking & Finance, 32(5), pp. 834–844. doi: 10.1016/j.jbankfin.2007.06.001.
Li, Y. (2009) 60 Year Fiance of New China. Trajectory Inc.
Lin, X. and Zhang, Y. (2009) 'Bank ownership reform and bank performance in China', Journal of Banking & Finance
Meeusen, W. and van Den Broeck, J. (1977) 'Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error', International Economic Review. WileyEconomics Department of

the University of PennsylvaniaInstitute of Social and Economic Research, Osaka University, 18(2), p. 435. doi: 10.2307/2525757.
Men, C. (2011) 'Analysis of city financial development after reform and opening-up policy', Modern economic research on both sides of the Taiwan straits.
Schmidt, P. and Sickles, R. C. (1984) 'Production Frontiers and Panel Data', Journal of Business & Economic Statistics, 2(4), pp. 367–374. doi: 10.1080/07350015.1984.10509410.
Sealey, C. W. and Lindley, J. T. (1977) 'INPUTS, OUTPUTS, AND A THEORY OF PRODUCTION AND COST AT DEPOSITORY FINANCIAL INSTITUTIONS', The Journal of Finance. John Wiley & Sons, Ltd (10.1111), 32(4), pp. 1251–1266. doi: 10.1111/j.1540-6261.1977.tb03324.x.
Shyu, J., Lieu, P.-T. and Chang, W. (2015) 'How the environment determines banking efficiency: a comparison of banking firms in Taiwan, Hong Kong, and Mainland China', International Transactions in Operational Research. John Wiley & Sons, Ltd (10.1111), 22(4), pp. 757–770. doi: 10.1111/itor.12097.
Staub, R. B., da Silva e Souza, G. and Tabak, B. M. (2010) 'Evolution of bank efficiency in Brazil: A DEA approach', European Journal of Operational Research, 202(1), pp. 204–213. doi: 10.1016/j.ejor.2009.04.025.
Sun, J., Harimaya, K. and Yamori, N. (2013) 'Regional economic development, strategic investors, and efficiency of Chinese city commercial banks', Journal of Banking & Finance.
Tabak, B. M., Miranda, R. B. and Fazio, D. M. (2013) 'A geographically weighted approach to measuring efficiency in panel data: The case of US saving banks', Journal of Banking & Finance. North-Holland, 37(10), pp. 3747–3756. doi: 10.1016/J.JBANKFIN.2013.05.022.
Tan, Y. and Floros, C. (2013) 'Risk, capital and efficiency in Chinese banking', Journal of International Financial Markets, Institutions and Money, 26(1), pp. 378–393. doi: 10.1016/j.intfin.2013.07.009.
Tsionas, E. G. and Michaelides, P. G. (2016) 'A Spatial Stochastic Frontier Model with Spillovers: Evidence for Italian Regions', Scottish Journal of Political Economy. John Wiley & Sons, Ltd (10.1111), 63(3), pp. 243–257. doi: 10.1111/sjpe.12081.
Vennet, R. Vander (2002) 'Cost and Profit Efficiency of Financial Conglomerates and Universal Banks in Europe', Journal of Money, Credit and Banking. Ohio State University Press, pp. 254–282. doi: 10.2307/3270685.
Wang, K. et al. (2014) 'Efficiency measures of the Chinese commercial banking system using an additive two-stage DEA', Omega (United Kingdom), 44, pp. 5–20. doi: 10.1016/j.omega.2013.09.005.
Wu, D., Yang, Z. and Liang, L. (2006) 'Efficiency analysis of cross-region bank branches using fuzzy data envelopment analysis', Applied Mathematics and Computation.
Chen, X., Skully, M. and Brown, K. (2005) 'Banking efficiency in China: Application of DEA to pre-and post-deregulation eras: 1993–2000', China Economic Review.
Xie, W; Zhu, H. (2009) 'Chinese city commercial bank development review and future plan after the reform and opening-up policy', Economic Research Guide, 6, pp. 54–56.
Zhang, J., Wang, P. and Qu, B. (2012) 'Bank risk taking, efficiency, and law enforcement: Evidence from Chinese city commercial banks', China Economic Review.