DALARNA
UNIVERSITY

Master Thesis in Microdata Analysis

The effects of shadow banking on bank efficiency: Evidence from China

Author:
Chuandong Chen

Supervisor:
Daniel Wikström

2015

Business Intelligence Program
School for Technology and Business Studies
Dalarna University

Abstract

This study examines the effects of shadow banking on bank efficiency using data on Chinese commercial banks during the period 1998–2012. I focus on two aspects: shadow banking activities inside and outside the commercial banks. Stochastic frontier analysis (SFA) is used to analyze the effects of shadow banking on cost-efficiency. The empirical results indicate that the higher relative size of shadow banking inside the commercial banks, the higher bank cost-efficiency is, while the higher relative size of shadow banking outside the commercial banks, the lower cost-efficiency is. This shows that there are gains from shadow banking for the Chinese financial system. It is important for policymakers to realize this but at the same time understand that shadow banking likely implies a trade-off between flexibility for the banking sector and higher risks.

Keywords: Shadow banking; Cost-efficiency; Chinese commercial banks; Stochastic frontier analysis

Contents

List of Tables and Figure

I. Introduction

With the slowdown of China's economic growth[1], it is more and more important to improve efficiency in every important sector. This study focuses on commercial banks in China. However, a new form of financial activities called "shadow banking" has appeared in recent years and there is an ongoing debate about its pros and cons.[2] In this thesis, I analyze the relationship between size of shadow banking and cost-efficiency of the commercial banks.

Sun and Chang (2011) looked into the relationship between risk and cost-efficiency of banking in eight Asian countries. They concluded that risk has significant effects on the cost-efficiency of banks. Li, Hsu and Qin (2014) analyzed risks in shadow banking system of China. Based on a stress test they found that there are some risks in the shadow banking system.

Shadow banking can be considered to be an integration of different types of risk. Although there are many studies on the relationship between risk and banks' cost-efficiency and also studies on the link between shadow banking and risks, as far as I know, there is no study on the connection between shadow banking and cost-efficiency of commercial banks.

Therefore, the objective of this thesis is to analyze effects of shadow banking on the cost-efficiency of Chinese commercial banks.

The remainder of this thesis is organized as follows. Section II gives the background of shadow banking and the current situation in China; Section III presents the data of the study; Section IV outlines the empirical methodology; Section V displays our empirical results and Section VI includes a robustness check of the results. Section VII concludes the thesis.

[1] China's economic growth slowed down to 7.4% in 2014, which is the slowest rate in decades.

[2] Paul McCulley introduced "shadow banking" in 2007 at the annual meeting of The Federal Reserve and since then this concept has been developed by many others such as the Financial Stability Board (FSB) and the International Monetary Fund (IMF). Shadow banking is considered to play an important role in the global financial crisis of 2008. In google scholar, there are around 129,000 hits for "shadow banking". In Springer link, ScienceDirect, Wiley Online Library, there are respectively 16655, 16542 and 23968 hits.

II. Background

There are always some dissensions about the definition of shadow banking which is still developing and changing over time. Financial Stability Board (FSB) defined it as:

"credit intermediation involving entities and activities outside the regular banking system". (Financial Stability Board, 2013).

International Monetary Fund (IMF) defined it as:

"*Financing of banks and nonbank financial institutions through noncore liabilities constitutes shadow banking, regardless of the entity that carries it out.* "(International Monetary Fund, 2014).

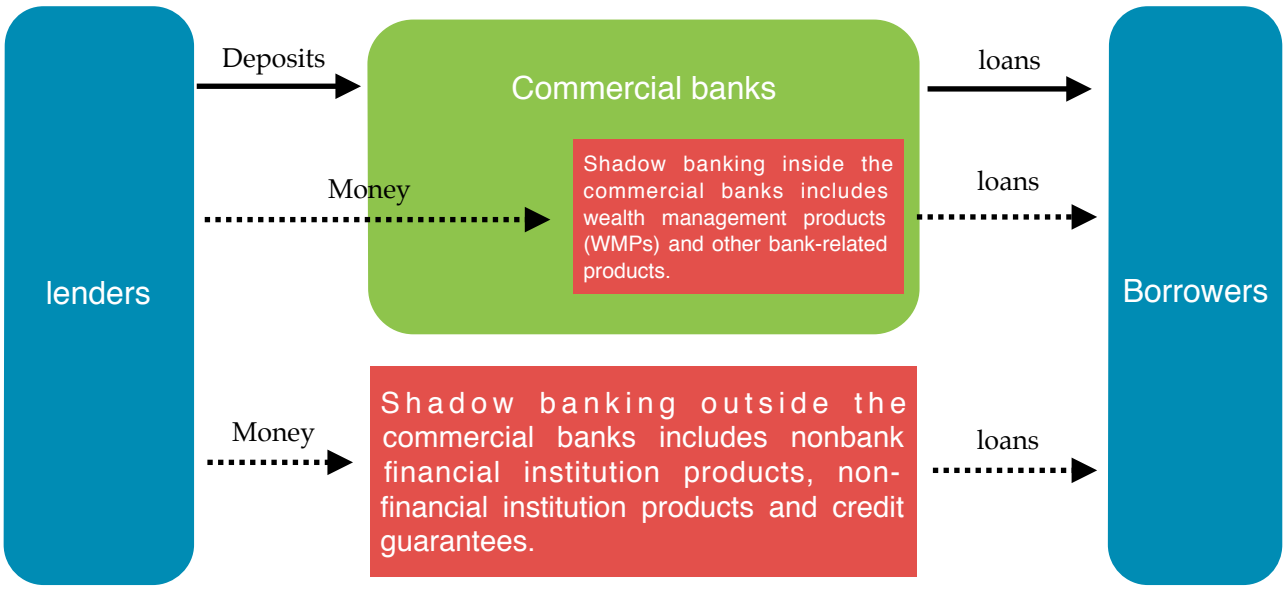
In the IMF definition, the concept "noncore liabilities" plays an important role. This concept was first introduced by Shin and Shin (2011). As we know, financial intermediations raise funds and lend them to their customers. When an economic boom emerges, credit is growing very rapidly. However, the poor traditional funding (core liabilities) is not sufficient to satisfy the increasing bank credit. In this case the funding from other sources (noncore liabilities) must be exploited to meet the increased credit. Thus, the core liabilities are supplemented by noncore liabilities. Usually the supervision of shadow banking is weak or even nonexistent.

Comparing to the definition of FSB, IMF captures nontraditional financial activities inside the traditional commercial banks, which fills a gap in the estimation of the size of shadow banking system. Considering the situation of China that a large number of shadow banking activities are inside the commercial banks, it is proper to use the definition of IMF as the definition interpreted in this thesis. Some other literatures also use a similar definition with IMF, for example, Lu, Guo, Kao and Fung (2014) underlined the composition of shadow banking system contains the parts both inside and outside the commercial banks.

Next is the types of shadow banking. According to the definition which I have adopted above and the prospective of Lu et al. (2014), I outline four types of shadow banking in China. The first one is "bank-related products". Among the bank-related products, one category draws out attention, wealth management products (WMPs), which is also called

licai in China.[3] Mao (2013) summarized details of WMPs on current situation and found that off-balance-sheet WMPs were much less regulated. Meanwhile, items on the off-balance-sheet are also my focus points when I want to calculate the amount of shadow banking inside the traditional commercial banks and analyze their influences on the efficiency of the traditional commercial banks. Other three types introduced in the article of Lu et al. (2014) are "nonbank financial institution products", "non-financial institution products" and "credit guarantees", respectively. According to the illustration of the definition and types of shadow banking, a simplified structure of shadow banking system can be seen in Figure 1.

Figure 1: Structure of shadow banking system.



Note: This is a simplified framework of the shadow banking system of China, showing the flow of money from lenders to borrowers. Elements in the red boxes show the shadow banking system. According to this framework, we can see the relationship among commercial banks, shadow banking inside the traditional commercial banks and wealth management products (WMPs): commercial banks contain the section of shadow banking inside the commercial banks and WMPs is one kind of bank-related products of shadow banking inside the commercial banks.

As I have talked above, shadow banking is treated as a integration of different kinds of risks. Here I introduce the main risks relating to shadow banking. In the report of International Monetary Fund (International Monetary Fund, 2014), the organization summarized some types of risks such as liquidity risk, maturity risk, credit risk, leverage,

[3] Firstly, Wealth Management Products (WMPs) can be treated as an innovation of financial activities inside the commercial banks. Furthermore, WMPs are created for satisfying the growing credit and the supervision of WMPs is usually poor, so this innovative financial activity - WMPs - belong to shadow banking system according to IMF definition. In practice, some innovative financial activities belong to shadow banking system and commercial banks are promoting shadow banking by marketing them as WMPs (or other shadow banking products). Secondly, as the state-owned characteristic of most Chinese commercial banks, WMPs are just as under the umbrellas of these banks. Thirdly, poor supervision usually can be treated as a loophole used by commercial banks.

interconnectedness and systematic risk. However, these risks were summarized according to the situations in euro area, Japan, and the United States.

For the circumstance of China, with the illustration of Lu et al. (2014), I describe the risk from three aspects. The first one is liquidity risk. Mostly it comes from maturity mismatch in the asset side and the liability side. From the aspect of liability side, shadow banking has mainly absorbed money from bank-related products such as WMPs, which, with a short-term trend. The reason of this short-term trend lies in the fierce business competition between commercial banks on products such as deposits, and also the quarterly assessment of loan-to-deposit ratio by regulator. From the aspect of asset side, more and more money acquired by shadow banks are finally linked to long-term projects which have no obligations to produce enough cash flow. Hence, this situation creates a maturity mismatch between the short-term bank-related products and the long-term projects. For the desirable return of the long-term products, shadow banks have to issue enough short-term financing products to relieve the pressure of liquidity risk generated by the maturity mismatch. However, what would happened in the case that the banks can not absorb enough short-term products? Usually relative large loss would emerge, for example, the banks may sell the long-term products even though they have not met the maturity.

The second one is solvency risk. Lu et al. (2014) illustrated this from two subjects. Firstly, China's local governments. There is always an intensive financing need for Chinese local governments under the condition of overmuch infrastructure projects investment and limitation of finance combing with prohibited deficit since 1994[4]. Hence, local-government financing vehicles (LGFVs) and shadow banking system become the best places for local government to address the large and urgent financing requirement. However, It is true that many of the developing projects undertaken by LGFVs are not making money (Sekiyama, 2013). When debts begin to mature, local governments are facing imminent bankruptcy and in the meantime, a solvency risk is raising up. Secondly, small and medium-size enterprises (SMEs) focusing on export. Combing with the difficulty of borrowing money from normal banks and the disappointing reality that China's net exports are decreasing since the global financial crisis of 2008, SMEs turn to shadow banking system. However, because of rising costs, harsh weak economic environment and more intensive global competition, the profits of exporting SMEs are reduced and ensued from a solvency risk.

[4] The budget law implemented in 1995 explicitly prohibit local governments to issue bonds or run a budget deficit while the new budget law implemented in January 1, 2015 removes these limitation which means the limitation of financing and prohibited deficit exist the stage of history formally. This change also treats as a regulatory measures for the shadow banking system.

The last one is moral hazard. Even though some experts give premonition of risk, a steady stream of funds still flow into investment products such as WMPs, and the deep reason of this situation is that people in China, because of the history and the political system of one-party system, usually have the belief that there would be a tacit guarantee when investments are related to a state-owned enterprises or a company containing national shares. Investors believe that even if there was a loss, the government and big banks together would cover the loss and control the risk into a acceptable range. However, moral hazard arises and the consequence is usually serious especially this 'safe' belief is widespread.

III. Variable definitions and data

3.1 Illustration of inputs and outputs

There are different opinions about the measurement of outputs and inputs in a special service industry, i.e., the banking industry. Especially for the outputs, on one hand, banks provide customers different kinds of facilitating and competitive services, and on the other hand, they also play as intermediaries with inherent function such as transforming funds from savers to borrowers (Colwell and Davis, 1992). Hence, it is quite difficult to distinguish the produces of banks and economists have a long-standing disagreement over this.

Generally speaking, I can find five approaches used in studies about identification of outputs of banks. According to the first approach, the "production approach", which treats business activities of financial institutions as a general production process of a manufacturing company. It emphasizes the role of producers for financial services which utilizes capital and labour to generate different kinds of deposit and loan accounts. (Freixas and Rochet, 1997). The second approach is the "intermediation approach". Comparing to the "production approach", it treats banks as intermediators of financial services between depositors and investors. For the measurement of outputs and inputs, the "intermediation approach" considers the loans and investments as the measurement of output. Correspondingly, labour and capital are treated as input measures.

The next three approaches are the "asset approach", the "user cost approach" and the "value-added approach" which are introduced in details by Berger and Humphrey (1992). The "asset approach" treats banks as financial intermediaries. However, comparing to the "intermediation approach", it just provides services between those who hold liability and those who accept funds. For those liability holders, they input their money as deposits and other liabilities into the intermediation (banks). In the meantime, for those who receive funds, loans and other assets are coming out from the intermediation (banks) as the outputs (see Sealey and Lindley, 1977). The "user cost approach" distinguishes the inputs and outputs from the view of the contribution to banks' net incomes. If the financial product can bring a positive (or negative) net income, which means that with the development of this financial product, the profits of banks will rise (or decline), and it makes this kind of financial product as an output (or input). The fifth approach is the "value-added approach". It considers the amount of the values of banks created by the factors as the criterion of judging its belonging, i.e., inputs of outputs.

Table 1 summarizes different measurements of inputs and outputs used in articles which talked about bank efficiency of China and frequently sited by Web of Science. Firstly, for the outputs, there are some controversies among different articles showing in Table 1 and here I choose total loans and total deposits. On one hand, as to the objection of this thesis is to detect shadow banking in the inefficiency factors and here I make other aspects as simple as possible by choosing the most frequently used variables, i.e., the total loans and the total deposits. On the other hand, these two variables are in keeping with the theory of the "production approach" introduced above. Secondly, for the inputs, I refer the methods of Hasan and Marton (2003) using an extensive scope to measure the price of inputs, i.e., the price of capital and the price of funds under the situation of the difficult of data acquisition (see Bonin, Hasan and Wachtel, 2005; Berger, Hasan and Zhou, 2009).

Table 1: Inputs and outputs measures on Chinese banks.

Authors	Inputs price	Outputs
Berger et al. (2009)	Unit interest cost of deposits	Loans
	Price of labor force inputs	Deposits
		Liquid assets
		Other earning assets
Bonin et al. (2005)	Interest expenses	loans
	Non-interest expenses	deposits
	Price of deposits	non-interest income
	Price of capital	
Berger, Hasan and Zhou (2010)	Price of funds	Loans
	Price of fixed capital	Deposits
	Price of labor	Liquid assets
		Other earning assets
Xiaoqing Maggie and Heffernan (2007)	Price of funds	Deposits
	Price of fixed assets	Loans
	Price of employees	Investments
		Non-interest income
Jiang, Yao and Zhang (2009)	Price of interest expense	Loans
	Price of labor force capital	Deposit
	Price of labour	Other earning assets

Matthews and Zhang (2010)	Price of bank deposits and borrowed funds	Loans
	Price of fixed assets	Other earning assets
	Price of operational costs	Non-interest income
Barros, Chen, Liang and Peypoch (2011)	Price of employees	Loans
	Price of deposits	Securities
	Price of total assets	
Sun et al. (2011)	Price of capital	Total loans
	Price of funds	Other earning assets
		Deposits
		Liquid assets
Jiang, Yao and Feng (2013)	Price of labour and physical capital(defined as non-interest expenses/ total assets)	Gross loans
	Price of funds(defined as total interest expenses/total interest bearing funds)	Other earning assets
		Deposits
Lee and Chih (2013)	Price of fixed assets	Total loans
	Price of funds	Investment

3.2 Data description

The sample is an unbalanced panel financial data of 166 Chinese commercial banks during the period of 1998~2012 and there are 873 observations in total. Most data come from Bankscope-Finch's International Bank Database while some come from annual Issues of China Statistical Yearbook,1999~2013. Descriptive statistics of the total costs, the outputs and price of inputs are in Table 2. All monetary values have been deflated using the Chinese GDP deflator with 1998 as the base year.

Table 2: Descriptive statistics of the outputs and the price of inputs.

Description		Mean	St.dev	Min	Max
	Total cost	4178.748	12223.53	1.188406	75599.47
Outputs	Total loans	83064.86	252969.8	23.25055	1718868
	Total deposits	133503.9	436342.6	27.66994	3093330
Price of	Price of funds	0.02371016	0.02807028	0.00015777	0.4427197

inputs	Price of capital	2.471937	3.937601	0.1269434	43.67774

Note:1,All variables in RMB million except for input prices;
2,All values have been deflated to 1998 price level.

3.3 Illustration of inefficiency factors

3.3.1 Choice of inefficiency factors

There are a lot of articles talking about the influence on banking efficiency from different aspects. Berger et al. (2009) studied the connection between bank proprietary and bank efficiency using the examples of Chinese banks. Pasiouras, Tanna and Zopounidis (2009) used SFA to analyzed the impact of the legislative, official supervision and regulation on bank efficiency. Sun et al. (2011) explored the influences of risk measures on banks' cost efficiency using banks in eight countries of Asia as examples. Table 3 summarizes main aspects of inefficiency measurement for banks that are used in some articles.

Table 3: Main aspects of bank inefficiency measurement.

Authors	Determinants of inefficiency
Berger and Mester (1997)	Variables showing the scale of bank;
	Variable showing the structure of institution or government;
	Some bank features;
	The feature of market;
	Geographic limitations on competition;
	Main federal supervisor;
	Behavior measurement.
Hasan et al. (2003)	Many accounting items, dummy variable reflecting bank proprietary, dummy variable reflecting the year and some other variables to reflect the features of banks.
Pasiouras et al. (2009)	Four variables showing the regulatory characteristic;
	Two variables showing the environment control of the macroeconomic;
	Two variables showing the environment control of the finance;
	Two variables showing the environment control of the market framework;
	One variable showing the countries with different situation in development.
	Indicators for supervisor framework;

Jiang et al. (2009)	Indicators for risks;
	Indicators for the conditions of macroeconomic;
	Dummy variable displaying years.

From Table 3 I can find that with different purposes, researchers focus on different aspects and describe them from different angles. On the basis of the financial and economic environment of China, and the directions given by Jiang et al. (2009), I represent the inefficiency factors from three aspects (see Table 4), i.e., shadow banking, macroeconomic environment and bank characteristics.

Table 4: Inefficiency factors of Chinese banks.

Aspects	Variables	Definition
Shadow banking	RSSB-CBS	Relative size of shadow banking inside the commercial banks.
	RSSB-Macro	Relative size of Chinese shadow banking.
Macroeconomic environment	WTOEntrance	China's WTO participation in 2001.
	FinancialCrisis	Global financial crisis in 2008.
	CBRCInitiate	Initiation of China Banking Regulatory Commission (CBRC).
Bank characteristics	TA	Logarithm of total assets.
	LA	Liquid assets to total assets.
	LTD	Loan-deposit ratio.

3.3.2 Description of the inefficiency factors in this study

Lu et al. (2014) summarized four major types of shadow banking products as I talked above. however, with the restriction of data, I merge them into two parts, i.e., shadow banking inside and outside Chinese commercial banks. For the inside part, Lu et al. (2014) concluded there existed many services and activities with the characteristic of shadow banking in traditional commercial banks. Furthermore, a large part of these services and activities belonged to off-balance-sheet items. Similar voice came from Calmès and Théoret (2010), which held the idea that a lot of off balance sheet activities were emerging in Canadian banking industry and generally, these activities with the identity of off-balance-sheet developed into a new important part in the traditional commercial banks, i.e., the shadow banking. Hence, I use items on off balance sheet given by Bankscope as the shadow banking activities inside the commercial banks and get our variable by:

Relative size of shadow banking inside the commercial banks (RSSB-CBS)=

$$\frac{\text{total amount of off balance sheet items (OFBS)}}{\text{total assets}} \quad (1)$$

Under the restriction of data acquisition, I use the relative size of shadow banking both inside and outside the commercial banks as the second variable, which can gives us a whole picture in macro aspect about the relation between the efficiency of banks and the whole volume of shadow banking of China. Here is the formula:

Relative size of Chinese shadow banking (RSSB-Macro)=

$$\frac{\text{the size of Chinese shadow banking}}{\text{gross domestic product (GDP)}} \quad (2)$$

For the calculation of the size of shadow banking inside the commercial banks, there are many ways for different situations with different angles. According to the data given in the Bankscope database I can get the amount of OFBS using six accounting items.

However, there are different measures on the whole volume of shadow banking. Different agents usually get different amount of shadow banking according to different definitions and scopes. Here I use a popular way among Chinese researches on the measurement of the shadow banking size, which is firstly introduced by Li (2010).

Li (2010) measured the scale of non-observed loans based on the relationship between economics and finance containing the knowledge of the System of National Accounts (SNA) and statistics applied on finance. The general idea is that in a given period of time, GDP achievement requires the support from a given amount of credit. Here according to the calculation by Li and Xu (2014) using the method of Li (2010), I obtain the data of relative size of shadow banking system directly from their paper as follows:

Table 5: Relative size of shadow banking system from 1998 to 2012.

Year	1998	1999	2000	2001	2002	2003	2004	2005
Relative size of shadow banking system	0.267502	0.265029	0.225249	0.206856	0.216115	0.222691	0.204899	0.175554
Year	2006	2007	2008	2009	2010	2011	2012	

Relative size of shadow banking system	0.175158	0.16223	0.156861	0.180305	0.182879	0.17397	0.164892

In consideration of the environmental variables, mainly following by Jiang et al. (2013), and here I use WTOEntrance, CBRCInitiate, and FinancialCrisis. In 2001, China joined in WTO and significant changes had brought for the whole economic environment including the traditional banking system. In 2003, with the initiate of China Banking Regulatory Commission (CBRC), the regulatory framework of banks in China had changed for the official identity of CRBC. FinancialCrisis means the global financial crisis in 2008 which played a significant role in the downturn of economic activity causing the global recession in the period of 2008 to 2012 and worsening the European debt crisis.

For the characteristics of banks, I mainly follow Berger et al. (1997) and Hasan et al. (2003) and choose three variables, i.e., logarithm of total assets, ratio between liquid assets and total assets, and ratio between loans and deposits. Logarithm of total assets reflects the size of banks. The liquids to total assets ratio is an important tool reflecting the liquidity of banks and also an important factor in liquidity management. A similar statistic for reflecting a bank's liquidity is the ratio of loans to deposits, and if the ratio is too low, there would not be a an optimal return for banks while if the ratio is too high, it means there might not be enough liquidity for banks.

IV. Methodology

4.1 Model introduction

This stochastic frontier model is widely used in the research of bank efficiency. Berger et al. (2009) used it to explore the relationship between proprietary and bank efficiency. Based on this model, Jiang et al. (2013) studied the static effects of ownership and the dynamic effects of privatization on bank performance in China. Gaganis and Pasiouras (2013) analyzed the connection between the framework of the government and the role authorities plays for bank efficiency by using a stochastic frontier model. Following Battese and Coelli (1995), a single-step stochastic frontier model can be expressed as follows:

$$Y_{it} = \exp(x_{it}\beta + U_{it} + V_{it}), \tag{3}$$

$$V_{it} \sim N(0, \sigma_v^2), \tag{4}$$

$$U_{it} = z_{it}\delta + W_{it}. \tag{5}$$

Where:
Y_{it} denotes the cost at t-th year (t=1998,1999,…,2012) for the i-th bank (i=1,2,…,166); x_{it} represents a vector of the values of output quantities and inputs price at t-th year (t=1998,1999,…,2012) for the i-th bank (i=1,2,…,166); β denotes a vector of unknown parameters; V_{it}s denote random errors which are independent and identically distributed following a normal distribution; U_{it}s denote the inefficiency effects which are not less than zero and independently distributed with V_{it}s. U_{it}s are obtained by truncation (at zero) of normal distribution. The mean of U_{it}s is $z_{it}\delta$ and the variance is σ_u^2; W_{it} denotes the random variable in equation (5) which is defined by the truncation of the normal distribution. The mean of W_{it} is zero and the variance is σ_u^2; z_{it} is a vector of variables that influences the inefficiency of bank i at year t; δ is a vector of unknown coefficients.

The parameters of equation (4) to (6) are estimated in one step by the method of maximum likelihood (see Battese et al., 1995). The variance of the composed error term and the measure of relative inefficiency variation can be obtained by the following expressions:

$$\sigma^2 \equiv \sigma_v^2 + \sigma_u^2, \tag{6}$$

$$\gamma \equiv \frac{\sigma_u^2}{\sigma^2}. \tag{7}$$

4.2 Empirical model specification

For banking industry, cost-efficiency is a measurement of the extent of a bank's efficiency on cost. It is carrying out by a contrast between a certain bank and a "best performance bank" with same outputs and same external environment (Berger et al., 2009). The normalization is implemented to reduce heteroskedasticity using bank's total assets and it also plays the role of controlling the scale biases. For the restriction of linear homogeneity in input prices, I would like to use the price of fund to remove. Hence, I estimate the stochastic frontier cost function using the commonly-used translog functional form as follows:

$$\begin{aligned}\ln\left(\frac{TC}{n\cdot p_2}\right)_{it} &= \alpha_0+\sum_{j=1}^{2}\alpha_j\ln\left(\frac{y_j}{n}\right)_{it}+\frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2}\alpha_{jk}\ln\left(\frac{y_j}{n}\right)_{it}\ln\left(\frac{y_k}{n}\right)_{it}\\ &+\beta_1\ln\left(\frac{p_1}{p_2}\right)_{it}+\frac{1}{2}\beta_{11}\ln\left(\frac{p_1}{p_2}\right)_{it}\ln\left(\frac{p_1}{p_2}\right)_{it}\\ &+\sum_{j=1}^{2}\theta_j\ln\left(\frac{y_j}{n}\right)_{it}\ln\left(\frac{p_1}{p_2}\right)_{it}\\ &+\eta_0 Year+\frac{1}{2}\eta_{11}Year^2+\sum_{j=1}^{2}\eta_j\ln\left(\frac{y_j}{n}\right)_{it}Year+\eta_3\ln\left(\frac{p_1}{p_2}\right)_{it}Year+U_{it}+V_{it}\end{aligned} \tag{8}$$

Where the inefficiency effects is specified as:

$$\begin{aligned}U_{it} &= \omega_0+\omega_1\mathrm{RSSB\_CBS}_{it}+\omega_2\mathrm{RSSB\_Macro}_t+\omega_3 WTOEntrance_t+\omega_4 CBRCInitiate_t+\omega_5 FinancialCrisis_t\\ &+\omega_6 TA_{it}+\omega_7 LA_{it}+\omega_8 LTD_{it}+W_{it}\end{aligned} \tag{9}$$

Where:

ln denotes the nature logarithm; TC represents total cost and includes interest expenses and non-interest expenses (see Sun et al., 2011); y_1 represents loans; y_2 represents deposits; p_1 (price of funds) is defined as the ratio between interest expenses and total deposits; p_2 represents price of capital and it is defined as the ratio between non-interest expenses and total fixed assets; n represents total assets; Year indicates the year of the observation involved; RSSB-CBS represents relative size of shadow banking inside the commercial banks (see Eqs.(1)); RSSB-Macro represents relative size of Chinese shadow banking system (see Eqs.(2)); WTOEntrance is a dummy variable which uses 1 to represent the year from 2002 to 2012 and 0 to represent the year from 1998 to 2001; CBRCInitiate is a dummy variable which uses 1 to represent the year from 2003 to 2012 and 0 to represent the year from 1998 to 2002; FinancialCrisis is also a dummy variable which uses 1 to represent the year from 2008 to 2012 and 0 to represent the year from 1998 to 2007; TA is logarithm of total assets; LA is ratio of liquid assets to total assets; LTD is ratio of loans to deposits. U_{it}, V_{it} and W_{it} are as defined in the previous section.

4.3 Monotonicity

According to Segal (2003), a cost function must satisfy the condition of monotonicity corresponding to economic theory. For outputs and price of inputs, monotonicity implies positive marginal costs and total costs increase as input price increases, respectively.

Given function (8) and (9), I set:

$$TC^* = \frac{TC}{n \cdot p_2}, \tag{10}$$

$$y_1^* = \frac{y_1}{n}, y_2^* = \frac{y_2}{n}, \tag{11}$$

$$p_1^* = \frac{p_1}{p_2}. \tag{12}$$

Then monotonicity requires that all marginal costs are positive:

$$\frac{\partial TC^*}{\partial y_1^*} = \left[\alpha_1 + \alpha_{11} \ln\left(y_1^*\right) + \alpha_{12} \ln\left(y_2^*\right) + \theta_1 \ln\left(p_1^*\right) + \eta_1 Year + \omega_8 \left(\frac{y_1}{y_2} \right) \right] \frac{TC^*}{y_1^*} > 0, \tag{13}$$

$$\frac{\partial TC^*}{\partial y_2^*} = \left[\alpha_2 + \alpha_{22} \ln\left(y_2^*\right) + \alpha_{12} \ln\left(y_1^*\right) + \theta_2 \ln\left(p_1^*\right) + \eta_2 Year + \omega_8 \left(-\frac{y_1}{y_2} \right) \right] \frac{TC^*}{y_2^*} > 0, \tag{14}$$

$$\frac{\partial TC^*}{\partial p_1^*} = \left[\beta_1 + \beta_{11} \ln\left(p_1^*\right) + \theta_1 \ln\left(y_1^*\right) + \theta_2 \ln\left(y_2^*\right) + \eta_3 Year \right] \frac{TC^*}{p_1^*} > 0. \tag{15}$$

Function (13), (14) are monotonicity in outputs and function (15) is monotonicity in the price of input.

4.4 Efficiency scores

According to the elaboration of Olsen and Henningsen (2011), I calculate the score of cost-efficiency by the formula:

$$TE_{it} = E\left[e^{-U_{it}} \mid \tau_{it} \right] \tag{16}$$

Where:

$$\tau_{it} = U_{it} + V_{it}. \tag{17}$$

TE_{it} estimated the score of cost-efficiency of bank i at year t; τ_{it} is the total residual.

V. Empirical results

5.1 Results of estimation

5.1.1 Brief introduction

Given the model showing in equation (8) and (9), I estimate the parameters of these two equations using maximum likelihood in one step. The estimation is performed by the "frontier" (Coelli and Henningsen, 2011) using R. Table 6 shows the estimation of parameters for this model. According to equation (9), the inefficiency term U_{it} and the variables inside it (usually people call this z-variables) have a positive relationship when the estimated parameter is positive, which also means that the bank is less efficient when values of estimation for parameters of z-variables are higher and vice versa.

σ^2 and γ are significant and γ is close to 1 but not so close to the boundary, which means the inefficiency item U_{it} has a significant effect on banks' cost-efficiency. From Table 6 I can see that in general the estimation of the stochastic frontier model is quite good and most variables have a significant effect on the model.

Table 6: Estimation result of model.

Variable	Par.	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	α_0	-0.51812910	0.12624592	-4.1041	4.058e-05 ***
ln(y1/n)	α_1	-0.37112606	0.14352813	-2.5857	0.0097171 **
ln(y2/n)	α_2	1.71972508	0.33656910	5.1096	3.229e-07 ***
ln(p1/p2)	β_1	0.78636596	0.03936657	19.9755	< 2.2e-16 ***
ln(y1/n)^2	α_{11}	-0.42413170	0.11478020	-3.6952	0.0002197 ***
ln(y2/n)^2	α_{22}	0.42922377	0.20291084	2.1153	0.0344017 *
ln(p1/p2)^2	β_{11}	-0.00639911	0.00842667	-0.7594	0.4476205
ln(y1/n)ln(y2/n)	α_{12}	0.73614386	0.17243347	4.2691	1.962e-05 ***
ln(y1/n) ln(p1/p2)	θ_1	-0.00705085	0.02492183	-0.2829	0.7772392
ln(y2/n) ln(p1/p2)	θ_2	-0.00705780	0.04353446	-0.1621	0.8712115
Year	η_0	0.05007224	0.01344985	3.7229	0.0001970 ***
Year^2	η_{11}	-0.00363128	0.00090658	-4.0055	6.189e-05 ***
ln(y1/n)Year	η_1	0.01117596	0.01021157	1.0944	0.2737617
ln(y2/n)Year	η_2	-0.02030937	0.01275424	-1.5924	0.1113034

ln(p1/n)Year	η_3	0.00579885	0.00247543	2.3426	0.0191515 *
Inefficiency equation:					
Intercept	ω_0	-4.96616108	3.43132996	-1.4473	0.1478131
RSSB-CBS	ω_1	-1.78563596	0.84177970	-2.1213	0.0338997 *
RSSB-Macro	ω_2	45.12847548	18.42131611	2.4498	0.0142937 *
WTOEntrance	ω_3	4.76615171	2.00339144	2.3790	0.0173577 *
CBRCInitiate	ω_4	-2.48540995	1.01767103	-2.4423	0.0145959 *
FinancialCrisis	ω_5	1.19019807	0.55235467	2.1548	0.0311797 *
TA	ω_6	-0.90182007	0.31558451	-2.8576	0.0042683 **
LA	ω_7	0.87908369	0.46823507	1.8774	0.0604577 .
LTD	ω_8	0.47179289	0.20782482	2.2701	0.0231987 *
sigmaSq		0.51441996	0.21871021	2.3521	0.0186697 *
gamma		0.97363624	0.01197020	81.3383	< 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
log likelihood value: 302.0671

5.1.2 Likelihood ratio test and monotonicity check

Table 7 displays the results of likelihood ratio test[5] with two null hypotheses. The first null hypothesis that all banks are efficient is strongly rejected according to the p-value. The second null hypothesis is that the eight inefficiency factors have no effects on the inefficiency of banks and from the p-value I can also strongly reject this null hypothesis.

Table 7: Likelihood ratio tests of hypotheses for parameters.

Null hypothesis	Test statistics	p-value
H_0: $\gamma = \omega_0 = \omega_1 = \cdots = \omega_8 = 0$	282.43	< 2.2e-16 ***
H_0: $\omega_1 = \cdots = \omega_8 = 0$	160.48	< 2.2e-16 ***

Note: 1. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1;
2. Details can be seen in Table 1A and Table 2A in appendix A.

Next I check the violation against the monotonicity assumption. Monotonicity is a conceptually important condition in Stochastic Frontier Analysis (SFA) using a translog function. However, given the problems of measuring concepts are input prices, output

[5] The likelihood ratio test statistics is: -2(log(likelihood(H_0))-log(likelihood(H_1))).

quantities and costs, some violations of economic theory is usually acceptable, while only in some suitable degrees. In practice, if I want to get a logical result, the characteristic of monotonicity is important when I estimate the efficiencies of individual banks. Here according to the functions of (10) to (15), I calculate the numbers and percentage of observations violating the monotonicity assumption as follows:

Table 8: Monotonicity for outputs and price of input in the model.

Variable	Number of observations violating the monotonicity assumption	Percentage of observations violating the monotonicity assumption
Loans	6	0.6872852%
deposits	24	2.749141%
Price of funds	0	0%

The variable of loans and deposits has some observations violating the monotonicity assumption, however, according to Kellermann (2014) and Olsen et al. (2011), which all have some observations violating the monotonicity assumption with the maximize percentage of 15.9% and 44.5%, respectively. Hence, I consider the violation goes into a acceptable range and expect no substantial consistency problems regarding monotonicity.

5.1.3 Explanation of outputs, price of input and variables on efficiency

As noted before, almost all the elasticities of outputs and the price of input, according to the results of monotonicity calculation, are positive. This means if the banks want more outputs or have a high input price, then the more costs are needed which agrees to the fact and logic. Hence, these results indicate the higher the price, with the more produced outputs, the higher the total costs are (same conclusion also see Sun et al., 2011).

RSSB-CBS enters a negative coefficient which means there exists a negative relationship between RSSB-CBS and bank inefficiency, and in other words, the higher RSSB-CBS, the higher bank cost-efficiency is. There are two aspects for the potential explanations. First, essentially, the generation of Chinese shadow banking is a spontaneous financial innovation behavior of Chinese commercial banks under the inhibiting financial environment. It expands the boundaries of traditional financial services and to some extent, shadow banking eases the negative impact of financial repression, and also increases the resource allocation efficiency and conversion capacity between savings and investment in the financial system (Zhang, 2013). Second, under the circumstance that the Chinese government frequently changes their macro control policies and people can not

accurately anticipate these uncertain changes which may bring disadvantages, Chinese shadow banking provides necessary liquidity buffers for all kinds of companies, which, under certain extent, alleviates the negative impact of macroeconomic regulation at the level of enterprise.

RSSB-Macro carries a positive signs indicating greater RSSB-Macro leads to lower cost-efficiency. As I merge the Chinese shadow banking system into two parts, i.e., the shadow banking inside and outside commercial banks, combining the conclusions of RSSB-CBS, which gives us potential evidences that the shadow banking outsides the commercial banks has a negative association with the cost-efficiency of commercial banks. There are two aspects for the potential explanations. First, financial disintermediation. Rapid development of Chinese shadow banking leads to the acceleration of financial disintermediation. A major feature of shadow banking is able to create credit business which is mostly done by traditional commercial banks. Usually, shadow banking raises funds through various channels in different names or methods such as the WMPs. However, these activities are similar with the nature of depositing and loaning. And as higher rate of deposits and lower threshold of loans for shadow banks comparing to traditional commercial banks, generally shadow banking has an alternative characteristic. Furthermore, with broadening direct financial channels and increase of the size, shadow banking replaces the existing loans of commercial banks. On the other hand, shadow banking squeezes the bargaining space of the incremental loans. Eventually, these intense asymmetric competitions decrease the cost-efficiency of traditional commercial banks. Second, risk. As I have talked before, shadow banks bring many potential risks including liquidity risk, solvency risk and moral hazard. The risks caused by a lager amount of shadow banking outside commercial banks will finally effect the cost-efficiency of commercial banks.

Turning to WTOEntrance and CBRCInitiate I observe that China's WTO entry has a significantly negative impact on cost-efficiency and the initiate of CBRC has a positive relationship with cost-efficiency. The same conclusion can be seen in Jiang et al. (2013). Potential explanations can be described into two aspects. First, after the entrance of WTO, there was a five-year interim period for most Chinese commercial banks to prepare and adapt the coming competition from foreign banks. When these five years were passed, foreign banks would have the same national treatment. During this periods, many Chinese commercial banks invested a lot of projects and advanced a series of comprehensive reforms. However, these activities temporarily lowed the efficiency to a

certain extent (Deng, 2013). Second, with the launch of CBRC in 2003, the regulatory framework of banks in China had changed because of the official identity of CRBC. Under the new and more sound supervisory environment, the cost-efficiency of Chinese commercial banks was generally improving (Jiang et al., 2013). Next element is financial crisis of 2008 with a negative relationship with cost-efficiency of banks. Before the crisis, there were a lot of problems about China's economics and domestic affairs, for example, the unusual high inflation, the increased risks of bankruptcies, the unstable social stability and the bubbles in real estate. In 2008, when the serious world spreading financial crisis arrived China, the harmful influence was amplified owing to the domestics problems and the inappropriate policy (see Overholt, 2010).

Last part is three variables about characteristics of banks. First one is TA, which is a representation of bank size and from Table 6 I can get that TA has a positive relationship with cost-efficiency of banks. According to Hasan et al. (2003), with more total assets, banks would cooperate with special-purpose institutions and develop different banking and financing productions to invest and help new business. Along with the innovative productions and the expanded scale and scope of banking activities, the overall efficiency will relatively increase. Same conclusion also can be seen from DeYoung and Nolle (1996). Second is LA, which equals to liquid assets/total assets and from Table 6 I can get that LA has a negative relationship with cost-efficiency. On the basis of the explanation summarized by Altunbas, Liu, Molyneux and Seth (2000), when banks hold a large number of liquid assets and not conduct investment and other financial activities, the relative costs will increase and the cost-efficiency will relative decrease, comparing to the "best performance bank". Last one is LTD, which is an indication of liquidity risk and according our estimation I can get that the more LTD is, the more liquidity risk is, the less cost-efficiency is. As I referring to above, LTD=loans/deposits, and when I increase LTD I would increase loans or (and) decrease deposits. In this increasing condition of LTD, banks need more deposits to support its relative high loans while the actual situation contradicts banks' requirement. Then the liquidity risk is raising up and the cost-efficiency is going down (see Jiang et al., 2009).

5.2 Cost-efficiency scores

Table 9 presents the estimates of cost-efficiency score by year showing mean and standard deviation.

Table 9: Cost-efficiency scores averaged by year.

Year	Obsrvation	Mean	St.Dev
1998	11	0.8456783	0.166918541
1999	13	0.853160969	0.113619182
2000	16	0.888286094	0.077811739
2001	15	0.860101753	0.074967729
2002	21	0.812633167	0.142543113
2003	27	0.847610489	0.152330622
2004	31	0.865185639	0.106626986
2005	45	0.901841147	0.066603944
2006	65	0.894559597	0.09672724
2007	85	0.910451721	0.084347463
2008	81	0.910681384	0.092961482
2009	92	0.847871522	0.122424602
2010	111	0.830494663	0.123188478
2011	127	0.871877637	0.122152348
2012	133	0.889250247	0.108732209

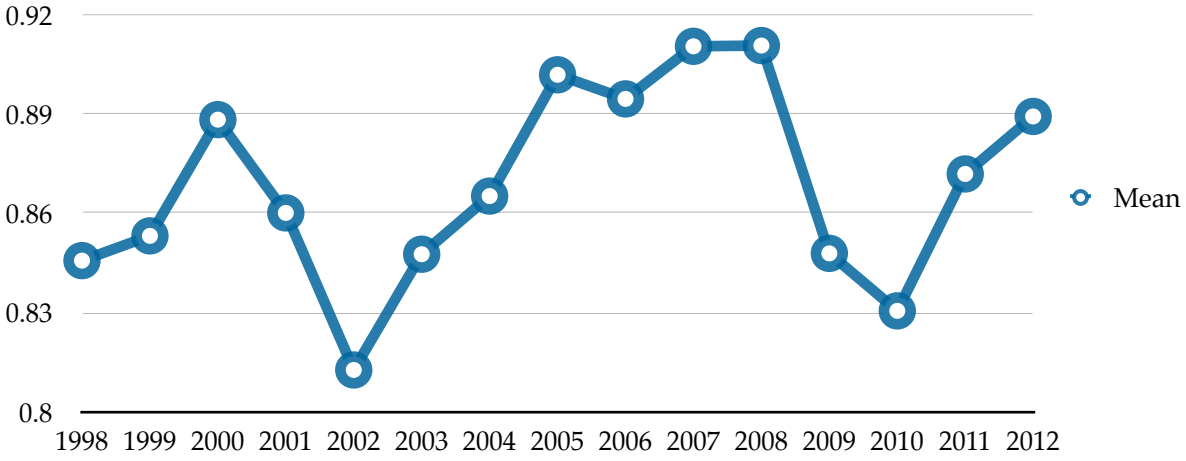
Firstly, the full sample overall cost-efficiency score is 0.8743984 which implies the average banks could reduce its costs by 12.56016% comparing to the "best performance bank". The highest and lowest scores by year emerge in 2008 and 2002 with the value 0.910681384 and 0.812633167, respectively. And the standard deviation, which is a measure of volatility with high values indicating lower stability of efficiency, has the highest and lowest figures by year appearing in 1998 and 2005 with the value 0.166918541 and 0.066603944, respectively.

Secondly, I find the average score of cost-efficiency decreases[6] in several years which are 2001, 2002, 2009 and 2010. For the situation in 2001 and 2002, a potential explanation is that China's WTO entrance in 2001 has a significantly negative impact on cost-efficiency and a "V"-type efficiency dynamic pattern[7] (see Figure 1) arises, which is consistent with the bank reforms aroused by the entrance of WTO and the same pattern showing around 2009 and 2010 can be explained by the impact of financial crisis in 2008.

[6] I ignore the decrease from 2005 to 2006 as the slight decrease from 0.901841147 to 0.894559597.

[7] Details can be seen in Deng (2013) page 192.

Figure 2: Cost-efficiency for Chinese commercial banks over the 1998~2012 period.



VI. Robustness check

In this section, I will check robustness of the model from two points of view. The first one is normalization. It is implemented to reduce heteroskedasticity using bank's total assets (n) and control for scale biases in the original model (function 8 and 9). Here I use bank's total earning assets to replace bank's total assets to test the robustness. The second one is about the inefficiency factors. As discussed above, I analyze the inefficiency from three aspects, i.e., shadow banking, macroeconomic environment and bank characteristics. And because the topic of this thesis is about the effects of shadow banking, here I use three models to check the robustness from three angles, i.e., the effects of shadow banking on banks' efficiency, the effects of shadow banking and macroeconomic environment on banks' efficiency and the effects of shadow banking and bank characteristics on banks' efficiency, respectively.

6.1 Robustness check on normalization

From Table 10 I can see that RSSB-CBS and RSSB-Macro enter a negative and positive coefficient, respectively. This results mean there exist a positive relationship between RSSB-CBS and bank efficiency and a negative relationship between RSSB-Macro and bank efficiency which are consistent with the original model. However, RSSB-CBS is insignificant and here I can just see the estimation of RSSB-Macro is robust when I use bank's total earning assets to reduce heteroskedasticity and control for scale biases.

Table 10: Estimation results for robustness check on normalization.

Variable	Par.	Estimate	Std. Error	z value	Pr(>|z|)
RSSB-CBS	ω_1	-0.96395238	0.94619869	-1.0188	0.3083154
RSSB-Macro	ω_2	47.18758887	16.91121928	2.7903	0.0052657 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

6.2 Robustness check on inefficiency factors

I use three models to check the robustness from three angles on inefficiency factors. Here I keep the equation (8) remains unchanged and only change the inefficiency factors in equation (9). Details can be seen in Table 11:

Table 11: Models for robustness check.

Models	Aspects of variables	Variables
RobustnessCheckModel_1	shadow banking	RSSB-CBS, RSSB-Macro
RobustnessCheckModel_2	shadow banking and macroeconomic environment	RSSB-CBS, RSSB-Macro, WTOEntrance, FinancialCrisis, CBRCInitiate
RobustnessCheckModel_3	shadow banking and bank characteristics	RSSB-CBS, RSSB-Macro, TA, LA, LTD

According to the results of estimation in Table 12 I can find that RobustnessCheckModel_1 to 3 under corresponding conditions have a negative coefficient with RSSB-CBS and a positive coefficient with RSSB-Macro which are consistent with the results of the original model. However, all the variables are insignificant no matter under which conditions. Hence, I do the likelihood ratio test in the following part to test the joint effects of shadow banking factors on bank efficiency in different models.

Table 12: Estimation results for robustness check on inefficiency factors.

Models	Variable	Par.	Estimate	Std. Error	z value	Pr(>|z|)
RobustnessCheckModel_1	**RSSB-CBS**	ω_1	-1.0617E+03	1.2255E+03	-0.8664	0.3862827
	RSSB-Macro	ω_2	2.7218E+03	3.1473E+03	0.8648	0.3871362
RobustnessCheckModel_2	**RSSB-CBS**	ω_1	-1.0344E+03	1.0741E+03	-0.9630	0.3355413
	RSSB-Macro	ω_2	7.7181E+03	8.0168E+03	0.9627	0.3356766
RobustnessCheckModel_3	**RSSB-CBS**	ω_1	-4.02951069	2.13867742	-1.8841	0.0595496 .
	RSSB-Macro	ω_2	20.92254062	13.26440615	1.5773	0.1147162

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

From Table 13[8] I can find that the null hypothesis, that there are no joint effects of shadow banking factors on bank efficiency, is strongly rejected. Hence, the result is robust under the condition that the inefficiency factors contain the aspect of shadow banking, the aspects of shadow banking and macroeconomic environment, the aspects of shadow banking and bank characteristics, respectively.

Table 13: Likelihood ratio test for robustness check on inefficiency factors.

Model and condition of inefficiency	Null hypothesis	Test statistics	p-value
RobustnessCheckModel_1	H_0: $\omega_1=\omega_2=0$	30.899	1.951e-07 ***
RobustnessCheckModel_2	H_0: $\omega_1=\omega_2=0$	41.953	7.762e-10 ***

[8] The details of likelihood ratio test can be found in Table 3A, Table 4A, Table 5A.

RobustnessCheckModel_3	H_0: $\omega_1=\omega_2=0$	9.0912	0.01061 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

In summary, the relationship between shadow banking and commercial banks' (in)efficiency is robust when I change the measurement aspects of (in)efficiency from three points of view. The robustness check on normalization shows the relationship between relative size of shadow banking system and commercial banks' (in)efficiency is robust while the relationship between relative size of shadow banking inside the commercial banks maybe not. Hence, generally I can conclude that the results of original model on the relationship between shadow banking and (in)efficiency of Chinese commercial banks are robust.

VII.Conclusion

This study explores the effects of shadow banking on bank cost-efficiency using data of Chinese commercial banks during the period 1998–2012. The empirical results all point towards positive effects on cost-efficiency due to shadow banking. The larger relative size of shadow banking inside of the bank, the better efficiency is, while the higher the relative amount of shadow banking is outside the bank the lower cost-efficiency is.

This shows that there are gains from shadow banking for the Chinese financial system. It is important for policymakers to realize this but at the same time understand that shadow banking likely implies a trade-off between flexibility for the banking sector and higher risks.

There is especially one policy implication given by the results of this thesis. As shadow banking inside the commercial banks can promote bank's efficiency, policymakers and banks should stimulate financial innovation for improving the size of shadow banking. Simultaneously, the policymakers have to be aware about the increased risks this can cause. Proper policies should be made to supervise actions of shadow banking and control these actions into a reasonable and legitimate scope.

There are many extensions for future research based on the research presented in this thesis. For example the trade-off between more shadow banking and higher risk. In our analysis I saw that the financial crisis had a negative effect on the cost-efficiency of banks. However, how, and if, this is linked to shadow banking was not treated in the thesis. For sure higher risk plays an important role in times of financial turmoil. It is essential to find a balance among size of shadow banking and the risks that may accumulate over time. It would for example be interesting to compare financial systems in different countries to compare risks, regulations and the effects both on efficiency and how the systems cope during times of crisis.

References

Altunbas, Y., Liu, M. H., Molyneux, P., & Seth, R. (2000). Efficiency and risk in Japanese banking. Journal of Banking & Finance, 24(10), 1605-1628.

Barros, C. P., Chen, Z., Liang, Q. B., & Peypoch, N. (2011). Technical efficiency in the Chinese banking sector. Economic Modelling, 28(5), 2083-2089.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical economics, 20(2), 325-332.

Berger, A. N., & Humphrey, D. B. (1992). Measurement and efficiency issues in commercial banking. In Output measurement in the service sectors (pp. 245-300). University of Chicago Press.

Berger, A. N., Hasan, I., & Zhou, M. (2009). Bank ownership and efficiency in China: What will happen in the world's largest nation?. Journal of Banking & Finance, 33(1), 113-130.

Berger, A. N., Hasan, I., & Zhou, M. (2010). The effects of focus versus diversification on bank performance: Evidence from Chinese banks. Journal of Banking & Finance, 34(7), 1417-1435.

Berger, A. N., & Mester, L. J. (1997). Inside the black box: What explains differences in the efficiencies of financial institutions?. *Journal of Banking & Finance*, *21*(7), 895-947.

Bonin, J. P., Hasan, I., & Wachtel, P. (2005). Bank performance, efficiency and ownership in transition countries. Journal of Banking & Finance, 29(1), 31-53.

Calmès, C. and Théoret, R. (2010). The impact of off-balance-sheet activities on banks returns: An application of the ARCH-M to Canadian data. Journal of Banking & Finance, 34(7), pp.1719-1728.

Coelli, T., & Henningsen, A. (2011). frontier: Stochastic Frontier Analysis. R package version 0.997-2.

Colwell, R. and Davis, E. (1992). Output and Productivity in Banking. The Scandinavian Journal of Economics, 94, p.S111.

DeYoung, R., & Nolle, D. E. (1996). Foreign-owned banks in the United States: Earning market share or buying it?. Journal of Money, Credit and Banking, 622-636.

Deng, Z. (2013). Foreign Direct Investment in China: Spillover Effects on Domestic Enterprises (Vol. 94). Routledge.

Financial Stability Board. (2013). "Strengthening Oversight and Regulation of Shadow Banking, Policy Framework for Strengthening Oversight and Regulation of Shadow Banking Entities." Consultative Document, Financial Stability Board, Basel.<http://www.financialstabilityboard.org/wp-content/uploads/r_130829c.pdf >

Freixas, X., & Rochet, J. C. (1997). Microeconomics of banking (Vol. 2). Cambridge, MA: MIT press.

Gaganis, C., & Pasiouras, F. (2013). Financial supervision regimes and bank efficiency: International evidence. Journal of Banking & Finance, 37(12), 5463-5475.

Hasan, I., & Marton, K. (2003). Development and efficiency of the banking sector in a transitional economy: Hungarian experience. Journal of Banking & Finance, 27(12), 2249-2271.

International Monetary Fund. (2014). Global Financial Stability Report: Risk Taking, Liquidity, and Shadow Banking. <http://asianbondsonline.adb.org/publications/external/2014/global_financial_stability_report_imf_oct_2014.pdf>, October, 2014.

Jiang, C., Yao, S., & Feng, G. (2013). Bank ownership, privatization, and performance: Evidence from a transition country. Journal of Banking & Finance, 37(9), 3364-3372.

Jiang, C., Yao, S., & Zhang, Z. (2009). The effects of governance changes on bank efficiency in China: A stochastic distance function approach. China Economic Review, 20(4), 717-731.
Kellermann, M. (2014). Dairy farming on permanent grassland: Can it keep up?. Journal of dairy science, 97(10), 6196-6210.doi:10.3168/jds.2013-7825.

Lee, T. H., & Chih, S. H. (2013). Does financial regulation affect the profit efficiency and risk of banks? Evidence from China's commercial banks. The North American Journal of Economics and Finance, 26, 705-724.

Li C.,& Xu, K.(2014). The size of the shadow banking system and stability of banking system.Business Studies, (3), 40-46.

Li,J.(2010).Change in the scale of non-observed loan:1978~2008. Financial Research,(4), 40-49.

Li, J., Hsu, S., & Qin, Y. (2014). Shadow banking in China: Institutional risks. China Economic Review, 31, 119-129.

Lu, Y., Guo, H., Kao, E. H., & Fung, H. G. (2014). Shadow banking and firm financing in China. International Review of Economics & Finance, 36, pp.40-53.

Mao, Q., (2013), Measuring the off-balance-sheet wealth management business of commercial banks - The case in China, p. 68-75 in Settlements, Bank for International eds., Proceedings of the Sixth IFC Conference on , vol. 36, Bank for International Settlements, http://EconPapers.repec.org/RePEc:bis:bisifc:36-04.

Matthews, K., & Zhang, N. X. (2010). Bank productivity in China 1997–2007: measurement and convergence. China Economic Review, 21(4), 617-628.

Olsen, J. V., & Henningsen, A. (2011). Investment utilisation, adjustment costs, and technical efficiency in Danish pig farms (No. 2011/13). University of Copenhagen, Department of Food and Resource Economics.

Overholt, W. H. (2010). China in the global financial crisis: rising influence, rising challenges. The Washington Quarterly, 33(1), 21-34.

Pasiouras, F., Tanna, S. and Zopounidis, C. (2009). The impact of banking regulations on banks' cost and profit efficiency: Cross-country evidence. International Review of Financial Analysis, 18(5), pp.294-302.

Sealey, C. W., & Lindley, J. T. (1977). Inputs, outputs, and a theory of production and cost at depository financial institutions. The Journal of Finance, 32(4), 1251-1266.

Segal, D. (2003). A multi-product cost study of the US life insurance industry. Review of Quantitative Finance and Accounting, 20(2), 169-186.

Shin, H. S., & Shin, K. (2011). *Procyclicality and monetary aggregates* (No. w16836). National Bureau of Economic Research, Cambridge, Massachusetts.

Sekiyama, Takashi (2013). The myth of China's financial time bomb. The Tokyo Foundation.<http://www.tokyofoundation.org/en/articles/2013/myth-of-china-financial-time-bomb> , October 01, 2013.

Sun, L., & Chang, T. P. (2011). A comprehensive analysis of the effects of risk measures on bank efficiency: Evidence from emerging Asian countries. Journal of Banking & Finance, 35(7), 1727-1735.

Xiaoqing Maggie, F. U., & Heffernan, S. (2007). Cost X-efficiency in China's banking sector. China Economic Review, 18(1), 35-53.

Zhang M.(2013). Chinese-style shadow banking:Definition, causes of risk and countermeasures. International Economic Review,(3),82-92.

Appendix A

Table A1: Result of LR test for the first null hypothesis.

Model 1: OLS (no inefficiency)
Model 2: Efficiency Effects Frontier (EEF)

Df	LogLik	Df	Chisq	Pr(>Chisq)
16	160.85			
26	302.07	10	282.43	< 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table A2: Result of LR test for the second null hypothesis.

Model 1: model_1_0
Model 2: model_1

Df	LogLik	Df	Chisq	Pr(>Chisq)
18	221.83			
26	302.07	8	160.48	< 2.2e-16 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table A3[9]: Result of LR test for the robustness check of RobustnessCheckModel_1.

Model 1: model_1_0
Model 2: RobustnessCheckModel_1

Df	LogLik	Df	Chisq	Pr(>Chisq)
18	221.83			
20	237.28	2	30.899	1.951e-07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table A4[10]: Result of LR test for the robustness check of RobustnessCheckModel_2.

Model 1: RobustnessCheckModel_2_0
Model 2: RobustnessCheckModel_2

Df	LogLik	Df	Chisq	Pr(>Chisq)
21	225.42			
23	246.40	2	41.953	7.762e-10 ***

[9] model_1_0 represents the model that the eight inefficiency factors are no effects on the inefficiency.

[10] RobustnessCheckModel_2_0 is the RobustnessCheckModel_2 without shadow banking variables (RSSB-CBS and RSSB-Macro).

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table A5[11]: Result of LR test for the robustness check of RobustnessCheckModel_3.

Model 1: RobustnessCheckModel_3_0
Model 2: RobustnessCheckModel_3

Df	LogLik	Df	Chisq	Pr(>Chisq)
21	287.14			
23	291.69	2	9.0912	0.01061 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

[11] RobustnessCheckModel_3_0 is the RobustnessCheckModel_3 without shadow banking variables (RSSB-CBS and RSSB-Macro).

Appendix B

Appendix B1 : R code.

```
install.packages("frontier")
install.packages("lmtset")
install.packages("micEcon")
install.packages("zoo")
install.packages("plm")

library(frontier)
library(lmtest)
library(micEcon)
library(zoo)
library(Formula)
library(plm)

#Input data.
data1<-read.table(file="/Users/chenchuandong/Desktop/thesis/input-output参考文献/data-MasterThesis.csv",
header=TRUE, sep= ";", dec=".", na.string="NA")
summary(data1)

data2<-plm.data(data1,c("BankNum","YEAR"))
summary(data2)

tc<-data2$TC
loans<-data2$LOAN
la<-data2$LA
oea<-data2$OEA
dstf<-data2$DSTF
pf1<-data2$PF1
pc<-data2$PC
z1<-data2$Z1
z2<-data2$Z2
tea<-data2$TEA
ta<-data2$TA
wto<-data2$WTO
cbrc<-data2$CBRC
fc<-data2$FC
year<-as.numeric(data2$YEAR)

#Descriptive statistics of the outputs and inputs variables.
mean(tc); max(tc); min(tc); sd(tc)
mean(loans); max(loans); min(loans); sd(loans)
mean(dstf); max(dstf); min(dstf); sd(dstf)
mean(pf1); max(pf1); min(pf1); sd(pf1)
mean(pc); max(pc); min(pc); sd(pc)

#Build model_1 (the original model).
 model_1<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
```

```
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |z1+z2+wto+fc+cbrc+log(ta)+log(la/ta)+I(loans/dstf),
          data=data2,ineffDecrease=FALSE)
summary(model_1)
lrtest(model_1)

 model_1_0<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |~1,
          data=data2,ineffDecrease=FALSE)

#LR test between model_1_0 and model_1.
lrtest(model_1_0,model_1)

#Monotonicity calculation.
h11<- (-0.37112606 -0.42413170*log(loans/ta)+0.73614386*log(dstf/ta)-0.00705085*log(pf1/pc)+0.01117596*year+
 0.47179289*(loans/dstf))*(tc/(pc*ta))/(loans/ta)


h22<-(1.71972508 + 0.42922377*log(dstf/ta)+ 0.73614386*log(loans/ta)-0.00705780*log(pf1/
 pc)-0.02030937*year-0.47179289*loans/dstf)*(tc/(pc*ta))/(dstf/ta)


h33<-( 0.78636596-0.00639911*log(pf1/pc)-0.00705085*log(loans/ta)-0.00705780*log(dstf/ta)
 +0.00579885*year)*(tc/(pc*ta))/(pf1/pc)


prec11<-(sum(h11<0)+sum(h11=0))/(sum(h11<0)+sum(h11=0)+sum(h11>0))

prec22<-(sum(h22<0)+sum(h22=0))/(sum(h22<0)+sum(h22=0)+sum(h22>0))

prec33<-(sum(h33<0)+sum(h33=0))/(sum(h33<0)+sum(h33=0)+sum(h33>0))

#Cost efficiency score calculation.
eff_1<-efficiencies(model_1)

RobustnessTestModel_1<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
```

```
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |z1+z2,
          data=data2,ineffDecrease=FALSE)
summary(RobustnessTestModel_1)

#LR test between model_1_0 and RobustnessTestModel_1.
lrtest(model_1_0,RobustnessTestModel_1)

RobustnessTestModel_2<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |z1+z2+wto+fc+cbrc,
          data=data2,ineffDecrease=FALSE)
summary(RobustnessTestModel_2)

RobustnessTestModel_2_0<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |wto+fc+cbrc,
          data=data2,ineffDecrease=FALSE)

#LR test between RobustnessTestModel_2_0 and RobustnessTestModel_2.
lrtest(RobustnessTestModel_2_0,RobustnessTestModel_2)

RobustnessTestModel_3<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |z1+z2+log(ta)+log(la/ta)+I(loans/dstf),
          data=data2,ineffDecrease=FALSE)
summary(RobustnessTestModel_3)

RobustnessTestModel_3_0<-sfa(log(tc/(pc*ta))~log(loans/ta)+log(dstf/ta)+log(pf1/pc)
        +I(0.5*log(loans/ta)^2)
        +I(0.5*log(dstf/ta)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/ta)*log(dstf/ta))+I(log(loans/ta)*log(pf1/pc))
```

```
        +I(log(dstf/ta)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/ta)*year)+I(log(dstf/ta)*year)  +I(log(pf1/pc)*year)
          |log(ta)+log(la/ta)+I(loans/dstf),
         data=data2,ineffDecrease=FALSE)

 #LR test between RobustnessTestModel_3_0 and RobustnessTestModel_3.
lrtest(RobustnessTestModel_3_0,RobustnessTestModel_3)

#Robustness test on normalization.
RobustnessTestModel_4<-sfa(log(tc/(pc*tea))~log(loans/tea)+log(dstf/tea)+log(pf1/pc)
        +I(0.5*log(loans/tea)^2)
        +I(0.5*log(dstf/tea)^2)
        +I(0.5*log(pf1/pc)^2)
        +I(log(loans/tea)*log(dstf/tea))+I(log(loans/tea)*log(pf1/pc))
        +I(log(dstf/tea)*log(pf1/pc))
        +year
        +I(0.5*year^2)
        +I(log(loans/tea)*year)+I(log(dstf/tea)*year)  +I(log(pf1/pc)*year)
          |z1+z2+wto+fc+cbrc+log(ta)+log(la/ta)+I(loans/dstf),
         data=data2,ineffDecrease=FALSE)
summary(RobustnessTestModel_4)
```