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Cost Efficiency in the Chinese Banking Sector: A Comparison of Parametric and Non-parametric Methodologies

by

Yizhe Dong

A Doctoral Thesis

Submitted in Partial Fulfilment of the Requirements for the Award of Doctor of Philosophy of Loughborough University

November 2009

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Abstract

Since the open door policy was embarked upon in 1979, China's banking sector has undergone gradual but notable reforms. A key objective of the reforms implemented by the Chinese government is to build an effective, competitive and stable banking system in order to improve its efficiency and reliability. This study employs both parametric stochastic frontier analysis (SFA) and non-parametric data envelopment analysis (DEA) methods to assess and evaluate the cost efficiency of Chinese banks over the period from 1994 until 2007, a period characterised by far-reaching changes brought about by the banking reforms. To this end, we first compare a number of specifications of stochastic cost frontier models to determine the preferred frontier model which are adopted in our efficiency analysis. The preferred model specification for our sample is the one stage SFA model that includes the traditional input prices, the outputs and the control variables (that is, equity, non-performing loans and the time trend) in the cost frontier and the environmental variables (that is, ownership structure, size, deregulation, market structure and market discipline) in the inefficiency term. Moreover, we also employ two cost DEA models (traditional DEA and New DEA) as a complement to the preferred SFA model for methodological cross-checking purposes. Similar to the previous empirical literature, we find that in most cases only moderate consistency across the different techniques.

The cost efficiency of Chinese banks is found to be 91% on average, based on our SFA model, over the period from 1994 until 2007. Based on the results of the DEA and New DEA models, the average cost efficiency for Chinese banks over the sample period is about 89% and 87%, respectively. We find that Chinese banking efficiency has deteriorated after China's admission to the WTO, suggesting that the significant external environmental changes which arose from China's WTO entry may have had a negative impact on its banking efficiency. In addition, we find that the majority of Chinese

banks reveal scale inefficiencies and as asset size increases, banks tend to pass from increasing, to constant, and then to decreasing returns to scale.

Our findings also show that both state-owned banks and foreign banks are more efficient than domestic private banks and larger banks tend to be relatively more efficient than smaller banks. These and other results suggest that in order to enhance Chinese banking efficiency, the government needs to continue with the banking reform process and in particular, to open up banking markets, to improve risk management and corporate governance in Chinese banks and to encourage the expansion of banks.

Keywords: Cost efficiency, Stochastic Frontier Analysis, Data Envelopment Analysis, Chinese Banking Reform.

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Abbreviations

ABC	Agricultural Bank of China
ADBC	Agricultural Development Bank of China
AE	Allocative efficiency
AMC	Asset management company
Basel I	Basel Capital Accord of 1998
Basel II	New Basel Capital Accord (2004)
BIS	Bank for International Settlements
BOC	Bank of China
BOCOM	Bank of Communications
CAR	Capital adequacy ratio
CBRC	China Banking Regulatory Commission
CCB	City commercial Bank
CCB	China Construction Bank
CDB	China Development Bank
CE	Cost efficiency
CITIC	Chinese International Trust and Investment Corporation
COLS	Corrected ordinary least squares
CR	Concentration ratio
CRS	Constant returns to scale
DEA	Data envelopment analysis
DFA	Distribution free approach
DMU	Decision making unit
EXIM	Export-Import Bank
FDH	Free disposal hull
FF	Fourier-flexible
GDP	Gross domestic product

GLS	Generalised least squares
HSBC	Hong Kong and Shanghai Banking Corporation
HHI	Herfindahl-Hirschman index
ICBC	Industrial and Commercial Bank of China
IMF	International Monetary Fund
JSCB	Joint-stock commercial bank
LAC	Long-run average cost curve
LR	Log likelihood ratio
MES	Minimum efficient scale
ML	Maximum likelihood
NIRS	Non-increasing return to scale
NPL	Non-performing loan
OLS	Ordinary least squares
PBC	People's Bank of China
PTE	Pure technical efficiency
RCC	Rural credit cooperatives
RMB	Renmingbi
ROA	Return on total assets
ROAA	Return on Average Assets
ROAE	Return on Average Equity
ROE	Return on equity
SAC	Short-run average cost curve
SAFE	State Administration of Foreign Exchange
SE	Scale efficiency
SFA	Stochastic frontier analysis
SME	Small and medium enterprises
SOB	State-owned bank
SOCB	State-owned commercial bank
SOE	State-owned enterprise

TA	Total assets
TC	Total costs
TE	Technical efficiency
TFA	Thick frontier approach
UCC	Urban credit cooperative
VRS	Variable return to scale
WTO	World Trade Organisation

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Chapter 1 Introduction

1.1 Introduction

Financial sectors throughout the world have witnessed significant developments over the last thirty years. The change of the environment in which banks operate has had substantial implications for the economic role of banks and their business activities. Deregulation, globalisation, financial innovation and technological progress have gradually reduced the costs of information processing and transmission and have been major forces impacting on the performance of the international banking sector (Girardone, *et al*, 2004). However, banking systems in developing countries have traditionally been considered as prone to relatively high levels of government control and excessive government intervention and this in turn has inhibited competition and the efficient allocation of resources. Bank performance in developing countries has been relatively poor because of this. Fortunately, in many developing countries regulators and government instrumentalities have gradually become aware of the role banking deregulation plays in promoting competition and efficiency and have therefore implemented a number of reforms which aim to create an effective, competitive, and stable banking sector.

The reforms to the Chinese economic system which began in 1979, have the aim of moving the country from a "planned economy supplemented with some market elements" to a "socialist market economy". As a part of these national economic reforms, the Chinese government has also liberalised and deregulated the operations of the Chinese banking sector. The liberalisation and deregulation programme applied to the Chinese banking sector includes amongst other things: establishing a two-tier banking system, separating so-called policy lending from commercial lending, removing the credit ceiling on deposits and loans, reducing the systemic risk of the banking sector, gradually privatising state-owned banks, encouraging state-owned banks to seek listing on the stock exchange and relaxing foreign bank entry into the local

market. An officially-stated objective of the liberalisation and deregulation programme is to enhance the efficiency and productivity levels of the Chinese banking sector. Therefore, it is important to investigate the efficiency levels of Chinese banks over the reform period. Assessing the effects of the liberalisation and deregulation programme on Chinese banking efficiency will assist government instrumentalities and banking regulators in policy choice and will also enable bank management to improve the way in which they allocate resources across the various investment opportunities available to them. With this in mind, we outline the objectives of the present study.

1.2 Objectives and Motives of the Thesis

Despite the large empirical literature which exists on the efficiency of the North American and European banking systems and the gradually increasing empirical evidence pertaining to developing countries, only a few empirical studies have been undertaken which investigate efficiency levels in the Chinese banking sector. Therefore, a principal aim of this study is to assess and evaluate the cost efficiency of the Chinese banking sector using both stochastic frontier analysis (SFA) and data envelopment analysis (DEA). We also explore the key determinants of Chinese banking efficiency and provide evidence about the consistency or otherwise of the two efficiency frontier approaches (SFA and DEA) employed in our empirical analysis. In particular, this study seeks *inter alia* to address the following questions:

1. Is accounting for heterogeneity across banks important for the SFA methodology?
2. Do the SFA and DEA methods provide consistent results?
3. What is the general level of cost efficiency of the Chinese banking sector and how has it varied over time?
4. Have the banking reforms implemented by the Chinese government improved Chinese banking efficiency?
5. Does cost efficiency vary across different bank types and size categories?
6. Are there any economies or diseconomies of scale in the Chinese banking sector?

7 Do returns to scale (economies of scale) differ across bank size categories?

8 What are the main determinates of Chinese banking efficiency?

Our study of Chinese banking efficiency is important for a number of reasons. First, to the best of our knowledge, this is the first study to apply *both* parametric (SFA) and nonparametric (DEA) frontier techniques in the context of Chinese banking efficiency. The choice of which frontier method to use is often dependent on which is seen as the easiest to implement; seldom are any rational arguments given or any optimal criteria specified to justify the chosen frontier method. Given this, we make comparisons between the results from the various frontier methods in order to make assessments about the robustness of the estimated cost efficiency scores obtained from our empirical analysis of Chinese banks. Moreover, to the best of our knowledge this is the first empirical study to estimate banking efficiency using the New DEA model developed by Tone (2002). Second, estimates of banking efficiency can be biased if bank heterogeneity (e.g. output quality, size, ownership structure, etc.) is ignored (Mester, 1997). However, to our knowledge, this is the first study to provide exhaustive empirical evidence on the effects of heterogeneity on Chinese banking efficiency levels. In other words we endeavour to fill an important gap in the literature by comparing a number of well-established stochastic cost frontier specifications which attempt to account for bank heterogeneity in different ways.

Third, this research contributes to the existing Chinese banking efficiency literature by providing the most recent and comprehensive evidence on the impact of the Chinese government's reform programme on the efficiency of the Chinese banking sector. The sample period investigated by previous Chinese bank studies, as we shall see in Chapter 3, is generally not long enough to shed much light on the impact of the Chinese government's banking reform programme. In contrast, this study uses a longer sample period (fourteen years) which covers both the second phase of banking reform (1994 -2001) and the third phase of banking reform (2002-2007). Fourth, the existing empirical literature does not provide clear and robust results with respect to the main determinants of Chinese banking efficiency. Hence, this study investigates the impact of the potential determinants of Chinese banking efficiency, such as ownership structure,

size, deregulation, market structure and market discipline - using both the one stage SFA procedure and the two stage DEA procedure. The findings provide important insights into both policy issues and the efficiency with which bank management use the resources available to them.

1.3 Research Methodology and Data

In this study, we use both parametric (SFA) and non-parametric (DEA) frontier methodologies to measure the efficiency of Chinese banks. In order to better estimate the cost efficiency levels of Chinese banks, we employ the so called one stage SFA model and then compare the empirical results we obtain from with four alternative stochastic cost frontier models. This one stage SFA model allows us to simultaneously account for some heterogeneity factors (e.g. the level of equity on issue, asset quality, etc.) which may have an impact cost efficiency frontier and to estimate the effect of a set of environmental variables (e.g. ownership structure, size, deregulation, etc.) on bank efficiency levels. The translog functional form is used to estimate the underlying cost function. Moreover, we also employ two DEA cost efficiency models as a complement to the preferred one stage SFA model to measure Chinese bank efficiency and then we use a variety of methodological cross-checking mechanisms in order to assess the robustness of the results obtained. In addition, in order to investigate the key determinants of Chinese banking efficiency, we employ the so-called two stage DEA procedure. More specifically, we use a Tobit regression model which regresses the efficiency scores obtained from the DEA models on a number of environmental variables such as ownership structure, size, market structure, etc.

Our sample is an unbalanced panel which consists of 41 Chinese banks over the period from 1994 to 2007 and totals 397 observations. The sample comprises the big four state-owned banks, three policy banks, twelve national and regional joint-stock banks, sixteen city commercial banks and six foreign banks. The data are mainly obtained from the Almanac of China's Finance and Banking (1994-2007) and BankScope. Additional data and double checks are made from other data sources, such as individual banks' statutory annual financial reports, the China Banking Regulatory Commission's

database and the China Statistical Yearbook, etc.

1.4 Structure of the Thesis

Our study is organised into eight chapters as fellows:

Chapter 2: Efficiency: Meaning, Theory and Measurement

This chapter first introduces the theoretical framework related to productive efficiency. Efficiency measures deviations in performance from the predicted performance of the "best practice" firms on the efficient frontier. The main types of efficiency include technical efficiency, allocative efficiency, scale efficiency and economic efficiency. Then we briefly discuss various theories of the firm. The traditional neoclassical theory of the firm views the firm as a rational entity which seeks to maximise profit. It seeks to explain how the market works but other than this treats the firm as a black box which transforms resources into saleable goods. The managerial theories of the firm, the behavioural theory of the firm and the X-efficiency theory of the firm highlight the possibility of internal inefficiency in the decision making processes of the firm and can explain why firms may not always operate efficiently. This chapter also reviews the parametric and non-parametric frontier techniques which enable one to estimate the efficiency frontier levels of firms and measure the efficiency of a firm relative to the other firms in the same industry.

Chapter 3: Empirical Studies of Bank Efficiency

This chapter provides a review of the literature on international banking efficiency. It first draws attention to empirical bank efficiency studies which employ two or more frontier approaches using a common set of data for the estimation and assessment of efficiency levels. Here it is important to note that there is no consensus about the existence of a single best frontier approach for measuring efficiency. Rather, the prevailing view is that methodological cross-checking is highly recommended in order to check for consistency across the various frontier approaches. This chapter also reviews empirical studies dealing with the efficiency of the Chinese banking sector as well as other developing countries. These studies mainly focus on investigating the

impact of deregulation and ownership structure on bank efficiency levels. Finally, this chapter also surveys empirical findings on the impact of ownership structure, size, deregulation, market structure and market discipline on the efficiency levels of banks. These factors are generally considered as the key determinants of banking efficiency.

Chapter 4: China's Banking System and Reforms

This chapter outlines the structural and institutional arrangements which characterise the Chinese banking sector as well as the banking reforms which have been implemented by the Chinese government over the last thirty years. The chapter provides much of the contextual background needed for assessing the empirical results we obtain on the efficiency analysis of the Chinese banking sector in subsequent chapters. Currently the Chinese banking system consists of a variety of institutions. The most notable characteristic of the Chinese banking system is that state-owned commercial banks dominate the banking sector and are the main official source for the financing of companies. As previously noted the Chinese government has implemented a series of banking reforms since 1979 with the aim of creating a safe and sound banking system. These reform measures can be subdivided into three phases and are discussed in detail in this chapter.

Chapter 5: Methodology

This chapter outlines the modelling framework used to measure the cost efficiency and scale economies of Chinese banks. The chapter first discusses five different stochastic cost frontier models which can be used to estimates cost efficiency levels in the Chinese banking sector. The theme running through the chapter is that a comparison between the results of these five models might identify a preferred SFA model for our sample of Chinese banks. Moreover, this chapter also presents two different DEA models as a complement to the SFA model for methodological cross-checking purposes. Then, following the recommendations of Bauer *et al.* (1998), we introduce five consistency conditions through which to assess the compatibility of the efficiency estimates generated by the SFA and DEA models. Finally, this chapter outlines the variables used in our empirical analysis, the sources from which we obtained our data and

provides a brief description of the data sample.

Chapter 6: Empirical Results: A Comparison of SFA and DEA

Chapter 6 is the first of two chapters that summarise the empirical results relating to the various efficiency methodologies outlined in the preceding chapter as they are applied to our sample of Chinese banks. This chapter first assesses the importance of accounting for heterogeneity across banks by comparing the results of five different stochastic cost frontier models which are used to estimate efficiency levels in the Chinese banking sector. Our analysis is based on log likelihood ratio tests and discusses the effects of bank heterogeneity on key parameter estimates, efficiency levels and efficiency ranks in order to obtain a preferred SFA model. Moreover, this chapter also checks the compatibility of the SFA, DEA and New DEA models using the distributional properties of the efficiency scores obtained under each technique (that is, mean, variance, skewness, maxima and minima, etc.), the correlations of rankings of efficiency scores across the various techniques, identification of the best and worst banks across the various techniques, the stability of efficiency scores over time and the relation between efficiency scores and standard non-frontier performance measures.

Chapter 7: Chinese Banking Efficiency and Analysis

This chapter empirically analyses the cost efficiency of the Chinese banking sector for the period from 1994 until 2007 using the preferred SFA, DEA and New DEA models. The analysis draws attention to how banking efficiency levels have changed as a result of the banking reforms implemented by the Chinese government. It also examines the diversity of the efficiency scores between the different types of bank (that is, big four state-owned banks, state-owned policy banks, joint stock commercial banks and city commercial banks) and size classes (that is, very big, big, medium, small and very small). This chapter also investigates whether scale economies exist for Chinese banks using both the SFA model and the DEA and New DEA models. Our analysis in this chapter seeks to assist bank management and regulatory authorities by tracing the potential sources of banking inefficiency and by exploring the impact that ownership structure, size, deregulation, market structure and market discipline can have on the cost

efficiency levels of Chinese banks.

Chapter 8: Conclusions and Limitations

This chapter summarises the main findings of our study. Policy implications are also discussed. This chapter also draws attention to some potential limitations of our empirical work and points up some avenues for further research

Chapter 2 Efficiency: Meaning, Theory and Measurement

2.1 Introduction

The main objective of this chapter is to introduce the theoretical framework related to productive efficiency and the measurement of efficiency. Section 2.2 briefly discusses the difference between the conventional and frontier efficiency approaches, which enables us to understand why the frontier efficiency approach is superior to conventional performance ratios. Section 2.3 develops the concepts of efficiency and economies of scale and scope. (In)efficiency will be defined as the departure of the individual firm from a benchmark, which is known as the efficient frontier. Economic efficiency (or cost efficiency) is normally viewed as consisting of two components, technical and allocative efficiency. Economies of scale is a measure of efficiency dealing with the size of the production unit being considered. Founded on the economic concept of economies and diseconomies of scale, technical efficiency can be investigated further and decomposed into pure technical efficiency and scale efficiency. Section 2.4 briefly discusses various theories of the firm. These theories seek to explain how the market works and why firms may not able to utilise their resources in the most efficient way possible.

Section 2.5 reviews the main frontier techniques used to measure efficiency. Generally, frontier techniques can be classified into two streams: non-parametric and parametric techniques. Non-parametric techniques refer to the data envelopment analysis (DEA) approach and free disposal hull (FDH) approach. They are mathematical programming approaches to estimating efficiency and represent an empirical implementation of Shephard's distance function methodology. Parametric techniques refer to the stochastic frontier analysis (SFA), distribution free approach (DFA) and thick frontier approach (TFA). These approaches require a pre-specified functional form for the best-practice frontier (cost, profit or production). A firm is labelled inefficient if its

costs are higher or profits are lower than the best-practice firm after removing random errors. In this section we also discuss the most widely used functional forms in the empirical literature on financial institutions and the main differences between the parametric and non-parametric approaches. Finally, section 2.6 summarises this chapter.

2.2 Conventional and Frontier Efficiency Approach

There are two main ways by which to measure the performance of banks. The first is the classical approach, based on simple profit-cost analysis, which is the simplest and most naive measure of efficiency. This approach is represented by conventional performance ratios which concentrate on examining financial ratios such as ROE, ROA[1], capital asset ratio, growth rate of total revenue, and cost/income ratio all of which are commonly used by regulators, financial institution managers and industry consultants to evaluate performance. However, conventional performance ratios fail to control for the influences of input price, output price and other exogenous market factors, which constrain the standard performance ratios from reaching closer estimations of the true performance. In the last thirty years, academic research has increasingly focused on another approach; named Frontier efficiency (or X-efficiency) approach, to measure the performance of financial institutions. Frontier efficiency measures deviations in performance from that of "best-practice firms" on the efficient frontier, controlling for the effect of a number of exogenous factors such as the prices faced in local markets. In other words, the Frontier efficiency method measures how well the financial institution performs relative to the predicted performance of the best firms facing the same market conditions in the industry. It represents the ability of management to control costs and use resources to produce output. Frontier efficiency measures summarise firm performance in a single statistic (efficiency score) that can control differences among firms in a sophisticated multidimensional framework that has its roots in economic theory (Cummins and Weiss, 2000). Therefore, frontier efficiency appears to be superior to conventional performance ratios and obtains better estimates of the underlying performance of firms.

[1] ROE is abbreviation of return on equity; ROA is abbreviation of return on total assets.

2.3 The Framework of Efficiency

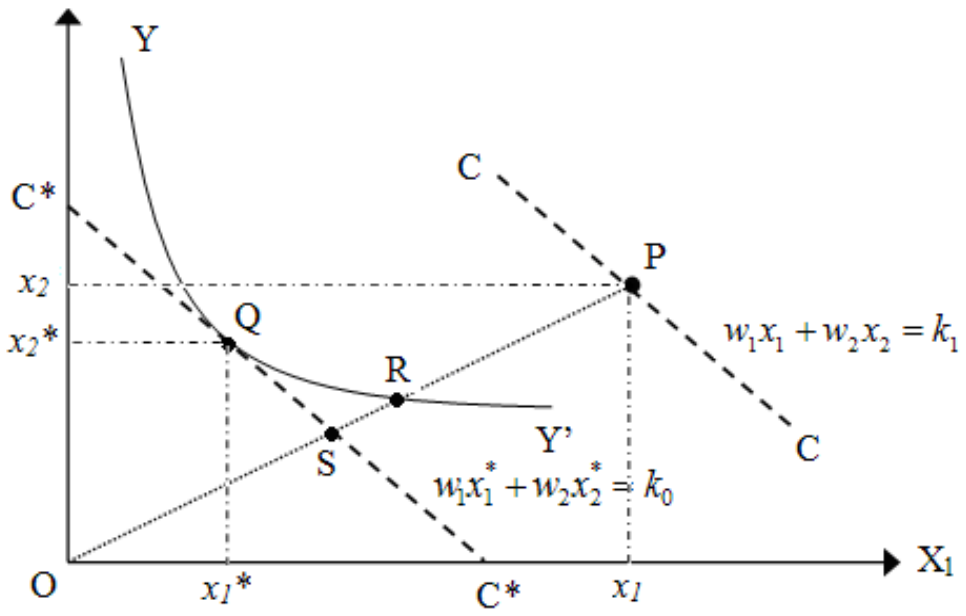
The primary purpose of this section is to introduce a number of commonly used efficiency concepts which may be employed in this study and to discuss how these measures may be calculated relative to a given frontier. The concept of economic efficiency flows directly from the microeconomic theory of the firm. Based on the ideas of Debreu (1951) and Farrell (1957) who built the standard framework of productive efficiency (production frontier), overall economic efficiency can be decomposed into scale efficiency, scope efficiency, pure technical efficiency and allocative efficiency. Theoretically, a firm is fully efficient if it produces the output level and mix that maximises profits and minimises possible costs.

2.3.1 Technical, Allocative and Cost Efficiency

Farrell (1957) has proposed a method of measuring productive efficiency which uses an "efficient isoquant" estimated as part of the convex hull of the observed points. Farrell proposes an assumption under which the production function is homothetic. A homothetic function is a monotonic transformation of a homogeneous function in which the marginal rate of technical substitution is constant along a ray drawn from the origin. For instance, let a production function $f(x_1, x_2)$ be homogeneous of the first degree in x_1 and x_2, and assume that the isoquant of this homogeneous production function is an efficient isoquant. An (increasing) monotonic transformation of a homogenous production function yields a homothetic production function in $F(X) = g[f(x_1, x_2)]$ where g is a strictly increasing monotonic transformation. A series of homothetic isoquants can be derived from the original (efficient) isoquant by appropriate scaling up. In other words, a proportional increase or decrease of all inputs should not affect the marginal rate of technical substitution along the isoquants. A comparison between the efficient isoquant and any other isoquant for given output would indicate departure from full efficiency (Clemhout, 1968).

The analysis of efficiency carried out by Farrell (1957) can be best illustrated, for the single output and two inputs case in the unit isoquant diagram (Figure 2.1).

Figure 2.1 Technical, Allocative and Cost Efficiency



Source: Cooper *et al*. (2007, p.258)

Farrell (1957) initially assumes that constant returns to scale (CRS) depicts the efficient production function or the frontier. The technological set is fully described by the unit isoquant YY' that captures the combination of the inputs (X_1, X_2) by which the firm can produce a certain output when it is perfectly efficient. In the other words, YY' shows minimum combinations of inputs needed to produce a unit of output. Thus, under this framework, every package of inputs along the unit isoquant is considered as technically efficient while any point above and to the right of it, such as point P, is defined as a technically inefficient producer since the input package that is being used is more than enough to produce a unit of output. Hence, the distance RP along the ray OP measures the technical inefficiency of a producer located at point P. This distance (RP) represents the amount by which all inputs can be reduced without decreasing the amount of output. Geometrically, the technical inefficiency level associated with package P can be expressed by the ratio RP/OP and, therefore, the *technical efficiency* (TE) of the producer under analysis would be given by the ratio OR/OP, which takes a value between zero and one. A value of one implies that the firm is fully technically efficient.

Allocative efficiency (AE) involves the selection of an input mix that allocates factors to their highest value uses and introduces the opportunity cost of factor inputs to the measurement of productive efficiency. Allocative inefficiency can also be derived from the unit isoquant plotted in Figure 2.1. Given information on the market prices of inputs (w_1, w_2), the isocost line CC through P is associated with $w_1x_1 + w_2x_2 = k_1$ and the slope of this line reflect the input price ratio. However, this cost can be further reduced by moving this line in parallel fashion until it is tangential to the isoquant at Q. The coordinates of CC then give $w_1x_1^* + w_2x_2^* = k_0$ achieving the minimal cost at the prescribed output level. Now we note that we can similarly determine the relative distances of S and R to obtain the ratio OS/OR. With respect to the least cost combination of inputs given by the point Q, the above ratio indicates the cost reduction that a producer would be able to achieve if it moved from a technically but not allocatively efficient input package (R) to both a technically and allocatively efficient one (Q). Therefore, the allocative efficiency that characterises the producer at point P is given by the ratio OS/OR.

There is another measure that is commonly referred to as *cost efficiency* or *economic efficiency*. It can be represented by the ratio of minimal cost (wx^*) to actual cost (wx_0), that is, the ratio wx^*/wx_0 = OS/OP. A cost efficient firm will choose its inputs and mixes according to their prices so as to minimise total cost. Cost inefficiency may arise from two different sources. One is deficiency in applying the technology (technical inefficiency) and another one is suboptimal allocation of resources (allocative inefficiency). Thus, total overall cost efficiency can be presented as the product of technical efficiency and allocative efficiency:

$$\text{Overall cost efficiency} = \text{allocative efficiency} \times \text{technical efficiency}$$

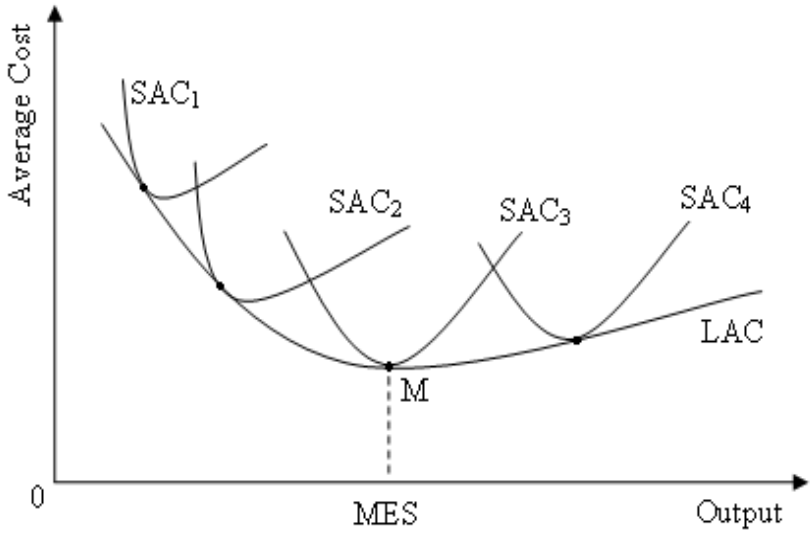
$$= \text{OS/OR} \times \text{OR/OP} = \text{OS/OP}$$

2.3.2 Economies of Scale

Economies of scale (or returns to scale) refers to the rate at which output changes as all factor quantities are varied and measures whether firms with similar production and managerial technologies are operating at an optimal size (Molyneux *et al*. 1996). Specifically, economies of scale (or increasing returns to scale) exist, over a given mix of outputs, if a proportionate increase in firm's outputs would lead to a less than proportionate increase in its total costs. Conversely, diseconomies of scale (or decreasing returns to scale) arise if a proportionate increase in a firm's outputs would lead to a more than proportionate increase in its total costs. Constant returns to scale occur if a proportionate increase in a firm's outputs would lead to the same proportionate increase in its total costs.

Economies of scale actually are based on the shape of the average cost curve and are explained in Figure 2.2. The Figure shows a series of short-run average cost curves (SACs) and a long-run average cost curve (LAC). Each short-run average cost curve represents the average cost of different-size firms during a short period of time. The firm will choose the size that yields the lowest average cost for that particular level of output. The long-run average cost curve is traced out from the SACs where each point of the LAC is to a point of tangency with a corresponding short run cost curve and it shows the least cost method of production for any level of output. Scale economies appear as the slope of an average cost curve indicating how costs vary with output (Humphrey, 1990). The downward-sloping LAC reflects economies of scale, because average costs of production decline as output increases. This cost characteristic exists only up to a certain firm size known as the minimum efficient scale (MES). A firm achieves the lowest attainable average cost at the point M and experiences constant returns to scale around that point. Beyond point M, the upward-sloping LAC indicates diseconomies of scale, because the average cost of production increase as output increases.

Figure 2.2 Cost Curves and Economies of Scale

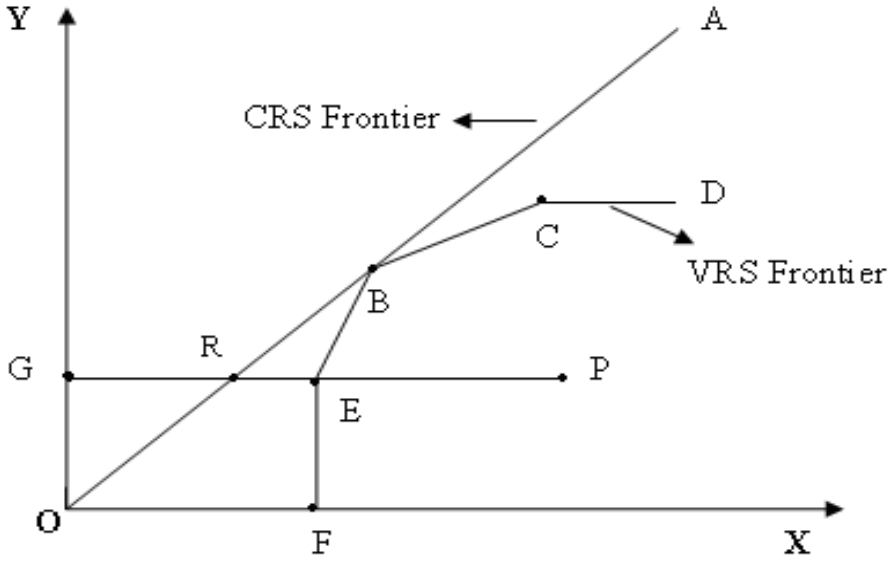


Source: Humphrey (1990, p.38).
Notes: SAC: short-run average cost curve; LAC: long-run average cost curve; MES: minimum efficient scale.

2.3.3 Pure Technical and Scale Efficiency

In Figure 2.1, the use of the unit isoquant assumes constant returns to scale (CRS), but this assumption does not always hold. A firm using more of both inputs than the combination represented by R may exhibit variable returns to scale (VRS). Thus, in general, technical efficiency can be further decomposed into measures of pure technical efficiency (PTE) and scale efficiency (SE). In Figure 2.3, assuming the simple case of one input X and one output Y, P represents an existing bank. OA represents the constant returns to scale frontier. Firms can either lie on, or below the frontier but cannot be above it. Therefore, the ratio of GR/GP represents the measure of technical efficiency of bank P which corresponds to OR/OP in Figure 2.1.

Figure 2.3 Pure Technical and Scale Efficiency



The concept of scale efficiency ascertains whether or not the firm operates at an optimum size. In order to measure scale efficiency, the assumption of variable returns to scale replaces that of constant returns to scale. In the above figure, FEBCD represents a variable returns to scale frontier. For the bank at point P, pure technical efficiency (PTE) equals the ratio of GE / GP. Scale efficiency is the ratio of GR / GE or equal to TE divided by PTE. The value of SE is unity when operating under constant returns to scale. Values of less than unity reflect scale inefficiency. Scale inefficiency could be caused by the firm having to operate under increasing returns to scale or decreasing returns to scale. In order to investigate this, the non-increasing returns to scale frontier is developed, represented by OBCD. If SE is not equal to unity and PTE is equal to GR/GP, decreasing returns to scale exists. If PTE is not equal to GR/GP which is based on the frontier OBCD, then the scale inefficiency is due to increasing returns to scale.

2.3.4 Economies of Scope

Economies of scope exist if two or more products can be jointly produced with lower

cost by a single firm than the total cost that is incurred in their independent production (Molyneux *et al*., 1996). For banks, this mean that potential cost savings are achievable through the joint production of financial services. Conversely, diseconomies of scope arise if joint production is more costly than independent production.

To illustrate the concept of economies of scope, we assume that a firm produces two outputs: y_1 and y_2. If the two outputs are produced independently, their separate cost function are $C(y_1,0)$ and $C(0, y_2)$. If the two outputs are produced jointly, the joint cost of producing is $C(y_1, y_2)$. Economies of scope exist if the total cost of producing the two outputs jointly is less than the combined cost of producing the same amounts of each output separately, that is, $C(y_1, y_2) < C(y_1,0) + C(0, y_2)$. If the inequality is reversed, then diseconomies of scope are said to exist. Given this example, the measure of economies of scope can be measured as follows:

$$\text{SCOPE}= \frac{C(y1,0)+C(0,y2)-C(y1,y2)}{C(y1,y2)}$$

where SCOPE > 0 indicates overall economies of scope and SCOPE < 0 diseconomies of scope. The estimation of economies of scope in the banking sector is not an easy task because of the lack of cost data for each output. Therefore, our study will not analyse economies of scope for Chinese banks.

2.4 The Economic Theory and Causes of Inefficiency

Before turning to the review of frontier efficiency methodologies, we briefly discuss various theories of the firm. The aim of this discussion is to link the theory of the firm with the frontier efficiency analysis literature. The discussion will address the question of why firms may not able to utilise their resources efficiently.

2.4.1 Conventional Neoclassical Theory of the Firm

The concepts of efficiency derive their basis from the microeconomic theory of the firm. The neo-classical theory of the firm stems from the static equilibrium framework first developed by Cournot in 1883. The conventional neoclassical theory treats the firm as a black box which transforms resources into saleable goods. This transformation of inputs into outputs is described by a production function or production possibilities set.

The conventional neoclassical theory of the firm assumes that the firm is operating in a perfectly competitive market[2]. In this market, all firms seek to maximise their profit which is accomplished by simultaneously maximising revenues and minimising costs. Consequently, a competitive general equilibrium is achieved by equating the marginal rates of substitution for all firms between any two economic variables (inputs or outputs) (Cohen and Cyert, 1975). The competitive equilibrium leads all firms to earn only a normal profit. In order words, firms cannot earn any more money than is necessary to cover their economic costs. In the short run, it is possible for some individual firms to make abnormal profits. The existence of abnormal profits will attract other firms to enter the market and compete with incumbent firms. Competition between firms will drive the market price down until all firms are earning a normal profit in the long run. If any firm is unable to make a normal profit due to inefficient operation, then in long run, these inefficient firms will be either acquired by efficient firms or withdraw from the market. Therefore, according to the conventional neoclassical theory of the firm, the firm which can efficiently allocate resources to produce the maximum level of output for given input will survive and the firm which is operating inefficiently will be driven out of the market. In other words, in a perfectly competitive market, any firm that fails to reach the efficiency frontier will be forced out of the market and only efficient firms will remain. Empirical research suggests, however, that not all firms operate on the efficient frontier and a number of firms do not produce at the point where long run average costs are minimised but still survive in the market. Thus, the traditional neoclassical theory fails to explain why inefficient firms survive in the

[2] The main characteristics of a perfectly competitive market: 1) a large number of producers and consumers in the market; 2) Goods and services are perfect substitutes; 3) Perfect and complete information between consumers and firms; 4) All firms are assumed to have equal access to resources and improvements in production technologies; 5) no barriers to entry into or out of the market.

market, and because of this some alternative theories have been developed to supplement the conventional theory of the firm.

Demsetz (1997) noted that the firm in neoclassical theory reflects the imperatives of the price system. If the price system works well, resources are allocated well. But the traditional theory pays little attention to the internal workings of the firm and provides no analysis of the decision-making process and no explanation of the factors that determine business success or failure. Therefore, the neo-classical theory of the firm has been challenged by alternatives such as managerial theories (Baumol 1959, Marris 1964, Williamson 1964), behavioural theories (Simon 1959, Cyert and March 1963), and X-efficiency theory (Leibenstein 1966, 1979). The literature on these theories is vast. Here we can only present a very brief overview of theories that can explain why firms may not always operate efficiently.

2.4.2 The Managerial Theories of the Firm

The conventional theory of the profit-maximising firm has been criticised as being much too unrealistic and narrow in the modern economy where a divorce of ownership and control exists in large organisations. In its place, managerial theories of the firm have been developed. Each of the managerial theories argues that the controlling management group will pursue their own interests and utility, rather than maximising the profit of the firm, although they are always subject to some kind of profit constraint. For example, firm's managers are most likely to seek those objectives from which they obtain prestige, power and greater personal monetary reward. In so doing, costs may not be minimised and a level of organisational slack would be built into the system (Brewster, 1997).

Baumol (1959) introduces the sales-maximisation model which argues that the managerial objectives (income, power, prestige, etc.) are highly correlated with sales revenue. Thus, Baumol suggests that the prime goal of management would be to maximise sales revenue after achieving some minimum level of profit necessary to satisfy shareholders. Marris (1964) develops a dynamic model of the firm by

assuming that the managerial objective is to concentrate on the maximisation of firm growth over time. Williamson (1964) formulated a more general managerial utility-maximising model in which managers attempt to maximise their own utility rather than to maximise the profit of the firm. He suggests that managers manifest 'expense preferences' which means managers achieve their objectives by spending some of the firm's potential profits for unnecessary purposes thereby increasing managerial satisfaction or utility.

In the 1970's managerial theories of the firm have developed in terms of principal-agent analysis. This analysis of the firm stems from two main sources. One is the work of Spence and Zeckhauser (1971) and Ross (1973) which is concerned with problems of arranging contracts with imperfect and asymmetric information. Another approach is known as "agency theory" as developed by Jensen and Meckling (1976) and Fama (1980). In principal-agent analysis the firm is considered as a nexus of contracts between a firm, the principal, and its subcontractor, the agent. The principals (shareholders) hire a group of agents (managers) to carry out certain tasks such as to maximise the value of the firm. In the firm, the principals cannot have full knowledge and information about the firm's operation and performance capabilities. The agents, however, have more information or knowledge than the principals. The existence of asymmetric information and uncertainty leads to a problem of "hidden action" or "moral hazard". The agents can pursue their own interests such as high salaries, better working conditions, on-the-job leisure, job security, etc. but the principals are unable to fully observe the actions of the agents. In order to monitor the behaviour of the agent, the principal has to spend additional costs, known as agency costs. Jensen and Meckling (1976) describe the costs of agency as the sum of monitoring expenditures incurred by the principal, bonding expenditures incurred by the agent and the value of the lost residual borne by the principal and attributable to the agency problem. The principal also tries to affect and motivate the agent's behaviour in the interests of the principal by creating an incentive compatible reward structure and remuneration package. Overall, however, the principal-agent problem reduces the firm's profit and induces inefficiency in the firm.

Principal and agent theory could be relevant particularly to Chinese banking efficiency studies. In China, whenever the state banks (the major components of the Chinese banking sector) run into difficulty, the principal (the state) has to bail them out. The agents (bank managers), knowing that the principal is the ultimate resort of help, lend relentlessly resulting in huge non-performing loans that might never be recovered and leading to operate inefficiently.

2.4.3 The Behavioural Theories of the Firm

The behavioural theory of the firm argues that, in practice, the firm's ability, need or even desire to optimise (maximise) objectives may be questionable. The business world faced by firms is characterised by uncertainty and the absence of complete information. Under these circumstances, Simon (1959) developed a theory of the firm that emphasises satisficing and bounded rationality in the decision-making process instead of pursuing a maximisation goal[3]. Individuals or groups in the firm want to act rationally, but they are unable to do so because they possess cognitive limitations in solving complex problems and in processing information (Brewster, 1997). Therefore, bounded rationality exists in the process of decision-making and decision-makers exhibit 'satisficing' behaviour which is set in terms of some aspiration level, rather than optimising behaviour. As a consequence, a firm operating this way will not keep costs down to a minimum and this results in productive inefficiency.

Cyert and March (1963) note that, building on the work of Simon (1959), the firm as an organisation is not a unified structure but a coalition of various participants such as owners, managers workers customers and so forth. Each of these groups or individuals will have varying interests and objectives. Moreover, the firm itself has five objectives – production, inventory, sales, market share, and profit. Some of the objectives may be conflicting. Consequently decision-making within the firm is a continual process of bargaining and aspiration level, in which side payments are made to ensure compliance or to entice individuals into some subgrouping. However, there may be a disparity between the resources available to the firm and the payments required to keep factors in

[3] The word satisfice was coined by Herbert Simon as a portmanteau of "satisfy" and "suffice".

their posts. The difference between total resources and total payments is termed organisational slack. For instance, wages in excess of those required to maintain labour may be paid. This organisational slack will increase unnecessary costs and reduce the overall efficiency of the firm. In a stable environment, the payments may converge towards aspiration levels thereby leading organisational slack to be close to zero. But in practice it is clear that the environment is not stationary. Not only are there business cycles, but there is the onward surge of technological progress, which ensures that firms must continue to strive to maintain themselves on a best-practice frontier. Given this flux, it is possible for inefficient firms to survive in the market (as long as they are not too inefficient) (Dobbs, 2000).

2.4.4 The X-efficiency Theory of the Firm

The X-efficiency theory which links behavioural theory and managerial utility theory was formulated in a succession of Leibenstein's papers (1966, 1975, 1977, and 1978). X-efficiency describes the general efficiency of a firm (given the resources it uses and the best technology available) in transforming inputs at minimum cost into maximum outputs. Leibenstein criticises the assumption of neoclassical theory that firms maximise profit. He claims not only that firms cannot maximise profit but that many of them maximise managerial-utility instead (Demsetz, 1995).

Leibenstein justifies his rejection of neoclassical theory by studies offering evidence of differential performance across firms. Leibenstein argues as follows:

> *One idea that emerges from this study is that firms and economies do not operate on an outer-bound production possibility surface consistent with their resources. Rather they actually work on a production surface that is well within that outer bound. This means that for a variety of reasons people and organisations normally work neither as hard nor as effectively as they could. In situations where competitive pressure is light, many people will trade the disutility of greater effort, of search, and the control of other peoples' activities for the utility of feeling less pressure and of better*

> *interpersonal relations. But in situations where competitive pressures are high, and hence the costs of such trades are also high, they will exchange less of the disutility of effort for the utility of freedom from pressure, etc.* (Leibenstein, 1966 p 413)

From the evidence, Leibenstein identifies two possible sources of inefficiency. One is a divergence between price and marginal cost, named allocative inefficiency. This divergence may be caused by monopoly, tariffs, and other impediments to competitive output rates. Another is labelled X-inefficiency which stems from the failure of businesses to achieve the lowest possible cost functions for producing their goods and this can account for wasted resources. X-inefficiency seeks to analyse intra-firm behaviour and relations and interactions of people within the firm, rather than the working of the price system. Leibenstein shows that inefficiency deriving from X-inefficiency is significant in comparison to inefficiencies deriving form allocative inefficiency.

Within X-inefficiency theory, Leibenstein (1978) identified non-maximising behaviour as the key idea of X-efficiency. The degree of X-inefficiency is primarily determined by the level of effort of individuals within the firm. The problem of principal–agent relationships is an important source of X-inefficiency. Moreover, due to the feature of incomplete contingent contracts between principals and agents, agents can evade the consequences of cost overruns and have no motivation to keep costs down. Then firms will be more X-inefficient.

2.5 The Measurement of Efficiency

Farrell suggested constructing the efficiency frontier using the observed sample of firms in the industry in question. The firms in the constructed frontier are defined to be efficient. Each firm is compared to a point on the efficient unit isosurface then a relative measure of efficiency is determined. Measuring efficiency and identifying peers by graphical techniques is only possible in simple cases. When a firm has

many inputs and outputs, more sophisticated techniques must be used to solve this problem. In the study of measuring efficiency, there are two separate streams: non-parametric approaches (data envelopment analysis, free disposal hull) and parametric studies (econometric studies, e.g., stochastic frontier, distribution-free). Non-parametric approaches are a linear programming technique for the evaluation of multiple-input/multiple-output firms. Parametric studies aim at improving the standard OLS estimates with the addition of an asymmetric structure for the residuals, so as to account for the distance between empirical observations and the theoretical efficient frontier. In this section, an overview of these frontier efficiency methodologies will be provided and our aim is to give a better understanding of the issues associated with measuring efficiency.

2.5.1 Data Envelopment Analysis

The idea of the non-parametric efficiency approach was originally presented in Farrell's (1957) seminal paper. However, his empirical work had been limited to the single–output case and did not deal with applications where large data sets with multiple input-outputs are involved. Moreover, this mathematical programming idea did not receive much detailed attention for about two decades, until the paper by Charnes *et al* (1978) was published. In this classic paper, they proposed a mathematical programming algorithm, termed data envelopment analysis (DEA), for assessing the performance of a set of homogeneous entities called *decision making units* (DMUs) which convert multiple inputs into multiple outputs. This approach forms an empirical production frontier or envelopment surface and measures and calculates efficiency relative to the constructed frontier. Since the pioneering work by Charnes *et al*. (1978) numerous papers have appeared which have extended and applied DEA methodology. Seiford (1997) lists over 400 papers in a comprehensive bibliography and Cooper *et al.* (2007) give over 2000 DEA references. Such rapid growth and widespread acceptance of DEA is testimony to its strengths and applicability.

CCR Model

Here we provide a description of one of the most basic DEA models, the CCR model, which was proposed by Charnes, Cooper, and Rhodes (1978). This model is used to measure the overall technical efficiency of decision making units (DMUs). They introduced a measure of efficiency for each DMU that is obtained as a maximum of a ratio of weighted outputs to weighted inputs. The ratio for every DMU has to be less than or equal to one. Here, it is possible to reduce the multiple-output / multiple-input situation for each DMU to a single virtual output and a single virtual input ratio. This ratio provides a measure of efficiency for a given DMU, which is a function of the weights of the virtual input-output combination- also called a function of the multipliers. Formally the efficiency for each DMU can be obtained by the following mathematical programming approach:

$$
\begin{aligned}
&\max h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \\
&subject \quad to: \\
&\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1;\ j = 1,2,\ldots,n, \\
&u_r, v_i \ge 0;\ r = 1,2,\ldots,s;\ i = 1,2,\ldots,m
\end{aligned}
\tag{2.1}
$$

where it is should be noted that x_{ij} is the observed amount of input of the *ith* type of the *jth* DMU ($x_{ij} > 0,\ i = 1,2,\ldots,m,\ \ j = 1,2,\ldots,n$) and y_{rj} is the observed amount of output of the *rth* type for the *jth* DMU ($y_{rj} > 0,\ r = 1,2,\ldots,s,\ \ j = 1,2,\ldots,n$). In other words, *jth* DMU uses an m-dimensional input vector to produce an s-dimensional output vector. Here, (x_{i0} , y_{r0}) is the input-output vector of the producer being evaluated. The objective function h_0 tries to maximise the ratio of virtual output to virtual input subject to the constraint that this kind of ratio for each DMU must be less than or equal to unity.

The variables u_r and v_i are the weights of output and input which must be non-negative and are determined by the above programming approach. However, a notable problem with this particular fractional formulation is that it has an infinite number of solutions; if (u^*, v^*) is optimal, then ($\alpha u^*, \alpha v^*$) will also be optimal for non-negative α. Thus Charnes *et al.* (1978) have transformed the above problem into an equivalent linear programming problem. They added an additional constraint $\sum_{i=1}^{m} v_i x_{i0} = 1$ so that the above transformation is achieved and the non-uniqueness problem identified above can be avoided. The notation changes from (u, v) to (μ, v) to reflect the transformation. The new linear programming problem is equivalent to the equations in (2.1). It can be written:

$$
\begin{aligned}
&\max_{\mu} z_0 = \sum_{r=1}^{s} \mu_r y_{r0} \\
&\sum_{r=1}^{s} \mu_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \quad j = 1,2,\ldots n \\
&\sum_{i=1}^{m} v_i x_{i0} = 1 \\
&\mu_r, v_i \ge 0; r = 1,2,\ldots,s; i = 1,2,\ldots,m
\end{aligned}
\tag{2.2}
$$

The above equations are known as the multiplier form of the DEA linear programming problem. Because the concept of duality exists in linear programming, the dual for DMU_0 can be derived as:

$$
\begin{aligned}
&\min_{\lambda} z_0 = \theta_0^{CCR} \\
&subject \quad to \\
&\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_0^{CCR} x_{io}, \quad i = 1,2,\ldots,m \\
&\lambda_j \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{2.3}
$$

The above problem is referred to as the envelopment form of DEA. Optimal solutions (θ, λ) are obtained for each of the DMUs being evaluated. The value of θ is the efficiency score for the particular DMU_0 and this efficiency score is a radial measure of technical efficiency, according to the Debreu-Farrell definition. A set of constraints assures that the value of θ is always less than or equal to unity and the efficiency score for each observed DMU is relative to other DMUs. DMUs for which $\theta = 1$ are identified as the technically efficient while when $\theta < 1$ we have a relatively inefficient DMU. The optimal λ can identify a project (boundary) point located on the constructed production frontier when the problem seeks the radial contraction of the input vector. Färe *et al*. (1994) point out that the CCR model imposes a feasible production set which is closed and convex, and presents constant returns-to-scale and strong disposability of inputs and outputs[4]. In later sections, some extension DEA models which relax some of its restrictive properties will be discussed.

The above DEA problem yields a piece-wise linear surface and some sections of this surface run parallel to the axes. So this radial efficiency measurement causes a difficulty in that for an efficient point, it is possible to reduce inputs without altering outputs or increase output without altering inputs. These input savings or output expansions are referred to as input or output slacks. Some authors (e.g., Ali and Seiford, 1993; Cooper *et al.* 2004) develop the following linear programming algorithm to deal with these slack problems:

[4] Constant returns-to-scale identifies inefficient units regardless of their scale size.

$$
\begin{aligned}
&\min_{\theta,\lambda,s_i^-,s_r^+} \theta_0 - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{i=1}^{s} s_r^+\right) \\
&\textit{subject to} \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{r0}, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_0 x_{io}, \quad i = 1,2,\ldots,m \\
&\lambda_j, s_r^+, s_i^- \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{2.4}
$$

Here the s_r^+, s_i^- are slack variables and ε is an infinitely small positive number. The above linear programming problem is solved by the two-stage procedure. The first stage minimises θ by solving (2.3). θ is known as weak efficiency and also called Farrell efficiency. Then we maximise the sum of slacks without altering the value of θ obtained from the first-stage results. DMUs attain full efficiency if and only if $\theta = 1$ and all slacks: $s_r^+ = s_i^- = 0$. This full strong efficiency satisfies the conditions for Pareto-Koopmans efficiency[5]. In sum, this two stage procedure ensures the identification of an efficiency frontier point by maximising the sum of slacks required to move from a Farrell efficient frontier to a Koopmans efficient frontier (Coelli, *et al.*, 2005).

BCC model

In Charnes *et al.* (1978)'s original paper, it was pointed out that the model assumes constant returns to scale (CRS). This assumption is appropriate only when all DMUs are operating at an optimal scale. But in the real word many factors such as constraints on finance, government regulations and imperfect competition may cause some DMUs not to operate at the optimal scale. Therefore, in this situation, the measures of technical efficiency using the CCR model will be confounded by scale inefficiencies. Subsequently Banker, Charnes and Cooper (1984) drop the CRS assumption. They propose a model that takes into account the effect of returns to scale within DMUs

[5] Pareto-Koopmans efficiency is a more strict definition of technical efficiency when contrasted with Farrell's definition. It defines a DMU as achieving efficiency if and only if it is not possible to improve any input or output without worsening any other input or output.

called the variable returns to scale (VRS) model or BCC model. The purpose of the VRS assumption is to attempt to determine the most efficient scale size for each DMU and at the same time, to identify its technical efficiency.

Banker *et al.* (1984) adds a convexity condition for λ_j: $\sum_{j=1}^{n}\lambda_j = 1$, which ensures that an inefficient DMU is only compared with similar sized DMUs. With this added constraint, the reference set is changed from the conical hull in the case of the CCR model to the convex hull in the case of the variable returns to scale model. This change ensures that the tested DMU is compared with a lesser number of combinations. Thus, technical efficiency scores provided by the CCR model are greater then or equal to those in the BBC model.

The input-oriented BCC model for DMU_0 in envelopment form can be written formally as:

$$
\begin{aligned}
&\min_{\theta,\lambda,s_i^-,s_r^+} \theta_0^{BCC} - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{i=1}^{s} s_r^+\right) \\
&subject \quad to \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{r0}, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_0 x_{io}, \quad i = 1,2,\ldots,m \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j, s_r^+, s_i^- \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{2.5}
$$

Solving the above problem for each DMU, BCC efficiency scores, θ, are obtained. These scores are also called the pure technical score since they are obtained from a model which allows for variable returns to scale and eliminates the problem of scale

efficiency from the analysis.

Furthermore, if $\sum_{j=1}^{n} \lambda_j = 1$ is replaced by $0 \le \sum_{j=1}^{n} \lambda_j \le 1$, then the non-increasing returns to scale (NIRS) envelopment model is obtained. That is if we replace $\sum_{j=1}^{n} \lambda_j = 1$ with $\sum_{j=1}^{n} \lambda_j \ge 1$, then we obtain the non-decreasing returns to scale (NDRS) envelopment model. These return to scale models are summarised in Färe *et al*. (1985), Aly *et al*. (1990) and Banker and Thrall (1992).

In the preceding analysis, DEA models are called input-orientated DEA models. The input-orientated DEA model maximises the proportional reduction in inputs as much as possible, given the current level of outputs. On the other hand, it is also possible to seek the proportional augmentation in outputs keeping at most the current level of inputs. Thus the output direction can also be applied in the above models. In the oriented models the envelopment surface (efficiency frontier) remains the same for either VRS or CRS. But the measures of inefficient firms may differ between the two methods. The choice of an appropriate orientation is made according to which quantities (inputs or outputs) the managers have most control over. Thus, for example, if producers are required to meet market demands, and if they can freely adjust input usage, then an input-oriented model seems to be appropriate. Or the firms may be given a fixed quantity of resources and asked to produce as much output as possible. Then an output-oriented model would be more appropriate (see. Coelli, 1998). However, some researchers have pointed out that the choice of orientation has only a minor effect on the scores obtained and therefore it may not be a crucial issue (see. Coelli and Perelman, 1999).

The DEA models of economic efficiency

The above DEA models only use quantity data to capture technical efficiency and cannot account for allocative efficiency. However, if price data are available, it is

possible to extend DEA models so that they measure economic efficiency. The objective of extended DEA models is to minimise cost or maximise revenue or profit (see Färe *et al*.,1985; Aly *et al*.,1990; Lovell,1993)

For the case of VRS cost minimisation DEA, economic (cost) efficiency can be solved by employing the following linear programming problem:

$$
\begin{aligned}
&\min_{\lambda, x_i} \quad w_{i0} x_{i0}^* \\
&\textit{subject to} \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - y_{r0} \geq 0, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j x_{ij} - x_{i0}^* \leq 0, \quad i = 1,2,\ldots,m \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{2.6}
$$

Where x_{i0}^* is the cost minimising input quantities for the evaluated firm, given the input prices w_{io} and output levels y_{ro}.

Based on an optimal solution (x_{ij}^*, λ_j) of the above linear programming problem, the cost efficiency of the evaluated firm is calculated as the ratio of the minimum cost to observed cost, that is, $CE = {w_{ij} x_{ij}^*}/{w_{ij} x_{ij}}$.

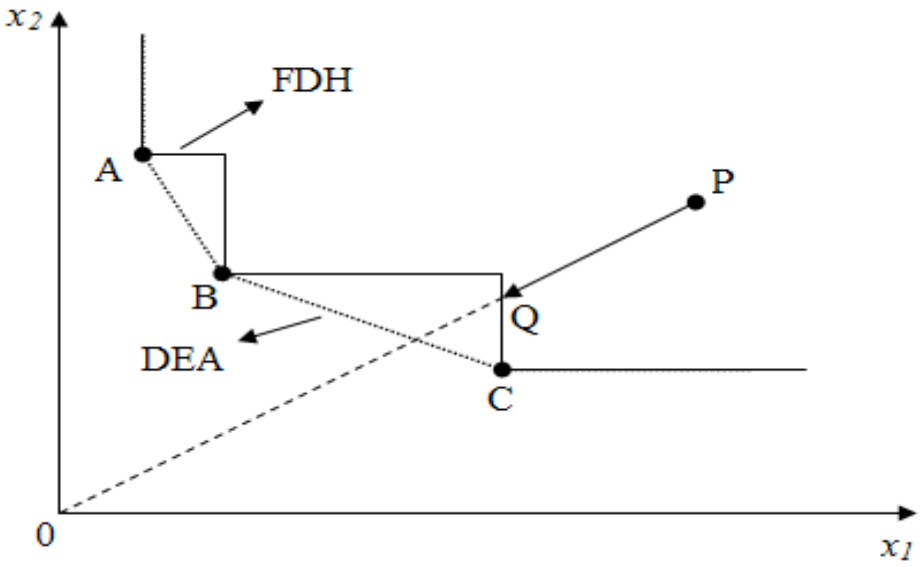
The estimation of revenue efficiency is similar to that of the estimation of cost efficiency. However, the objective here is to maximise revenues by using an output-oriented approach rather than to minimise costs by an input-oriented approach.

A variety of other DEA models have been developed to address specific issues in the literature. For instance, Banker and Morey (1986) proposed a model to assess DEA efficiency involving the effects of exogenous environment factors. Land *et al*. (1993) developed a stochastic DEA model which tries to capture the influence of noise. Thanassoulis and Dyson (1992) proposed models to estimate target input and output levels to render a firm efficient under pre-specified preferences regarding improvements to output and input levels. Tone (2001) proposed a slacks-based measure (SBM) model which deals with slacks directly but neglects the radical characteristics of input and outputs. Tone (2002) developed the New cost DEA model which is motivated by the idea that the unit prices might not identical among DMUs.

2.5.2 Free Disposal Hull

Another non-parametric frontier model which has received some research attention is the Free Disposal Hull (FDH) model as first formulated by Deprins *et al*. (1984) and extended by Tulkens (1993). The FDH approach can be viewed as a special case of the DEA model. The FDH approach relaxes the assumption of convexity and presumes that no linear substitution is possible between observed input or output combinations on a piecewise linear frontier. The FDH production possibilities set is composed only of the DEA vertices and the free disposal hull points interior to these vertices (Berger and Humphrey, 1997) and this ensures that efficiency evolutions are affected from only actually observed performances. The FDH model is formulated by adding to equation (2.6) the additional constraints $\lambda_j \in \{0, 1\}$, $j = 1,...,n$ to relax convexity. The FDH problem is a mixed integer programming problem. The DEA and FDH frontiers are compared in Figure 2.4. The FDH frontier has a staircase shape and envelops the data more tightly than the DEA frontier does. Therefore, the FDH approach typically generates larger estimates of the efficiency score than does the DEA approach. Consequently, slack is much more serious problem in FDH than in DEA.

Figure 2.4 Free Disposal Hull (FDH)



Source: Lovell (1993, p 32)

2.5.3 Functional Form for the Parametric Methods

In some engineering or physical production processes, it is possible to determine the exact form of the production function. However, in most industries, especially in the services sector, the exact production or cost function is not known. Therefore, we have to use some approximation to the production or cost function, which specifies the algebraic (functional) form for estimating the relationship between the dependent and explanatory variables, through which to analyse efficiency. This in turn means the measurements of inefficiency are the deviations of cost away from some minimal levels found in the data rather than from any true technologically based minima.

Cobb-Douglas Functional Form

The Cobb-Douglas functional form of the production function is widely used to represent the relationship of inputs to outputs, and was developed by Cobb and Douglas (1928). The Cobb-Douglas form of the cost function is

$$TC = \alpha_0 \prod_{i=1}^{n} y_i^{\alpha_i} \prod_{j=1}^{m} p_j^{\beta_j}$$

or upon taking logarithms:

$$\ln TC = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln y_i + \sum_{j=1}^{m} \beta_j \ln p_j$$

where, TC is total costs, y_i is the *ith* output, p_j is the price of the *jth* input and α_0, α_i and β_j are parameters to be estimated, symbolising the cost elasticities of the outputs and input prices.

The Cobb-Douglas cost function is homogeneous of degree one in inputs prices, only if $\sum_{j=1}^{m} \beta_j = 1$. This linear homogeneity restriction is imposed in the estimation of the cost function and implies a proportional increase of all input prices results in the same proportional increase of total costs. The Cobb-Douglas cost function is easy to estimate and the results are easy to interpret as well. However, the main shortcoming of the Cobb-Douglas production function is that it is a first-order approximation and thus it exhibits a constant value for elasticity of scale. Therefore, it is not possible to test within the Cobb-Douglas framework whether different firms exhibit different values for economies of scale (Kuenzle, 2005). Consequently, some more flexible functional forms have been developed to address this problem.

Translog Functional Form

One of the most important developments for econometric frontier modeling was the development of the translog (transcendental logarithmic) production function by Christensen *et al* (1973). They use a second-order Taylor expansion as a local approximation to some unknown 'true' underlying production function.

Murray and White (1983) first used the translog function to estimate economics of scale for the banking industry, and since then the translog functional form has become one of the most popular functional forms through which to estimate bank efficiency. They

proposed the translog cost function which relates minimum attainable costs to input prices and output quantities in an explicitly non-linear fashion[6]. This type of flexible functional form permits variable returns to scale and estimates the typical U-shaped average cost curve. The translog cost function can be specified as follows:

$$\ln TC = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln y_i + \sum_{j=1}^{m} \beta_j \ln p_j + \frac{1}{2}\sum_{i}^{n}\sum_{k}^{n} \sigma_{ik} \ln y_i \ln y_k$$
$$+ \frac{1}{2}\sum_{j}^{m}\sum_{h}^{m} \gamma_{jh} \ln p_j \ln p_h + \sum_{i}^{n}\sum_{j}^{m} \delta_{ij} \ln y_i \ln p_j + \varepsilon$$

where, TC is total costs, y_i is the *ith* output, p_j is the price of the *jth* input and ε is the error term. Because the duality theorem requires that the cost function should be linearly homogeneous in input prices, the following restrictions are imposed on the parameters of the cost function equation in order to satisfy the homogeneity condition: $\sum_{j}^{m} \beta_j = 1; \sum_{j}^{m} \delta_{ij} = 0; \sum_{j}^{m} \gamma_{jh} = 0$. In addition, symmetry restrictions are imposed on the second-order parameters, that is, $\sigma_{ik} = \sigma_{ki}$; $\delta_{ij} = \delta_{ji}$ and $\gamma_{jh} = \gamma_{hj}$.

While the translog functional form is one of most widely used functional forms in the empirical literature on bank efficiency, it has some disadvantages that have led some researchers to use alternative cost functional forms. A limitation of the translog function is that it imposes a symmetric U-shape on the average cost curve. The translog function does not necessarily fit the data well when it is far removed from the mean in terms of output size (Berger and Mester, 1997). One approach to solve this problem is to use the Fourier functional form because a Fourier series is capable of representing any function form well throughout the entire range of data (Gallant,1982). The Fourier functional form contains a linear combination of the sine and cosine functions. It gives a flexible and global approximation to the unknown cost or profit function. Several studies have shown the Fourier-flexible functional form is superior

[6]Translog cost function is known as a nonhomothetic function and allows the ratios of cost minimising cost input demands to depend on the level of output.

to the commonly specified translog form in estimating bank cost functions (see, McAllister and McManus, 1993; Mitchell and Onvural, 1996; Berger *et al*., 1997; Berger and DeYoung, 1997).

Other functional forms have also been specified in the bank efficiency literature. Diewert (1971) proposed the generalised Leontief cost function. Mester (1992) estimated a hybrid translog function. Berger *et al* (1993) estimated a Fussy normalised quadratic variable profit function and Pulley and Braunstein (1992) applied a composite cost function.

2.5.4 Stochastic Frontier Analysis

As a very popular method for estimating efficiency, the stochastic frontier analysis proposed by Aigner *et al*. (1977), Battese and Corra (1977), and Meeusen and van Den Broeck (1977), is motivated by the idea that deviations from the frontier might not be totally under the control of the DMUs being studied. SFA allows for random errors associated with the choice of the functional form, resulting in a stochastic frontier. It is often referred to as a composed error model where the part representing statistical noise follows a symmetric distribution and the other part, representing inefficiency, follows a particular one-sided distribution[7].

To illustrate the essential idea of the stochastic frontier approach, consider the single-equation stochastic cost function model:

$$\ln C_i = \ln C(y_i, w_i) + \varepsilon_i = \ln C(y_i, w_i) + v_i + u_i$$

where C_i is the observed total cost, y_i is a vector of outputs, w_i is an input price vector, v_i is a two-sided noise component, and u_i is a nonnegative disturbance which represents

[7] Statistical noise represents those external events which cannot be controlled by firms, such as luck, labor market conflicts, climate, topography and machine performance.

the individual firm's deviations from the efficient cost frontier and serves as a proxy for both technical and allocative efficiency. $C(y_i, w_i)$ is a deterministic cost frontier and the stochastic cost frontier is $C(y_i, w_i)\exp(v_i)$.

The most common distributional assumption is the normal distribution for v_i and the half-normal or exponential distribution for u_i, proposed by Aigner *et.al* (1977) and Mester (1993). The assumption of half-normal or exponential distributions term on inefficiency imposes a restriction that most firms are clustered near full efficiency, with higher degrees of inefficiency being increasingly unlikely (Berger, 1993). But this is not necessarily true and the inefficiencies could be more evenly distributed. Other studies have argued that alternative distributions for inefficiency may be more appropriate than the half-normal. Stevenson (1980), and Berger and DeYoung (1997), for example, use the truncated normal model. Greene (1990) considers the normal-gamma distribution model. However, these flexible distributions of inefficiency may make it difficult to separate inefficiency from random error in a composed-error framework, because the truncated normal and gamma efficiency distributions may be close to the symmetric normal distribution assumed for the random error (Berger and Humphrey, 1997).

The parameters of the frontier model and the composed error, ε_i, can be obtained using either the maximum likelihood (ML) estimation or the corrected ordinary least squares (COLS) directly[8]. Some studies suggest that ML estimation is the preferred method. For example, Coelli (1995) and Olesen *et al.* (1980) show that ML estimation tends to outperform COLS in large sample sizes. Specifically, "the ML estimator can be shown to be consistent and asymptotically normally distributed (CAN) with variances that are no larger than the variances of any other CAN estimator (that is,, the ML estimator is asymptotically efficient)" (Coelli *et al*. 2005, pp 218).

Next step, observation-specific estimates of inefficiency can be obtained by using the distribution of the inefficiency term conditional on the estimate of the entire composed

[8] See Battese and Coelli (1992, 1995), Coelli (1995) and Fried *et.al* (1993)

error term (Jondrow *et.al.*,1982). In other words, inefficiency measures are taken as the conditional mean or mode of the distribution of the inefficiency term, given that the observation of the composed error term, that is, E[*exp(u|ε)*] is used to measure inefficiency.

2.5.5 Distribution Free Approach

The distribution free approach (DFA) is a panel estimation method which avoids imposing distributional assumptions on the error component. DFA was introduced by Schmidt and Sickles (1984) and Berger (1993). DFA specifies a functional form for the efficiency frontier as does SFA, but it uses a different way to separate the inefficiencies from the residual. DFA disentangles inefficiencies from random errors by assuming that inefficiencies are relatively stable and should persist over time. Random errors are ephemeral and should tend to cancel one another out over time by averaging. In particular, a cost or profit function is estimated for each period of a panel data set. The residual in each separate regression is comprised of the inefficiency and random error terms. Since the random error component is assumed to average out over time, the average of a bank's residuals from all of the regressions is an estimate of the inefficiency of the bank.

Because no restrictive assumptions are imposed on the distribution of either inefficiency or the random error, the distribution-free approach is easier to implement than the stochastic frontier approach because it does not require the use of maximum likelihood methods to estimate the cost or profit function. We can estimate the function either by generalised least squares (GLS), as in Schmidt and Sickles (1984) or by using ordinary least squares (OLS), as in Berger (1993). The inefficiency is then estimated for each firm as the difference between its average residual and the average residual of the firm on the frontier. This gives the formula:

$$INEFF_{it} = \exp(\min(\ln \bar{\varepsilon}_t) - \ln \bar{\varepsilon}_{it})$$

where $\ln \bar{\varepsilon}_{it}$ is the average residual over the period and $\min(\ln \bar{\varepsilon}_t)$ is the minimum value of the average error term for all firms in the sample.

A problem with DFA is that it may give misleading results if the period chosen is too long, the inefficiency component of the error term is not constant over time or if the number of available data years is not sufficient to average out the random error term. Thus the accuracy of the efficiency results may depend on the length of the period of the study. De Young (1997b) shows that a six year time period is long enough to address all these issues.

2.5.6 Thick Frontier Approach

The thick frontier approach (TFA) was developed by Berger and Humphrey (1991, 1992). It specifies a functional form for the frontier cost function as do the other parametric frontier approaches. But this approach estimates a thick frontier rather than a frontier *edge* for measuring efficiencies and also avoids distributional assumptions for cross-sectional data. As it is usually implemented, this method estimates the cost function for both the lowest average cost quartile of firms and the highest average cost quartile of firms. Firms in the lowest average cost quartile are assumed to be of greater than average efficiency and to form a thick frontier. Similarly banks in the highest performance quartiles are assumed to have less efficiency than average. The differences in predicted performance between the highest and lowest average-cost quartiles reflect a combination of inefficiencies and exogenous differences in the regression. The error terms within each of the frontiers are assumed to represent random error and luck. In most applications, TFA predicts cost efficiency using the differences in the parameters of the upper and lower cost frontiers, whereas the differences in the lowest and highest cost function are estimated as exogenous factors. TFA does not provide point estimates of efficiency for individual DMUs but instead provides an estimate of the overall level of efficiency. One potential disadvantage of TFA is that its assumptions seldom hold exactly. Because of this TFA may not yield precise estimates of the general level of overall efficiency. But Berger and Humphrey (1991, pp121) defend the thick frontier approach by nothing that “precise measurement

is not (our) main purpose. Rather, (our) goals are to get a basic idea of the likely magnitude of inefficiencies".

2.5.7 Is There A 'Best' Frontier Method?

The non-parametric techniques for estimating the frontier and the measurement of efficiency relative to the constructed frontier differ from the parametric techniques. The two approaches employ different techniques to envelop data more or less using different assumptions for random noise and for flexibility in the structure of the efficient frontier. The primary advantage of the econometric approach is its ability to accommodate both the random error and the inefficiency component in efficiency estimation. However, this methodology specifies the functional form that presupposes the shape of the efficient frontier and assumes a probability distribution for the efficiency level. Once these assumptions are mis-specified, the measured efficiency will have errors. The non-parametric approach avoids this type of specification error because it does not require a priori assumption about the analytical form of the production function or an assumed probability distribution for efficiency. However, it suffers from the drawback that it does not allow for random errors owing to measurement error and luck in the optimisation problem and all deviations from the frontier are reported as inefficiency. Since both parametric and non-parametric techniques have their own merits and the true level of efficiency is unknown, the choice of a suitable estimation method has been quite controversial. Some researchers (e.g. Ferrier and Lovell, 1990; Bauer *et al*. 1998; Eisenbeis *et al*., 1999; Huang and Wang, 2002) argue that it is not necessary to have a consensus on which is the best method for measuring frontier efficiency. Instead, they recommend a checking process which uses more than one methodology to assess the robustness of results. This methodological cross-checking provides useful information and diagnosis for regulatory analysis and the decision maker[9].

[9] Methodologies cross-checking is advocated by Charnes, Cooper and Sickles (1988)

2.6 Summary and Conclusion

This chapter presents a theoretical framework relating to productive efficiency. Efficiency measures deviations in performance from the predicted performance of the "best practice" firms on the efficient frontier, facing a number of exogenous market factors. Economic efficiency refers to the ability of a firm to select the input and/or output levels and mixes to optimise an economic goal, such as cost minimisation or profit maximisation (Lovell, 1993). It can be decomposed into pure technical efficiency, allocative efficiency and scale efficiency. When a firm maximizes the output from a given level of input, pure technical efficiency occurs. Allocative efficiency measures the extent to which a firm is able to use inputs and outputs in optimal proportions, given prices and the production technology. A firm has scale efficiency when it operates in the range of constant returns to scale. Scope efficiency occurs when a firm operates in different diversified locations. The economic (cost) efficiency analysis provides an overall, objectively determined, numerical efficiency value and ranking of banks. Therefore, this research intends to focus on analysing cost efficiency levels in the Chinese banking sector.

This chapter also discusses various theories of the firm which are related to the efficiency of firm. Traditional neoclassical theory views the firm as a unified rational economic agent. The firm should operate efficiently; otherwise the market will penalize the inefficient firm by driving it out of the market. However, this theory does not explain why firms may not able to operate efficiently. We then review some alternative theories of the firm such as the managerial theory of the firm, the behavioural theory of the firm and the X-efficiency theory of the firm. These theories highlight the internal inefficiency of the firm and can explain why firms may deviate from the optimal level of resource utilisation.

Finally, this chapter reviews the main frontier approaches (both non-parametric and parametric) used to measure the efficiency of firms. The non-parametric approach constructs a piecewise linear combination or frontier that connects the set of 'best-practice observations' in the data set under analysis and measures efficiency

relative to the constructed frontier. It does not allow for random errors owing to measurement error and any deviation from the frontier is considered as inefficiency. The parametric approach allows for noise in the measurement of efficiency but it requires a pre-specified functional form for the efficient frontier and the distribution of efficiency. It includes the stochastic frontier analysis, the distribution free approach and the thick frontier approach. The main difference between these models is the way in which inefficiencies are separated from the random errors and the probability distributions assumed for the inefficiencies. Both non-parametric and parametric approaches have their own advantages and disadvantages and there is no agreement in the literature regarding which approach can produce a better estimate of efficiency scores. Therefore, methodological cross-checking is highly recommended for efficiency analysis. The following chapter provides an extensive summary of the empirical evidence in the banking efficiency literature, especially those which employ two or more frontier techniques for the estimation of bank efficiency and seek to examine bank efficiency in emerging markets or developing countries.

Empirical Studies of Bank Efficiency

3.1 Introduction

The previous chapter briefly introduced relevant theoretical issues relating to the efficiency with which firms conduct their productive operations and reviewed both the parametric and non-parametric approaches utilised in the literature for both measuring and assessing efficiency. Starting in the late 1980s, a substantial research effort has gone into measuring the efficiency of financial institutions, particularly commercial banks. A comprehensive review of efficiency studies as they relate to financial institutions has been provided by Berger and Humphrey (1997). They survey 130 studies that between them apply at least five major frontier efficiency analyses to financial institutions across 21 countries. Within this survey, applications of non-parametric (69 studies) and parametric approaches (60 studies) are split fairly evenly. Therefore, this chapter focuses mainly on reviewing the related empirical literature on the efficiency of banks. We are particularly interested in banking efficiency studies that have compared the parametric and non-parametric methodologies and have been applied to the data of developing countries, including China. Moreover, this chapter also highlights the studies which have investigated the important determinants of banking efficiency.

The remainder of this chapter is structured as follows. Section 3.2 briefly reviews empirical banking efficiency studies which apply two or more frontier techniques to a common set of data for the estimation and assessment of efficiency levels. Section 3.3 provides a brief survey of the literature devoted to banking efficiency as it affects transition and developing countries. Section 3.4 reviews empirical studies on the efficiency of the Chinese banking sector. Section 3.5 introduces a number of hypotheses that may help explain variations in the efficiency levels of banks and outlines the relationship between ownership structure, size, deregulation, market discipline and market structure and the level of banking efficiency. Finally, section 3.6

summarises the main conclusions of this chapter.

3.2 Evidence on Earlier Banking Efficiency Comparisons

Despite the vast literature on banking efficiency, only a handful of studies have used two or more frontier techniques for the estimation of bank efficiency on the same data set. These empirical studies aim to provide evidence about the consistency of efficiency frontier methods and obtain robust information regarding the efficiency of banks. Table 3.1 displays the main research on financial institution efficiency comparisons.

In the 1990's proponents of methodological cross-checking started to debate the relative advantages and disadvantages of the parametric and non-parametric approaches for measuring bank efficiency. These studies applied both linear programming and econometric methods to common data sets and conducted explicit comparisons of the results obtained from the two methods for measuring efficiency. This comparative method continues a practice initiated by Ferrier and Lovell (1990). Ferrier and Lovell (1990) analysed the cost structure of 575 U.S. banks by applying both the SFA and DEA methodologies. They find that both DEA and SFA methodologies generally draw similar conclusions on the level of average cost efficiency. One interesting result they find is that the DEA cost efficiency score is usually higher than the SFA efficiency score. This result seems to contradict the expectation that the DEA model generally returns higher inefficiency scores than the SFA model (Coelli *et al*., 2005). Ferrier and Lovell (1990) explain this outcome by suggesting that the DEA frontier is sufficiently flexible to envelop the data more closely than the translog cost frontier. When they decompose cost inefficiency into technical inefficiency and allocative inefficiency, both techniques lead to different conclusions on the magnitudes of the above two inefficiency scores. Furthermore, the rank correlation coefficients between DEA and SFA technical efficiency and cost efficiency are 0.014 and 0.017, respectively, and are not significantly different from zero. Thus, the efficiencies derived from DEA and SFA do not lead to consistent rankings. Ferrier and Lovell (1990) argue that the linear programming model and stochastic frontier model differ both in structure and in implementation and

that the debate over the attractiveness of the two approaches will be substantial and will continue for some time.

Drake and Weyman-Jones (1996) use both parametric (SFA) and non-parametric techniques (DEA) to the estimate cost efficiency of 46 British building societies. They report that the inefficiencies in the building society sector are of the order of 12% to 13% and that there is a very high rank-order correlation between the two sets of efficiency scores. Resti (1997) provides further evidence on European banking efficiency. He examines cost efficiencies for a panel sample of 270 Italian banks using multiple frontier techniques. He shows that the mean efficiency scores range from 66% to 76% under both DEA and SFA, and also that there is a very high positive correlation for score rankings between the two approaches. Based on these similarities, Resti (1997) argues that results obtained from DEA and SFA do not differ substantially. Moreover, he reports that efficiency gaps exist when efficiency values are grouped by geographic areas and bank size. Specifically, DEA and SFA generate very similar results grouped by geographic area classes but the results grouped by size classes are not consistent. Resti (1997) also reports that for the Italian banks he studied DEA scores (variable returns to scale model) increase as bank size increases. In contrast, the econometric approach yields results in the opposite direction; namely, that the efficiency of Italian banks declines with the size of the affected banks.

A very significant study was authored by Bauer, *et al*. (1998), who applied four frontier approaches - SFA, DFA, TFA and DEA - on a panel data set of 683 large U.S. banks over the 12 year period from 1977 to 1988. Bauer, *et al.* (1998) notes in particular that the approach taken in their study provides a comprehensive investigation of the consistency of the various frontier approaches that had not previously appeared in the banking efficiency literature. Bauer, *et al.* (1998, p. 87) argue that "*it is not necessary to have a consensus on which is the single best frontier approach for measuring efficiency*"; instead, they propose six consistency conditions that efficiency measures derived from the various approaches should meet if they are to provide useful information for decision makers. Specifically, the efficiency estimates derived from the different techniques should be consistent in the distribution of efficiency levels, the rank order correlation of efficiency levels should be very high, and the identification of best and

worst practice firms should be the same. Also the efficiency estimates should be stable over time and consistent with competitive conditions and traditional financial performance measures. They argue that the first three consistency conditions may be designed for measuring the degree to which various approaches are mutually consistent and the remaining three conditions may be thought of as measuring the degree to which the efficiency measures derived from the various frontier techniques are consistent with reality or are believable.

Bauer, *et al.* (1998) find that the mean cost efficiency of six parametric approach models is much higher than that of two nonparametric approach models, averaging 83% for the parametric models as against 30% for the nonparametric models. The average rank-order correlation between the DEA and the parametric techniques is only 10%, which suggests that the nonparametric and the parametric approaches give only very weak consistency in their efficiency scores. Moreover, the identification of best and worst practice banks is not consistent between the DEA and parametric techniques. However, there is noticeable similarity in the distributional characteristics of the efficiency scores and the efficiency rank-order correlation when, instead of comparing the nonparametric with parametric approaches, the comparison is within one of these categories. All approaches are stable over time although DEA generally shows slightly better stability than parametric techniques. This may indicate that many banks tend to maintain their efficiency levels over time. Bauer, *et al.* (1998) also find that parametric techniques seem to be more consistent with the competitive conditions in the market which suggests that because competition should drive most very inefficient banks out of the business, most of the remaining or "long term" banks should be reasonably efficient. Finally, they show that parametric methodologies seem to be consistent with the standard non-frontier (that is, financial ratio) performance measures. The nonparametric measures, in contrast, are only weakly related to financial ratio performance measures. In sum, Bauer *et al.* (1998) conclude that there is no dominant way to assess the efficiency of a firm's productive operations - and banking firms in particular. Thus, when applying frontier efficiency analysis, the use of multiple techniques is highly recommended and the conclusions drawn from the methodological cross-checking analysis implied by the application of these multiple techniques should result in more robust and believable assessments of firm efficiency.

Eisenbeis *et al.* (1999) estimate the cost efficiencies of a sample of 254 large US bank holding companies over the period 1986-1991. In order to compare the robustness of the results obtained, they employ both a stochastic frontier approach and a linear frontier approach. They find that DEA inefficiency scores are two or three times larger than those generated by SFA, averaging 30% for DEA as against 15% for SFA. After banks are classified into size-based quartiles, they find that the level and variation of smaller banks' inefficiency scores on average are higher than those of larger banking firms. Moreover, the inefficiencies seem to persist over time. However, the persistence results are significantly greater for the linear programming estimates than they are for the econometric estimates. Furthermore, the efficiency rank-order correlations between the two approaches range from a low of 0.44 to a high of 0.58. Eisenbeis *et al.* (1999) conclude from this that significant differences may arise in the efficiency measures provided by the DEA and SFA techniques. Another contribution of Eisenbeis *et al.* (1999) is to explore the "informativeness" of the efficiency scores estimated by the DEA and SFA techniques[10]. For both techniques they examine the relationship between bank efficiency and their risk-taking behaviour, managerial competence and stock returns. They find that the SFA estimates have more explanatory power than the DEA estimates in explaining banks' risk-taking behaviour, managerial competence and stock price return behaviour. Summing up, they conclude that both parametric and non-parametric efficiency estimates produce reasonably good and "informative efficiency scores". However, the SFA estimates should be given more weight in assessments of banking efficiency than those provided by the DEA methodology.

To the author's knowledge, Huang and Wang (2002) is the only published study using an Asian data set which compares more than one variant of each efficiency assessment methodology. They evaluate the economic efficiency and economies of scale of 22 Taiwanese commercial banks over the period from 1982 until 1997, using DEA, SFA and DFA (Distribution Free Approach). They report that the average efficiency score generated by DEA is roughly the same as that for the SFA and DFA approaches.

[10] Most comparative studies only examine the consistency of the estimated efficiency scores obtained from two different approaches. However, they do not in general explore the information content of the efficiency scores they obtain.

However, Spearman rank correlation coefficients between the parametric (SFA and DFA) and non-parametric (DEA) efficiency measures are quite small and this indicates that these two techniques are not consistent in their efficiency rankings. However, like most previous studies, Huang and Wang (2002) report that whilst the efficiency measures they obtain are generally different across the alternative methodologies within methodologies the efficiency scores are generally quite stable across time. Furthermore, the Fourier flexible function seems to provide more stability and persistency in the efficiency measures over time than the translog function. With regard to the consistency between frontier efficiency and traditional performance measures, Huang and Wang (2002) report that parametric measures (SFA, DFA) correlate more with conventional performance measures (that is, financial ratios) than do the non-parametric measures (DEA). Regarding scale economics which is relevant for making decisions about mergers and acquisitions, Huang and Wang (2002) find evidence of scale economics under the parametric estimation approach. This may lead one to the conclusion that mergers reduce average total costs. However, against this Huang and Wang (2002) report no evidence of scale economies under the DEA methodology. Finally, Huang and Wang (2002) conclude that the particular frontier method used to measure efficiency can result in significantly different conclusions across several dimensions of the efficiency spectrum (e.g., relative value of the efficiency score, correlation between efficiency scores over time, the existence of scale economies). Given this, decision makers would be well advised to apply methodological cross-checking in order to insure that the conclusions they reach are not driven by chance and mis-specification.

Weill (2004) provides evidence about the consistency of efficiency frontier techniques on a European banking data set. He uses DEA, SFA and DFA to measure the cost efficiencies of banks in France, Germany, Italy, Spain and Switzerland. The study shows that the mean efficiency scores across the five countries vary widely, irrespective of the technique (DEA, SFA, DFA) used to measure efficiency. Weill (2004) reports that the average efficiency scores between the parametric (SFA, DFA) approaches and the nonparametric (DEA) approach are broadly comparable. However, the SFA and DFA efficiency scores are somewhat dissimilar. Against this, Weill (2004) also reports that whilst the SFA and DFA techniques return generally dissimilar measures of

efficiency for any given firm, yet the SFA and DFA efficiency scores are generally highly correlated. However, the correlation between the DEA and SFA and DEA and DFA efficiency scores are generally poor. These results are consistent with those reported by Bauer *et al.* (1998). Furthermore, Weill (2004) also investigates two important policy issues; namely, the relationship between cost efficiency and size and the link between differences in efficiency between banks and the specialised markets in which they trade and operate (e.g., co-operative banks, savings bank). Here mixed results are obtained. He finds some degree of consistency between efficiency and size from all three (DEA, SFA and DFA) frontier approaches. However, the link between efficiency differences and specialisation is dependent on which methodology is used. In general, Weill (2004) finds that the efficiency scores from the three cost efficiency frontiers lack consistency, although there are some similarities between them.

A recent bank efficiency study by Fiorentino *et al.* (2006) examines the robustness of the cost efficiency scores derived from the SFA and DEA approaches with five consistency checks. Their examination of consistency conditions is in the spirit of Bauer *et al.* (1998). The sample is collected from German universal banks according to year and banking group. The efficiency measures from SFA and DEA are substantially different in magnitude and variation in average efficiency level. They point out that the non-parametric (DEA) approach is much more sensitive to outliers due to the impact of measurement error[11]. This evidence supports Berger and Humphrey's (1997) suggestion that DEA should be used with care when large measurement errors are known to exist. The results also show that the efficiency scores obtained under the two methods are poorly correlated. The mean rank-order correlation between the DEA and SFA efficiency scores is only around 20%. However, when efficiency measures use DEA on a more homogenous banking group sample, the rank-order correlation increases to 45%. Moreover, Fiorentino *et al.* (2006) also report that there is little commonality between the most and least efficient quartile banks under the DEA and SFA approaches. Against this both the DEA and SFA techniques demonstrate reasonable stability in the efficiency scores they return over time. With

[11] Fiorentino *et al.* (2006) drop some extreme efficiency score observations and re-estimate the efficiency score with both DEA and SFA. They find that the DEA score increases dramatically but the SFA score is much more stable.

respect to the consistency of frontier efficiency measures and standard accounting performance measures (that is, financial ratios), they find that the correlation between frontier efficiency and traditional performance indicators is positive but quite low and may indicate that frontier measures contain additional information when compared to these standard performance measures. In conclusion, Fiorentino *et al*. (2006) show that there is very little consistency between both the efficiency scores and the conclusions to be gleaned from them under the parametric (SFA) and non-parametric (DEA) techniques.

Delis and Papanikolaou (2009) measure the cost and profit efficiency for 28 Greek commercial banks over the period from 1993 until 2005. Their results show that the DEA average cost efficiencies are much lower than those of SFA. Both approaches indicate that there is a positive relationship between cost efficiency and size, but the findings regarding the effect of ownership status are contradictory between the two approaches. Finally, they conclude that the efficiency scores obtained from the various methods are substantially different over time.

Overall, the empirical evidence from the recent literature generates mixed results for the comparison of frontier efficiency techniques. Some studies find a strong relationship between the findings of the different techniques, whilst others report a lack of consistency between the parametric and non-parametric approaches. But there is nonetheless some consensuses in the literature. First, these articles demonstrate that neither the nonparametric nor parametric method have an absolute advantage over the other. Nevertheless, in certain specific situations, depending on the number of units in the sample or on the amount of noise and inefficiency in the data, some estimation techniques may outperform others. Second, because each approach has specific advantages and disadvantages in comparison to other approaches and the efficiency measures derived from different methods offer valuable information, it is advisable to use the parallel application of competing methods to cross check results. The robustness or otherwise of the results should give the decision maker more useful and reliable information. Third, the comparison of different methods within the same categories shows more consistent results than that between different categories. Given the above conclusions, this study proceeds with an empirical analysis which uses both

parametric and non-parametric techniques applied to Chinese banks over an extended period of time in order add to the empirical evidence which is available in the area.

Table 3.1 Summary of the Frontier Efficiency Technique Comparisons

Author/ Date	Country	Sample	Methodology	Results
Ferrier & Lovell (1990)	U.S.	575 banks, 1984	DEA, (VRS) SFA, (translog)	DEA: Mean TE 84%; AE 95%; CE 79% SFA: Mean TE 91%; AE 83%; CE74% Spearman's rank correlation coefficient: 0.014-0.018 Mixed results: comparable mean but not consistent with efficiency rankings
Drake and Weyman-Jones (1996)	UK	46 building societies, 1988	DEA SFA	DEA: Mean TE 95%; AE 92%; Mean CE 87.5%; Spearman's rank correlation coefficient 0.9715 DEA and SFA providing extremely similar results
Resti (1997)	Italian	270 banks, 1988-92	DEA, (CRS; VRS) SFA, (restricted translog)	DEA: Mean CE 66%-76% SFA: Mean CE 69%-70% High correlation between two methods – 0.71-0.89 DEA and SFA results do not differ substantially
Bauer (1998)	U.S.	683 banks, 1977-88	DEA, (VRS) SFA; DFA;TFA, (translog)	DEA: Mean CE 21%-39% Parametric: Mean CE 87%-88% Spearman's rank correlation coefficient: 0.1 (between); 0.756 (with same category) Parametric methods consistent with one another, but non-parametric and parametric not consistent
Cummins and Zi (1998)	U.S.	455 life insurance companies 1988-1992	DEA, (VRS) FDH SFA; DFA, (translog)	DEA: Mean CE 46% FDH: CE 91% SFA Mean CE 61%-85% DFA Mean CE 91% Consistent within the set of econometric methods, while less consistent between econometric and mathematical programming

Table 3.1 Summary of the Frontier Efficiency Technique Comparisons (continued)

Author/ Date	Country	Sample	Methodology	Results
Eisenbeis *et al.* (1999)	U.S.	254 large banks 1986-1991	DEA, (VRS) SFA, (translog)	DEA Mean CE 60%-72% SFA Mean CE 81%-92% Spearman's rank correlation coefficient : 0.44-0.58 SFA seems to be more informative then DEA
Huang and Wang (2002)	Taiwan, (China)	352 banks 1982-1997	DEA, (CRS; VRS) SFA; DFA, (translog; fourier flexible)	DEA: Mean EE 58%-86.5% Parametric: Mean 63%-90% Low Spearman's rank correlation coefficient between DEA and parametric methods Translog and FF functional forms generate similar rankings.
Casu and Girardone (2004)	Italy	168 banks 1996-1999	DEA, (CRS; VRS) SFA, (translog; fourier flexible)	DEA: Mean CE 72% TE 86% AE 83% SFA: Mean CE 68-74% PE 82% Results consistent across methodologies
Weill (2004)	France, Germany, Italy, Spain Switzerland	688 banks 1992-1998	DEA SFA; DFA, (fourier flexible)	Mean CE: Fr 40-50%; Ger 60-83% It 67-84% Sp 63-78% Swi 44-65% No great similarities of efficiency level among different methods Efficiency rank correlations are high for parametric methods while quite low between non-parametric and parametric methods
Fiorentino *et al*. (2006)	Germany	34,192 banks 1993-2004	DEA SFA, (translog)	DEA: Mean CE 55% SFA: Mean CE 84% Average rank order correlation between DEA and SFA is around 0.2
Delis and Papanikolaou. (2009)	Greece	244 banks 1993-2005	DEA (VRS) SFA, (translog)	DEA: Mean CE 62%-90% SFA: Mean CE 72% - 85% Weak consistent rankings between DEA and SFA

Notes: TE = technical efficiency; AE = allocative efficiency; CE = cost efficiency;

3.3 Evidence on Bank Efficiency in Transition and Developing Countries

Zaim (1995) examines the effect of financial liberalisation on the technical efficiency of Turkish commercial banks, using the nonparametric DEA approach. The years 1981 and 1990 represent the pre and post financial liberalisation period, respectively. Zaim (1995) finds that the technical efficiency of Turkish banks has improved by 10%, on average after the implementation of the liberalisation programme implemented by the Turkish Government and which aims to create a more competitive banking environment. When the study decomposes overall technical efficiency into pure technical efficiency and scale efficiency, Zaim (1995) finds that most Turkish banks are operating under constant returns to scale and that technical inefficiency is mainly attributable to low pure technical efficiency.

Isik and Hassan (2002a) use the SFA approach to estimate the cost and "alternative" profit efficiencies of Turkish banks. The average cost and profit efficiencies over the years studied range from a low of 84% up to a maximum of 90%. The correlation coefficient between the cost and profit efficiencies is poor (only 19%) suggesting that high cost efficiency does not necessarily lead to high profit efficiency. Isik and Hassan (2002a) also examine the impact of bank size, corporate control and corporate governance and ownership on cost and profit efficiency. Their results suggest that domestic private banks are much more efficient than state-owned banks and smaller banks tend to be operating more efficiently than larger banks.

Hao *et al.* (2001) employ SFA to examine the cost efficiency of Korean banks over the period from 1985 until 1995. The authors point out that during the period from 1960 until 1980 the Korean government had a policy of consistent interference in the operations of banking and financial institutions and this, in turn, had an adverse impact on the efficiency of the banking system as well as on resource allocation throughout the Korean economy. However, after 1980 the Korean government began to privatise banks and deregulate its financial sector in order to alleviate the problems caused by governmental interference. Hao *et al.* (2001) show that the average cost efficiency score over the period from 1985 until 1995 is 89% and that there is no significant

efficiency improvement over this sample period. In the second stage regression, Hao *et al.* (2001) seek to indentify the key determinants of Korean banking efficiency. They find that banks with higher rates of asset growth, fewer employees per value of assets in place, larger amounts of core deposits and banks that operate nationwide tend to be more efficient. In addition, they find that efficiency levels are positively correlated with the level of foreign equity ownership but negatively correlated with the level of government ownership.

Using a stochastic cost frontier approach, Karim (2001) investigates banking efficiency in the four ASEAN counties (Indonesia, Malaysia, the Philippines and Thailand) over the period from 1989 until 1996. The average cost efficiency of these ASEAN banks deteriorates over this sample period. Karim (2001) suggests that the deterioration in efficiency over this period may have contributed to the Asian financial crises in 1997. Moreover, his results show that there are significant differences in banking efficiency across the four ASEAN countries. On average, Thai banks are the most efficient, followed by Malaysian banks, Indonesian banks, whilst Philippino banks are the least efficient. Karim (2001) also finds that privately owned banks are more cost efficient than state-owned banks and that larger banks tend to have higher cost efficiency scores than smaller banks.

Ataullah *et al.* (2004) provide a comparative analysis of the evolution of the efficiency of commercial banks in India and Pakistan covering the period from 1988 until 1998. They employ two alternative DEA specifications (loan-based and income-based models) to measure technical efficiency. They find that the overall technical efficiency of both Indian and Pakistani banks has improved gradually over the sample period. In the case of Indian banks, this improvement is attributed to both increases in pure technical and scale efficiency. For Pakistani banks, however, the increased overall technical efficiency is primarily attributed to an improvement in scale efficiency. Moreover, comparing the results of the loan-based and income-based models, they find that banks are relatively more efficient in generating earning assets than in generating income.

Fries and Taci (2005) employ the Battese and Coelli (1995) one-step SFA estimation procedure to estimate the cost efficiency of 289 banks in fifteen East European countries over the period from 1994 until 2001. During this period East European governments adopted policies which promoted the transformation of their socialist banking systems into market-oriented systems. Fries and Taci (2005) find that there are non-linear variations in cost efficiency over time and that the early stages of reform were associated with greater cost efficiency improvements than the later stages of the reform process. They also find that country level specific factors, such as banking systems with lower nominal interest rates, a higher proportion of total banking assets being owned by foreign majority-owned banks and higher intermediation ratios tend to be significantly associated with more favourable banking cost efficiency scores. Fries and Taci (2005) seek to explain the variation in estimated efficiency scores over the period of their analysis by correlating the efficiency scores they obtain with bank level factors such as ownership structure, market share and the capital to total assets ratio. At the bank level, Fries and Taci (2005) find that private banks are more cost efficient than state-owned banks and that majority foreign-owned banks show the most favourable cost efficiency scores amongst the different types of private banks. Fries and Taci (2005) suggest that one way of increasing the efficiency of the East European banking sector is for majority-owned foreign banks to take significant ownership interests in state-owned East European banks.

Sensarm (2006) uses a stochastic cost frontier approach to investigate the efficiency and total factor productivity (TFP) of Indian banks during the period from 1986 until 2000. He employs a one-step estimation procedure to estimate the cost efficiency of Indian banks and then decomposes TFP into technical change, scale effect and efficiency growth. Sensarm (2006) finds that banks have improved their performance during the sample period in terms of cost efficiency and TFP. His results suggest that deregulation in the Indian banking sector has achieved the desired effect of increasing Indian banking efficiency. Sensarm (2006) also investigates the role of ownership in determining cost efficiency and TFP growth. The results show that foreign banks exhibit the worst performance in terms of both cost efficiency and productivity growth when compared with Indian state-owned banks and private domestic banks.

Kyj and Isik (2008) investigate the x-efficiency and scale efficiency of commercial banks in the Ukraine over the period from 1998 until 2003 using the DEA technique. They estimate both a common efficiency frontier for all banks and separate efficiency frontiers for each bank size group (small, medium and large). They find that efficiency scores are significantly correlated between the common and separate frontier results. Their results also show that the average technical efficiency is only 47% and that the dominant source of inefficiency is driven by poor management decisions (pure technical efficiency) rather than there being any scale inefficiencies. They also examine the impact of size and ownership location factors on the efficiency of the Ukrainian banking sector. Here they find that large banks tend to be more pure technically efficient but less scale efficient than small banks. Moreover, the results suggest that joint venture banks with majority foreign ownership appear to be the most efficient and that a bank's geographic location is also an important determinant of its relative efficiency.

Table 3.2 Bank Efficiency Studies in Transition and Developing Countries

Author / Year	Sample	Method	Variables	Main Results
Zaim (1995)	42 Turkish banks in 1981 and 56 banks in 1990.	DEA	Outputs: demand deposits, time deposits and loans. Inputs: number of employees, interest expenses, depreciation and expenditure on furniture.	The implementation of financial liberalisation enhances banks' efficiency by 10% . Technical inefficiency is mainly attributed to low pure technical efficiency. State owned banks are more efficient than private banks.
Bhattacharyya *et al*. (1997b)	70 Indian banks, 1986-1991.	DEA	Outputs: advances, investments and deposits. Inputs: interest expense and operating expense.	Bank performance declined significantly between 1988 and 1991. State-owned banks more efficient than foreign and private banks. Capital adequacy has significant impact on the efficiency of foreign and domestic private banks.
Hao *et al*. (2001)	19 Korean private banks.	SFA	Dependent variables: total costs. Outputs: total loans, demand deposits and fee income. Input: borrowed funds and physical capital. Control variables: equity capital.	Banks with faster growth rates, fewer employees, and larger amounts of core deposits and operating nationwide are more efficient. The financial deregulation in 1991 had no significant effect on the level of banking efficiency.
Karim (2001)	82 Indonesian, 31 Malyasian, 27 Philippine and 15 Thai banks.	SFA	Dependent variables: total cost. Outputs: commercial and industrial loans, other loans, time deposits, demand deposits, securities and investment. Inputs: labor, physical capital, borrowed funds.	The average efficiency levels of banks across the four countries are significantly different. Cost efficiency tends to decrease over the sample period. Private banks are more efficient than state-owned banks. The ASEAN banks, on average, experience increasing returns to scale. Larger banks tend to be more cost efficient.

Table 3.2 Bank Efficiency Studies in Transition and Developing Countries (continued)

Author / Year	Sample	Method	Variables	Main Results
Hardy and Patti (2001)	33 Pakistani banks, 1981-1997.	DFA	Dependent variables: profits; costs; revenues. Outputs: total earning assets. Input prices: price of borrowed funds and non-interest unit costs.	Financial reforms have led to an increase in both revenue and cost but not in profitability. The public sector and privatised banks have made progress in improving cost efficiency and their relative profitability.
Isik and Hassan (2002a)	Sample of Turkish banks from 1988,1992 and 1996.	SFA	Dependent variables: total costs; net income Outputs: Short-term loans, long term loans, off balance items and other earning assets. Inputs: labour, capital, loanable funds.	The average cost and profit efficiencies are 90% and 84%, respectively. Very low correlation between the two efficiency measures. Domestic private banks are much more efficient than state banks.
Isik and Hassan (2002b)	36 Turkish banks in 1988, 50 banks in 1992 and 53 banks in1996.	DEA	Outputs: Short-term loans, long term loans, off balance items and other earning assets. Inputs: labour, capital, loanable funds.	Cost and profit efficiencies of Turkish banks have declined over time. Inefficiency is mainly due to technical inefficiency rather than allocative inefficiency. The relationship between bank size and efficiency is strongly negative. Foreign banks are more efficient than domestic peers.
Tsionas *et al.* (2003)	19 Greek banks, 1993-1998.	DEA	Outputs: loans, investments and liquid assets. Inputs: labour, physical capital and deposits.	The majority of Greek banks exhibit high efficiency levels. Inefficiencies are mainly attributed to allocative inefficiency rather than technical inefficiency. A positive but not substantial TFP change of the Greek banking system is associated with efficiency improvement for medium-sized banks and to technical change improvement for larger institutions.

Table 3.2 Bank Efficiency Studies in Transition and Developing Countries (continued)

Author / Year	Sample	Method	Variables	Main Results
Ataullah, Cockerill and Hang (2004)	Sample of Pakistani and Indian banks, 1988-1998.	DEA	Loan-based specification: Outputs: loans and advances and investment. Inputs: operating and interest expenses. Income-based specification: Outputs: interest and non-interest income. Inputs: operating and interest expenses.	The overall technical efficiency of the banking sector of both Indian and Pakistan has improved following financial liberalisation. The efficiency scores from loan-based models are much higher that those from income-based models.
Sensarma (2006)	A panel of 86 Indian banks, 1986-2000.	SFA	Dependent variables: total operating costs. Inputs: labour and capital. Outputs: fixed deposits, saving deposits, current deposits, investments, loans and advances and the number of branches. Environmental variables: time trend, deregulation, size and ownership.	Both cost efficiency and total factor productivity have improved during the sample period. Foreign banks are the worst performers as compared with state owned and private domestic banks.
Fries and Taci (2005)	289 banks in 15 post-communist countries.	SFA	Outputs: loans to customers and deposits. Inputs: labour and physical capital Control and environmental variables: per capita GDP; level of nominal interest rates, the density of deposits, market concentration ratio, intermediation ratio and asset share of foreign banks.	Banking systems with lower nominal interest rates, a greater share of majority foreign-owned banks in total assets and a higher intermediation ratio trend to be more cost efficient. Private banks are more cost efficient than state-owned banks. Banks with majority foreign ownership are more efficient than domestic banks.
Havrylchyk (2006)	Sample of Polish banks, 1997-2001.	DEA	Outputs: Loans, treasury bonds and off-balance sheet items. Inputs: Deposits, fixed assets and labour.	Bank efficiency has not improved over the sample period. Foreign banks are more efficient than domestic banks

Table 3.2 Bank Efficiency Studies in Transition and Developing Countries (continued)

Author / Year	Sample	Method	Variables	Main Results
Kraft *et al*. (2006)	A sample of Croatian banks, 1994-2000.	SFA	Dependent variables: Total costs. Outputs: loans to enterprise, loans to households and deposits to enterprise. Inputs: funds, labour and physical capital. Control variables: total assets, total equity and ownership.	Privatisation does not seem to have an immediate effect on improved efficiency. Foreign banks are more efficient than domestic banks.
Grigorian and Manole (2006)	Banks in 17 transition economies, 1995-1998	DEA	Outputs: loans and investment securities. Inputs: funds, capital and labour.	Banks in countries with lax foreign exchange exposure limits exhibit better performance. Banks with majority foreign ownership are more efficient than domestic banks Privatisation would improve bank efficiency.
Kyj and Isik (2008)	Ukrainian commercial banks, 1998-2003	DEA	Outputs: loans and investment securities. Inputs: funds, physical capital and labour	Average technical efficiency, pure technique efficiency and scale efficiency are 47%, 62% and 78%, respectively. Most small and medium sized banks are operating under increasing returns of scale. Large banks tend to be more pure technical efficient and less scale efficient than small banks. Majority foreign owned joint venture banks are the most efficient.

3.4 Evidence on Bank Efficiency in China

There are only a few papers on Chinese banking efficiency that are written in English. Fortunately, there is a growing appreciation of the importance of the Chinese banking system amongst the international community and a steady stream of studies on Chinese banks has emerged in recent years that have used frontier efficiency approaches to measure relative efficiency.

Wang *et al*. (2005) apply several nonparametric models including various DEA models (CCR, BCC, Bilateral, Slack-Based Measures) and the free disposal hull (FDH) model to evaluate the efficiency of sixteen Chinese commercial banks. Their analysis shows that the FDH model seems to have difficulty in distinguishing between efficient banks and inefficient banks when compared with other nonparametric (DEA) models. Moreover, they find that private banks tend to have higher efficiency scores than the state-owned banks. Although the study reaches some useful conclusions, it only estimates the different kinds of efficiencies (technical efficiency, pure technical efficiency, scale efficiency, etc.) of the sampled banks and does not explore what might be the driving factors behind the efficiency scores obtained.

It is well known that the Chinese banking sector has undergone considerable deregulation since the 1990s. Several studies investigate the impact of deregulation on Chinese banking efficiency. In order to identify the changes of Chinese banking efficiency over the reform period, Chen *et al.* (2005) use DEA to estimate the cost, technical and allocative efficiency of 43 Chinese banks over the period from 1993 until 2000. The results show that the four big state-owned banks have higher technical efficiency and allocative efficiency than the joint-stock banks, especially the national joint-stock banks. This contradicts some previous studies which find that joint stock banks are more efficient than state owned banks (for example, Karim, 2001). Moreover, both large banks and small banks show a relatively higher level of cost efficiency than medium sized banks. This finding may indicate that the Chinese banking sector is not characterised by a U-shaped average cost curve. Furthermore,

Chen *et al.* (2005) find that the financial deregulation which was implemented in 1995 improved both the technical and allocative efficiency of the Chinese banking sector in the early years after deregulation. However, they also find that the impetus towards higher efficiency fell away after 1997. This may be due to the impact of the Asian financial crisis, to the huge increase in non-performing loans as a consequence of the reckless lending policies pursued by many state owned banks or a variety of other more minor factors. Chen *et al.* (2005) also provide evidence that technical efficiency makes a greater contribution to cost efficiency than does allocative efficiency, implying that Chinese banks need to improve their ability to minimise costs through more efficient use of their input factors.

Economies of scale and/or scope in the banking industry have been studied extensively in developed countries (e.g., Mester, 1993, Mitchell and Onvural, 1996, Altunbas *et al*. 2001). However, relatively few studies in this area have focused on the Chinese banking sector. Of those that do, Fu and Heffernan (2006) investigate economics of scale and scope in the Chinese banking sector over the period from 1985 until 2002. They use stochastic frontier and traditional non-frontier translog cost models to estimate both the ray and expansion path measures of scale and scope economies. Their results show that the stochastic frontier model appears to outperform the traditional non-frontier model for measuring scale and scope economies. Fu and Heffernan (2006) also find that the expansion path measures for the economies of scale and scope outperform the ray economies of scale and scope. Moreover, they find that state-owned banks in the later phases of the reform process and joint-stock banks exhibited constant returns to scale which may indicate that the reforms have had little impact on banks' optimal scale. However, diseconomies of scale are found in state-owned banks in the early phases of the implementation of the banking reforms. Fu and Heffernan (2006) also provide evidence of significant economies of scope in the Chinese banking sector.

Fu and Heffernan (2007) employ SFA to investigate the X-efficiency of the Chinese

banking sector over the period from 1985 until 2002[12]. The results show that, on average, the X-efficiency of Chinese banks ranged from a low of 40% up to a high of 50%. The joint-stock banks are more efficient than the state-owned commercial banks, having X-efficiency scores which ranged form 49% to 41%. In order to analyse and explain the variation in these efficiency scores, Fu and Heffernan (2007) propose a two-stage regression procedure which employs efficiency scores as the dependent variable, regressed against a set of explanatory variables such as bank size, market structure and ownership, etc. The results suggest that Chinese banking cost efficiency could be improved if more state banks are converted into joint-stock ownership, and if the state-owned banks change their soft budgetary constraints into hard budgetary constraints. However, as Berger and Mester (1997) point out the two-stage approach is legitimate only if the additional explanatory variables in the second stage are exogenous and are not correlated with the input and output variables in the first stage. Therefore, one serious problem for Fu and Heffernan's (2007) study stems from the variables chosen in the second stage of their regression procedures. Some of the variables employed in the second stage are endogenous – for example, the ratio of purchased funds to total assets, the ratio of total loans to total assets and the ratio of total investment to total assets – all of which are correlated with the input and output variables. The endogeneity problem that this engenders makes the conclusions reached by Fu and Heffernan's (2007) about the direction of causation somewhat problematic.

Based on agency theory and budgetary constraints theory, Yao *et al.* (2007) argue that ownership reforms and hard budgetary constraints may be important for raising Chinese banking efficiency levels. The study applies a single-stage SFA model to investigate the effects of ownership structure and hard budget constraints on Chinese banking efficiency over the period from 1995 until 2001. The empirical results show that the average level of technical efficiency over the sample period is about 63%. Yao *et al.* (2007) find that Chinese joint-stock banks are more efficient than their state-owned counterparts. In addition, banks facing harder budgetary constraints tend to outperform banks that have been heavily capitalised by the state or regional

[12] The sample has 187 observations collected from four state owned and ten joint stock banks.

governments. Finally, Yao *et al.* (2007) suggest that the Chinese government should reduce the way that it interferes in banking operations and also, to allow to re-capitalise from private sources.

Kumbhakar and Wang (2007) employ an input distance function approach to examine the technical efficiency and total factor productivity changes of 14 national Chinese banks over the period from 1993 until 2002. They adopt a one-step estimation procedure that incorporates explanatory variables into the efficiency analysis. Here it should be noted that this one-step estimation procedure is superior to a two-step estimation procedure[13]. Kumbhakar and Wang (2007) find that the big four state-owned commercial banks are less efficient than the joint stock commercial banks and that most Chinese banks are operating below the optimal scale. In addition, they find that small banks tend to be more efficient than large banks and that deregulation has not improve Chinese banking efficiency significantly. Their results also show an improvement in total factor growth, at the rate of 4.4% per annum, in the Chinese banking sector.

Ariff and Can (2008) use the DEA technique to investigate the cost and profit efficiency of 28 Chinese commercial banks over the period from 1995 until 2004. They show that the overall cost efficiency score (79.8%) is much higher than the overall profit efficiency score (50.5%), suggesting that the most important inefficiencies are on the revenue side. Moreover, the joint stock and city commercial banks, on average, appear to be more efficient than the big four state-owned commercial banks. They also employ a second stage regression procedure to investigate the influence of ownership structure, size, risk profile and key environmental changes on banking efficiency. They find that medium sized Chinese banks are significantly more efficient than their small and large scale counterparts and also, that credit risk is negatively related to both cost and profit efficiency.

[13] The two-step estimation procedure suffers from some serious biases. See Wang and Schmidt (2002) for details.

The issue of structure–performance relationships is important over the Chinese banking reform period. Fu and Heffernan (2009) develop a structured performance model for China's banking system. In order to examine both the market power hypothesis and the efficient structure hypothesis during the two distinct phases of regulatory reform (1985-1992, 1993-2002), the model incorporates measures of market share, concentration, X-efficiency, scale efficiency and an ownership dummy into the estimating equation[14]. The results support the relative-market power hypothesis in the first reform stage but not during the second reform stage. The efficient-structure hypothesis is also doubtful, because there is no significant positive relationship between efficiency and market structure. Furthermore, they extend the model to test the "quiet life" hypothesis and the impact of the bank ownership effect. They find that joint-stock banks are relatively more X-efficient than state-owned banks and also, they find that the "quiet life" hypothesis does not hold in the Chinese banking system[15]. Finally, Fu and Heffernan (2009) suggest that ongoing policy should be directed towards increasing the joint-stock banks' market share, thereby reducing market concentration. They also suggest that Chinese banking efficiency would be improved if interest rates were determined in a competitive market and not by government edict.

Ownership is always a "hot issue" in the discussion of financial sector reform. Generally, it is believed that ownership structure is an important factor that affects the level of banking efficiency. Berger *et al.* (2009) use the stochastic frontier approach to analyse the profit and cost efficiency of Chinese banks over the period from 1994 until 2003. They compare the efficiency of the big four state-owned banks, the non-big four state owned banks, private banks and foreign banks. With respect to cost efficiency, the average efficiency across all banks is 89.7%. Berger *et al.* (2009) find that foreign banks and non-big four state-owned banks are the most efficient Chinese banks, followed by the Big Four banks with private banks being the least efficient. With regard to the profit side, the mean profit efficiency level is 46.7%. Foreign banks are the most efficient, followed by private banks and non-big four state owned banks, with big four state owned banks being measured as the least efficient. Berger *et al.* (2009)

[14] A more detailed discussion of the market power hypothesis and the efficient structure hypothesis are to be found in a later section of this chapter.
[15] A more detailed discussion of the quiet life hypothesis is to be found in a later section of this chapter.

argue that the inconsistency between the findings for profit efficiency and cost efficiency of state-owned banks may be explained by the "skimping hypothesis" and government cost subsidies, etc. To the author's knowledge, Berger *et al.* (2009) are also the first to study the efficiency effects of minority foreign ownership in the wider (that is, international) banking sector[16]. The results show that minority foreign ownership is associated with higher efficiency either for both efficiency concepts (profit and cost) or for both categories of majority domestic ownership (non-big four state-owned and private domestic banks). In other words, Chinese banks have benefited from minority foreign ownership during the transition deregulation period from 2002 until 2006. Berger *et al.* (2009) also apply an additional set of robustness checks for "selection effects". The checks suggest that the effects of minority foreign ownership in most cases do reflect improvements above and beyond any selection effects. Because of the efficiency benefits to foreign ownership of Chinese banks, they recommend that the Chinese government should reduce ownership restrictions and encourage more foreign ownership into Chinese banks.

In conclusion, the extant Chinese efficiency studies have already provided some useful information for both government and academic researchers. However, a few studies show mixed or contradictory results on the relative efficiency of state-owned banks and on the effects of prior regulatory reforms (for example, Fu and Heffernan (2007)). These studies use either the non-parametric or parametric approach to estimate efficiency levels for the Chinese banking sector. But none of theses studies apply *both* (parametric and nonparametric) frontier approaches for cross checking purposes. In this study we employ a variety of cross-checking mechanisms and in so doing we endeavour to fill this gap in the Chinese banking efficiency literature and to add to the evidence available in the research literature.

3.5 The Determinants of Bank Efficiency

As we noted in chapter two, the conventional neoclassical theory of the firm provides a

[16] We know only of prior studies of majority foreign ownership in other nations (e.g. Fries and Taci (2005)).

poor basis for assessing the potential sources of differences in efficiency levels across firms and industries. It assumes that the objective of the firm is to maximise profit and that all firms in the market should operate in this way. However, we base much of our empirical analysis on alternative theories of the firm (e.g, agency theory, managerial theory, behavioural theory, etc.) and these theories generally provide a more robust basis for assessing the potential sources of differences in efficiency levels across firms than does the standard neoclassical theory. Relying on these theories, the determinants of efficiency may be due to internal bank-specific characteristics (e.g. ownership structure, risk preferences, etc.) and various external environmental factors (e.g. market structure, government regulation, etc.).

In the context of the banking sector, substantial research efforts have gone into exploring the determinants of efficiency. For example, Mester (1996), Altunbas *et al*. (2001), Berger and Mester (1997), Isik and Hassan (2003), Girardone *et al*. (2004) have all empirically investigated the potential correlates of efficiency. However, there is no consensus on the sources of the variations in measured efficiency (Berger and Mester, 1997). Moreover, the investigation of the sources of inefficiency in the banking sector is an important issue which can inform government policy and improve managerial performance. Thus, the potential benefits from investigating the determinants of Chinese banking efficiency are very large.

3.5.1 The Impact of Ownership Structure on Efficiency

Based on different theories or hypotheses, such as the theories of the firm, principal-agent theory, and market discipline hypothesis etc., many studies have investigated whether different ownership forms may lead to different efficiency levels. These studies provide useful information on comparative managerial performance and offer potential insights into the direction of future government policies.

State-owned versus private ownership

State-owned and private firms (in our context, banks) might have different objectives

that are not closely aligned (Shapiro and Willig, 1990). Generally, the principal goal of the government is to try to maximise social welfare. Therefore, state-owned banks might be seen as vehicles for raising capital to finance projects with high social returns, but possibly low profit returns or to provide finance to favoured groups (e.g. state owned enterprises) which may perform quite poorly in purely economic terms (Clarke *et al*. 2005). Moreover, according to public choice theories of government, politicians and bureaucrats might use state ownership to pursue their political goals, such as securing political office, accumulating power, seeking rents etc. State-owned banks find it difficult to resist such harmful government interference, whereas private banks are more able to oppose it, and employ more sensible prudential lending policies and/or cost minimisation strategies as a consequence (Shirley and Nellis, 1991; Shleifer and Vishny, 1994). Furthermore, state-owned banks may face less competition than private banks. State-owned banks may not have to worry as much about running into financial difficulties, because losses and excess costs are invariably covered by government subsidies. This in turn implies that state-owned banks have less incentives to maximise profits or to minimise costs when compared to private banks - which have to make a normal profit over the longer term in order to survive. Finally, state-owned banks seem to suffer more serious agency problems when compared to private banks. Alchian (1965) argues that because all citizens can be considered as the owners of state-owned enterprises (SOEs), SOE's ownership will be more dispersed than with private firms. Because of this non-transferable and widely distributed ownership of state-owned banks, private citizens have less motivation to monitor the performance of the management of SOE's in comparison to the owners of private banks. Hence, managers of SOE's are likely to enjoy more freedom to pursue a personal agenda because of this. In addition, private banks also face threats of hostile takeover or the possibility of bankruptcy when compared to stated-owned banks (Berglof and Roland, 1998; Schmidt, 1996; Sheshinski and Lopez-Calva, 2003). These threats provide a natural incentive for the managers of private banks to install more efficient operating procedures than will be the case with the managers of their state owned counterparts.

According to the above theoretical arguments, state-owned banks may operate less efficiently than comparable private banks. This lower efficiency may be due to greater political intervention, less competition, and weaker corporate governance (Shirley and

Walsh 2000). However, it does not necessarily mean that private banks always outperform state-owned banks. Many factors could prevent private banks from performing efficiently, such as an under-developed capital market and inadequately developed procedures for takeovers and bankruptcy administration, etc. (Clarke, Cull and Shirley, 2005). Moreover, state-owned banks are generally required to finance politically motivated projects. This means that they will receive larger subsidies and more favourable government treatment than private banks. This could reduce a bank's costs and lead to greater efficiency, at least in the short run (Kraft *et al.,* 2006).

Empirical evidence is ambiguous on the relative efficiency of private banks and state-owned banks. Fries and Taci (2004) examine cost efficiencies in 15 east European transition countries and they observe higher cost efficiency in private banks when compared to state-owned banks. Bonin *et al.* (2005a)'s empirical results also show that state-owned banks in six transition countries, with respect to both cost and profit efficiency, are less efficient than private banks. Likewise, state-owned banks in China are found to be less efficient than privately owned banks (Wang *et al*. 2005, Yao *et al.*, 2007). However, there are some studies which generate different results. Altunbas *et al.* (2001) find little evidence in support of the hypothesis that private banks are more efficient than publicly owned banks in terms of both cost and profit efficiency in the German banking sector. Bhattacharya *et al.* (1997b) find that state-owned banks are more efficient than private banks in India. Isik and Hassan (2002a) investigate the relationship between efficiency and ownership for Turkish commercial banks. They report similar results to those reported earlier in that state-owned banks outperform private banks after controlling for several important determining factors (e. g. market structure, bank size and corporate governance, etc.).

Foreign versus domestic ownership

Berger *et al.* (2000) provide a comprehensive survey on cross-border banking performance in a globalisation context. In this survey, Berger *et al*. (2000) propose two alternative hypotheses to explain the impact of foreign/domestic ownership on bank efficiency; namely, the *global advantage hypothesis* and the *home field advantage*

hypothesis. Under the global advantage hypothesis, foreign-owned banks will be more efficient than domestic banks. This arises from the observation that foreign banks may possess comparative advantages compared with domestic banks. These comparative advantages stem from superior managerial expertise and experience, lower costs of capital, and the use of hard-information technologies and procedures in banking operations. Moreover, superior risk management skills and access to higher quality services could also increase foreign banks' revenues and reduce their costs in comparison with domestic banks. According to Berger *et al.* (2000), there are two forms of the global advantage hypothesis; namely, the general and the limited forms. The general form asserts that foreign banks, regardless of the location of their headquarters, are able to out-perform domestic banks. The limited form argues that only some foreign banks with headquarters in a particular set of nations are able to operate more efficiently than domestic banks.

In contrast to the global advantage hypothesis, the home field advantage hypothesis suggests that domestic banks are generally more efficient than foreign-owned banks. There may be some adverse factors which weaken the foreign banks' comparative advantages and increase their operating costs. For example, a foreign bank's headquarters, which by definition will be located in its "home" country, may find it difficult to monitor and evaluate the behaviour and effort of disparate managers because of the distances involved. Moreover, the diseconomies of operation in the retail sector may lead to foreign banks finding it difficult to attract and maintain customers. Furthermore, foreign banks may face difficulties due to lack of knowledge about local markets or barriers of language, culture and regulations. Therefore, foreign banks may fail to overcome these cross-border disadvantages and operate less efficiently than their domestic counterparts.

There is a vast empirical literature which investigates the relationship between domestic and foreign ownership and bank efficiency. Most studies are based on the experiences in the U.S. banking sector and find that foreign-owned banks have a significantly lower cost or profit efficiency on average than domestic banks (DeYong and Nolle, 1996; Hasan and Hunter, 1996; Mahajan *et al.*, 1996 and Chang *et al.*, 1998). Berger *et al.*

(2000) investigate the relative efficiency of foreign versus domestic banks in five home countries – France, Germany, Spain, UK and the US. They find that foreign banks in these countries exhibit both lower cost efficiency and lower profit efficiency in comparison to domestic banks. This finding is consistent with most other U.S. studies and supports the home field advantage hypothesis. However, after disaggregating the results by nation of origin, Berger *et al.* (2000) find that foreign banks from the United States are more efficient than their domestic counterparts. This result is interpreted as supporting the limited global advantage hypothesis.

By contrast, efficiency studies on developing and transition countries generally support the hypothesis that foreign-owned banks outperform domestic-owned banks. Classens *et al*. (2001) investigate the differences in performance between domestic and foreign banks in eighty countries over an eight-year period from 1988 until 1995. They find that foreign banks have higher profits than domestic banks in developing countries, but that the opposite is the case for developed countries. Cross country evidence from transitional economies also suggests that foreign owned banks are more efficient than domestic-owned banks (Weill 2003; Bonin *et al.*, 2005a,b; Fries and Taci, 2005). In addition, there are some recent single-country studies of banking efficiency which analyse the relationship between ownership and banking efficiency. Hasan and Marton (2003) use SFA to measure the efficiency of Hungarian banks and find that foreign banks and banks with a significant foreign ownership interest are generally more efficient than domestic Hungarian banks. They also demonstrate that the entry of foreign banks creates an environment in which the entire banking system is forced to become more efficient, both directly and indirectly. Likewise, Isik and Hassan (2002a,b) on the Turkish banking industry, Kraft *et al*. (2006) on Croatia's commercial banks and Sturm and Williams (2004) on the Australian banking sector generally find that foreign banks have substantially better efficiency scores than those of domestic banks.

3.5.2 The Impact of Deregulation on Efficiency

Whether the "regulated" or "market based" banking system performs better in

promoting economic development is a long-standing and heavily debated issue. Deregulation of the banking sector is motivated by a desire to prevent market failure, which in turn enhances the stability of the economy and the solvency of all financial institutions (see Stiglitz, 1994; Fry, 1995)[17]. Hence, some researchers (e.g Mckinnon, 1973; Shaw, 1973; Winston, 1998) argue that de-regulation of the banking sector will enable the financial system to perform its main function of allocating scarce economic resource more efficiently and thus benefit the whole economy.

In the last three decades, a large number of countries, especially developing countries, have deregulated their banking systems and liberalised the operation of their financial markets. The primary goal of this deregulation has been to create a competitive and flexible environment in which banks have more control over their operations and are forced to reduce their costs and improve the efficiency and productivity of the way they operate. Deregulation of the banking system in developing countries frequently includes the following measures as summarised by Fry (1995): 1) removal of interest rate ceilings on deposits and loans; 2) removal of the credit ceiling; 3) reduction of government direct lending; 4) removal of restrictions on bank's portfolios; 5) reduction of bank reserve requirements; 6) reduction of restrictions on foreign exchange transactions; 7) relaxation of foreign banks' entry into the local market; 8) liberalisation of foreign investment and 9) privatisation of state-owned banks.

An important aspect of deregulation is its impact upon the efficiency of the banking system. Empirical studies hypothesise that banking deregulation enhances the efficiency and productivity of banks. However, the empirical evidence on this matter is mixed. Berg *et al*. (1992) examine the impact of deregulation on productivity growth in the Norwegian banking system during the deregulation period of the 1980s. They indicate that starting in 1984, restrictions on the volume of bank lending and interest rates were gradually removed in Norway. As of 1988 Norwegian banks have been completely free to set interest rates and lending volumes as they wish. They find

[17] Market failure describes a situation in which the production or use of goods and services by the market is not efficient. A market failure can occur for four main reasons: 1) imperfect competition; 2) externalities; 3) public goods; 4) asymmetric information (see Krugman and Wells, 2006 for details).

that the productivity of Norwegian banks was in decline prior to the deregulation period (1980-1984). However, after deregulation took place (1985-1989), the productivity of Norwegian banks improved substantially. Bhattacharyya *et al*. (1997b) investigate the total factor productivity (TFP) growth of Indian commercial banks over the long period from 1970 until 1992. India introduced many deregulation measures in the mid- and late 1980's in order to liberalise the operations of its banking sector. The deregulation measures mainly included the relaxation of controls on interest rates, allowing foreign owned banks to enter the Indian banking sector and liberalising the restrictions on market entry for domestic banks. Bhattacharyya *et al.* (1997a) find that the productivity growth rate accelerated substantially during the phase of gradual banking deregulation (1985-1992). Gilbert and Wilson (1998) investigate the effects of deregulation on the productivity and efficiency of Korean banks over the period from 1980 until 1994. They find that most Korean banks experienced efficiency gains during the period of deregulation as government controls were both lifted and relaxed. Likewise, in Turkey (Zaim, 1995), in Thailand (Leightner and Lovell, 1998), in Portugal (Canhoto and Dermine, 2003) and in Australia (Sturm and Williams, 2004) deregulation is found to have had a positive impact on the efficiency and productivity of the domestic banking sector.

Although the principal aim of deregulation is to improve the productivity and efficiency of the banking sector, many empirical studies find that deregulation appears to lead to a deterioration or at least, no significant improvement in productivity or efficiency levels. In the early 1980s, the U.S. banking sector was substantially deregulated. The key banking deregulation measures included removal of controls over interest rates, the allowing of interstate branch expansion and thrift institutions being allowed into consumer and business lending (Winston, 1998). The empirical evidence for the U.S. shows that measured productivity and efficiency decreased following deregulation (Humprey 1993; Bauer *et al*. 1993; Humprey and Pulley, 1997; Wheelock and Wilson, 1999). This decline is mainly attributed to interest rate deregulation inducing a competitive scramble to pay higher interest rates on deposits (Berger and Humphrey, 1997). Grifell-Tatjé and Lovell (1996) find that the liberalisation of the Spanish banking industry following its admission into the European Economic Community has also had a negative impact on Spanish banking efficiency. Similarly, the deregulation

of the Turkish banking sector during 1990s also resulted in a decline in banking efficiency (Denizer *et al.* 2000; Isik and Hassan, 2003). Moreover, the major financial deregulation of the Korean banking system in the early 1990s is found to have had little or no impact on the level of banking efficiency (Hao *et al.*, 2001).

3.5.3 The Impact of Market Structure on Efficiency

Efficiency analysis has been used to investigate a number of economic hypotheses and to offer insights through which to inform government policy and improve managerial performance. One important issue that has been investigated is the effect of market structure on firm (bank) performance or efficiency. Most empirical research on this issue mainly stems from the structure-conduct-performance (SCP) paradigm which links the conduct (firm behaviour) and performance of firms in terms of market structural characteristics, such as the number and size distribution of banks and entry conditions into the market. The SCP paradigm asserts that firm concentration and other impediments to competition create market power in setting prices and engenders collusion that is less favourable to consumers. In turn these factors affect both bank performance and banking efficiency. From this perspective, high concentration is a useful signal of a potentially uncompetitive and hence, inefficient market. An important critique of the traditional SCP model is that market structure measures seem to assume that all firms react in a similar way to changes in market concentration. Therefore, Cowling (1976) and Bos (2004) develop a market power model that is based on a straightforward extension of a Cournot oligopoly model. The model accommodates asymmetric market structure and differences in collusive behaviour and describes the relationship between firm performance and market share. This Cournot model does not measure exactly the same relationships as the SCP model. The former concentrates on individual banks' market share, but the latter focuses on the impact of market structure (Bos, 2004).

More recent research has gone beyond the SCP paradigm, and tests some different hypotheses that directly link bank efficiency and market structure. The "quiet life" hypothesis is one explanation of the relationship between efficiency and market concentration or market power. The "quiet life" hypothesis is based on the famous

observation made by Sir John Hicks:

"The best of all monopoly profits is a quiet life."(Hicks, 1935, p.8)

Banks with more market power can charge higher prices in excess of competitive levels, and then managers may enjoy a "quiet life" stemming from the benefits of these higher prices. Due to high profitability led by an insufficient level of competition or other market distortions, management may not control the costs of their operations to the maximum possible extent. In addition, market power may allow managers to pursue non-profit maximisation objectives, such as expense preference behaviours (e.g. plush offices, first class instead of economy class travel, etc). Such behaviours will raise costs and reduce measured cost efficiency. Therefore, banks with more market power or in higher concentrated markets may exhibit lower cost efficiency than do other banks. In order words, the "quiet life" hypothesis suggests that market power or concentration is negatively related to cost efficiency.

Efficient structure theory is another alternative explanation for the relationship between market structure and the efficiency of firms. The efficient structure hypothesis proposes that more efficient banks tend to have lower costs of production and that they use these lower costs of production to gain greater market share and markets become more concentrated because of it. Therefore, there is a positive relationship between market power or concentration and bank efficiency. There are two versions of the efficient structure hypotheses, the *X-efficiency structure hypothesis* and the *scale-efficiency structure hypothesis*. The X-efficiency structure hypothesis argues that efficient banks with better management and better production technologies have relatively lower costs and therefore obtain a higher market share and this leads to higher concentration in the market (Demsetz, 1973; Peltzman, 1977). The scale-efficiency structure hypothesis asserts that banks producing at a more efficient scale level than others, will have lower unit costs and higher unit profits. These scale efficiency firms are assumed to gain larger market shares that may result in higher market concentration, yielding a positive profit-structure relationship (see Lambson, 1987; Berger, 1995).

There are many empirical studies that deal with the impact that banking structure has on

the efficiency of banks, but these produce generally ambiguous results. Berger (1995) investigated the relationship between bank concentration and efficiency in the U.S. banking industry by testing two comparative hypotheses; namely the *efficient structure hypothesis* and the *relative-market power* hypothesis[18]. Berger (1995) developed a series of regression models which directly included measures of both market structure and efficiency to test the above hypothesises. He reported limited support for both the relative-market power hypothesis and the X-efficiency structure hypothesis. Goldberg and Rai (1996) examine the relationship between concentration and performance for European banks. In contrast to Berger (1995), they find strong evidence in support the X-efficiency structure hypothesis. Berger and Hannan (1997) tested the "quite life" hypothesis on a U.S banking dataset. They found strong evidence that banks in more concentrated markets exhibit lower cost efficiency, thereby supporting the "quite life" hypothesis. Isik and Hassan (2003) test both the "quite life" hypothesis and the efficient structure hypothesis for Turkish banks. Their results do not show a significant relationship between market power and efficiency and seem to support neither of the hypotheses.

It is also important to note that the various hypotheses have potentially opposing policy implications. If high profits are generated by market power, then anti-trust actions may be socially beneficial since they will move prices towards competitive levels and allocate resources more effectively. However, if high concentration is created by high efficiency, then breaking up efficient firms that have gained large market shares or forbidding them to acquire other firms may raise costs and lead to less favorable prices for consumers (Berger and Humphrey, 1997). Therefore, this study will test these hypotheses using data from the Chinese banking sector. The results may give explanations for the difference in measured efficiency across Chinese banks and help the Chinese government and other policy makers to take the right policy initiatives in relation to the Chinese banking sector.

[18] The relative-market power hypothesis asserts that banks with large market shares and well-differentiated products are able to earn supernormal profits (Shepherd, 1982)

3.5.4 The Impact of Size on Efficiency

Alongside the measurement of bank efficiency, investigation of the impact of size on the estimated efficiency levels of banks is a fairly standard practice. Analysis of the relationship between size and bank efficiency provides useful information for regulators and allows bank managers to assess the optimal scale at which to conduct their operations. Within the banking literature, size has often been found to be an important factor that drives variations in efficiency across banks. It is often argued that larger banks possess more flexibility in financial markets and are better able to diversify their credit risks (Cole and Gunther, 1995). Moreover, larger banks may have more professional management teams which are more effective in cost control, thereby resulting in higher profits (Evanoff and Israilevich, 1991). Casu and Girardone (2006) also point out that larger banks may have experienced economies of scale and scope from growth and joint production opportunities. All these factors enable large banks to exploit their size advantages and achieve more efficient operating outcomes. On the other hand, larger banks are more complex and therefore more difficult to manage. Hence, bureaucratic problems may arise in large banks, and these lead to less efficient operating outcomes for the affected banks (Delis and Papanikolaou, 2009).

Here it is interesting to note that there is no consensus in previous empirical studies about the relationship between bank size and banking efficiency. Berger *et al.* (1993) use both the logarithm of total bank assets and the logarithm of the number of bank offices to proxy for bank size. They find a significant positive relationship between the two size measures and the level of banking efficiency, suggesting that larger U.S. banks tend to be more efficient. Other studies find similar results, such as Miller and Noulas, 1996; Altunbas *et al*; Hasan and Marton, 2003; Ataullah and Hang, 2006; Perera *et al*., 2007. Isik and Hassan (2003) divide Turkish banks into three size categories according to their total assets; namely, small banks, medium sized banks and large banks. This size classification allows for the testing of a potentially non-monotonic relationship between banks size and efficiency. They find that medium sized banks are more efficient than both small and large banks in terms of technical efficiency. However, a note of caution is in order here as the cost efficiency estimates they employ do not vary much across the three size categories. Similarly, Aly *et al.* (1990), Mester (1993), Pi and Timme (1993), Berger and Hannan (1998) and

Havrylchyk (2006) do not report a significant relationship between size and banking efficiency. A number of other studies, however, find a significant negative relationship between size and banking efficiency and suggest that small banks may posses operational advantages that bring about higher efficiencies (e.g. Hermalin and Wallace, 1994; De Young and Nolle, 1996; Isik and Hassan, 2002; Girardon, *et al.*, 2004; Kumbhakar and Wang, 2007)

3.5.5 The Impact of Market Discipline on Efficiency

There are some studies that have attempted to link two distinct issues: market discipline and bank efficiency. They investigate whether or not market forces act as an effective discipline mechanism on bank efficiency levels. Market discipline in banking can be described as "private counterparty supervision" (Greenspan, 2001). Private sector agents (stockholders, depositors or creditors) face costs that are positively related to the risks undertaken by banks and make portfolio and investment decisions on the basis of these costs (Berger, 1991). The concept of market discipline incorporates two distinct aspects: market monitoring and market influence. Market monitoring refers to private agents able to evaluate a bank's true condition and incorporate those assessments promptly into the bank's security price and deposit rates. Market influence is the process by which market monitoring engenders bank (managers) to respond to counteract adverse changes in the bank's financial position (Bliss and Flannery, 2002). Market discipline may reduce the moral hazard incentives and/or improve the efficiency of banks by forcing some of the relatively inefficient banks to become more efficient or to exit from the industry. But the disciplining role of the market may not materialise because of a lack of corporate transparency (e.g. obscurity in the way the bank's financial information is presented to potential investors). Moreover, government sponsored protection policies may also undermine market discipline. For example, a "too big to fail" policy reduces the incentives of shareholders to monitor risk.

The listing of banks on the stock exchange will explicitly impose supplementary disclosure requirements, corporate governance norms and added regulatory pressure and thereby enhance the operation of market discipline. Market discipline may also force banks to place a greater emphasis on risk, income and expenditure management, which

in turn improves banking efficiency. Thus, many empirical studies on banking efficiency consider the stock exchange listing of banks as an important determinant of efficiency and test the proposed *market discipline hypothesis* using it as an important determining variable in their regression equations. Girardon *et al.* (2009) compares cost efficiency between listed and not-listed European banking institutions. The results show that listed banks appear to be more cost efficient than their non-listed counterparts. Similarly, Ray and Day (2009) find that the profit efficiency levels of listed Indian banks are higher than those of non-listed banks. Berger and Mester (1997) find that listed U.S. banks tend to have both higher cost and profit efficiencies. But here we should emphasise that the empirical evidence is not always compatible with the market discipline hypothesis. Havrylchyk (2006) finds that the listing effect has no impact on Polish banking efficiency and this in turn is compatible with the hypothesis that the Polish capital market exerts only weak discipline over bank management. Isik and Hassan (2003) find that there is no significant relationship between being listed on the stock exchange and the levels of X-efficiency for Turkish banks. Isik and Hassan's (2003) results also indicate that public scrutiny does not exert much market discipline over Turkish banks.

3.6 Summary and Conclusion

In the context of the banking sector, substantial research efforts have gone into measuring the efficiency of banks. However, the studies use different frontier methodologies and different input and output variables. It is difficult to make comparisons between many of the studies on banking efficiency because of this. Therefore, some researchers have used two or more frontier techniques to measure the efficiency of banks on the basis of the same dataset in order to provide more definitive and useful information for decision markers. However, these studies often produce ambiguous results for the comparison of parametric (SFA, DFA and TFA) and non-parametric (DEA and FDH) frontier efficiency approaches. Some studies find that the different frontier approaches generate similar results, while others report a lack of consistency between the different frontier approaches. Moreover, the studies generally conclude that there is no consensus on which is the best frontier approach for measuring banking efficiency. Indeed the use of multiple frontier techniques is generally

recommended for methodological cross-checking purposes.

This chapter reviews many empirical studies dealing with the efficiency of the Chinese banking sector as well as other developing countries. This is particularly relevant to our study as our principal objective is to investigate the relative efficiency of the Chinese banks. In recent decades, most banking sectors in developing countries have experienced institutional, structural and legal changes through implementing programmes of deregulation and/or liberalisation of banking operations. Therefore, most banking efficiency studies dealing with developing countries focus on investigating the impact of deregulation and ownership structure on bank efficiency levels and also attempt to shed light on the effectiveness of the reform programme and the optimal architecture of banking systems. This chapter also reviews empirical evidence on the impact of ownership structure, size, deregulation, market discipline and market structure on bank efficiency levels. These factors are generally considered as the key determinants of banking efficiency. In the following chapter, the main structure of the Chinese banking sector and the banking reforms undertaken in China over the last thirty years will be discussed and summarised.

China's Banking System and Reforms

4.1 Introduction

Since the late 1970's the Chinese government has gradually implemented a series of reforms aimed at improving the stability and efficiency of its banking system. Hence, over the last thirty years, the Chinese banking sector has experienced significant institutional and structural changes. The main objective of this chapter is to outline and summarise the important institutional mechanisms and structures of the Chinese banking sector and to review the history of Chinese banking reforms since the late 1970's. In particular, this chapter provides the background necessary for understanding the empirical analysis of Chinese banking efficiency presented in subsequent chapters of this dissertation.

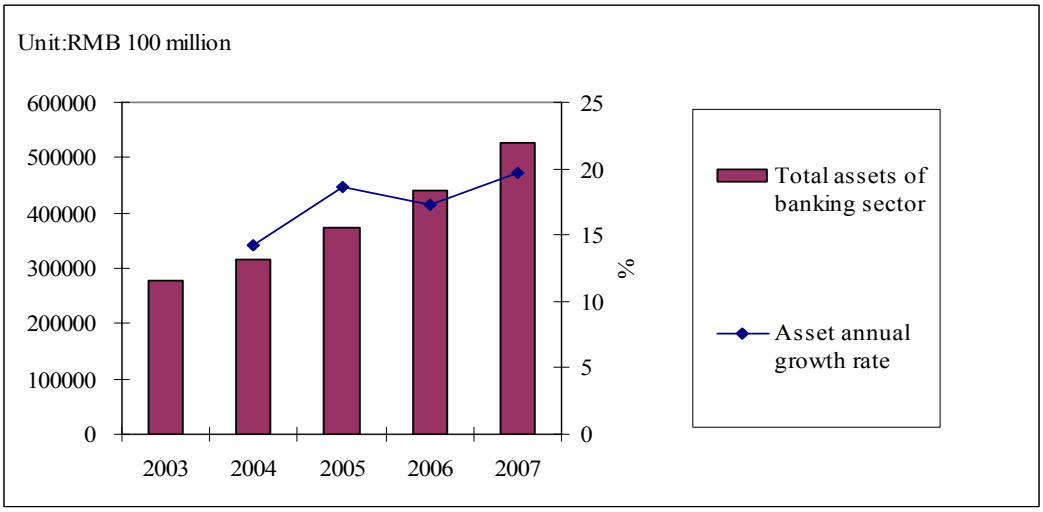
Section 4.2 discusses the important attributes of the Chinese banking sector and provides a description of the roles, characteristics and current standing of different types of banking institutions in China. Section 4.3 briefly reviews the evolution of the reforms that have taken place in the Chinese banking sector over last three decades. As previously noted, the aim of the reforms is to improve the stability and efficiency of the Chinese banking sector. Finally, section 4.4 provides some brief summary conclusions for this chapter.

4.2 The Structure of China's Banking Sector

The Chinese socialist banking system was established in the late 1940s based on the system in the former Soviet Union. The Soviet–style central planning system

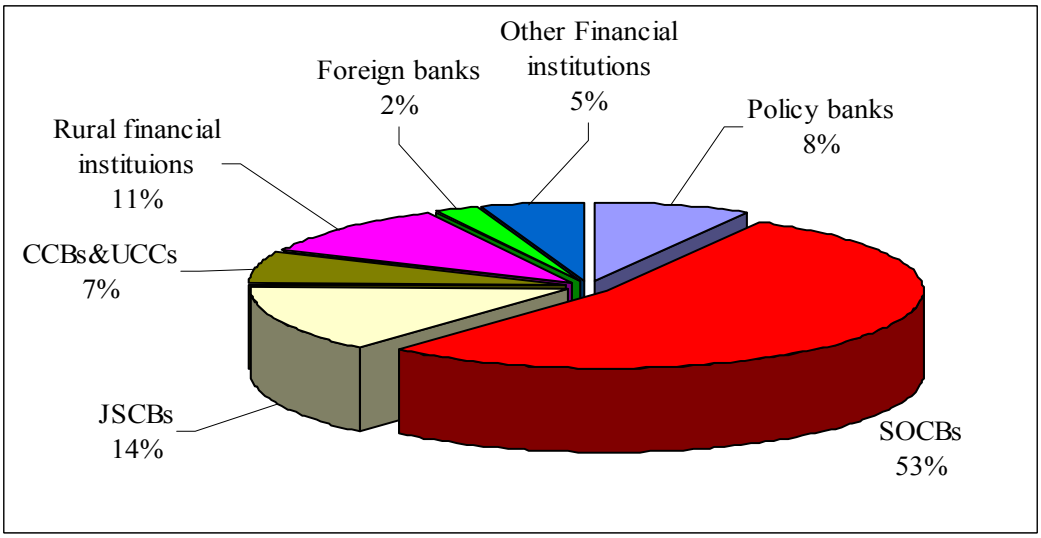
condemned the Western banking model to almost complete irrelevance. Before 1983, the Chinese banking system followed a mono-bank model. The central bank, People's Bank of China (PBC), had some of the functions of a central bank but simultaneously engaged in many commercial banking operations. In 1979, China embarked on market-oriented economic reforms in order to improve resource allocation in the domestic economy. These included a number of significant reforms to redesign and rebuild the banking sector. As the numerous reforms were implemented, China's banking system became quite diverse, so that there is now a wide range of banking institutions in place. According to the China Banking Regulatory Commission's (CBRC) classification scheme, at the end of 2007, China's banking sector consisted of 3 policy lending banks, 5 large-scale commercial banks, 12 joint-stock commercial banks (JSCBs), 124 city commercial banks (CCBs), 29 locally incorporated foreign bank subsidiaries, 42 urban credit cooperatives (UCCs), 17 rural commercial banks, 8,348 rural credit cooperatives (RCCs), 113 rural cooperative banks, 19 village and township banks, 4 lending companies, 8 mutual credit cooperatives, 4 financial asset management companies, 1 postal savings bank, 54 trust companies, 73 finance companies of enterprise groups, 10 financial leasing companies, 2 money brokerage firms, and 9 auto financing companies. China's banking sector comprised a total of 8,877 banking institutions, made up of a total of 189,921 outlets and 2,696,760 employees. The total assets of China's banking sector reached RMB 52.6 trillion in 2007, with an annual average growth rate of 17.5% over the period from 2003 until 2007 (see Figure 4.1 for further details). One of the main features of the Chinese banking sector is that state-owned commercial banks (SOCBs) dominate the banking system and are the main official source for the financing of companies (see Figure 4.2 for further details).

Figure 4.1 Total Assets of China's Banking Sector (2003-2007)



Sources: CBRC annual report 2007

Figure 4.2 Market Share by Assets of Chinese Banking Institutions, 2007



Sources: CBRC annual report 2007
Note: Rural financial institutions include rural credit cooperatives, rural commercial banks, and rural cooperative banks.

4.2.1 The Banking Authority

Today China's banking system is accountable to two regulatory authorities, the People's Bank of China (PBC) and the China Banking Regulatory Commission (CBRC), both ultimately overseen by the State Council of the People's Republic of China. The PBC is currently structured so as to focus more of its attention on monetary and credit policy in order to ensure overall financial stability and the provision of financial services, and it aims to promote economic development and the stability of prices. The PBC sets

interest rate bands for deposits and loans, the reserve requirements and the rediscounting rate. It also undertakes open market operations in order to manipulate bank liquidity and the money supply and provides lending facilities for selected banks charged with the financing of government backed infrastructure and development programmes.

The China Banking Regulatory Commission (CBRC) was established in 2003 to take over the functions of banking regulation and supervision from the PBC in order that the PBC could concentrate on monetary policy issues and other central bank responsibilities. The CBRC focuses on the supervision of banking institutions, capital adequacy issues and the restructuring of the banking sector. Its regulatory objectives include protecting the interests of depositors and consumers, maintaining market confidence and stability in the banking system, enhancing banks' competitiveness, educating the public in the knowledge of modern finance and combating financial crimes. In contrast to the multiple and overlapping regulatory agencies in the US and other western economies, the CBRC is the primary banking regulatory authority in China.

4.2.2 Five Large-scale Commercial Banks

The biggest four state-owned commercial banks (SOCBs), commonly known as the Big Four, were initially founded as fiscal budget distributors to state-owned enterprises (SOEs) in specific sectors of the economy. These are: the Agricultural Bank of China (ABC), the Bank of China (BOC), the China Construction Bank (CCB), and the Industrial and Commercial Bank of China (ICBC). The Big Four initially specialised in sectoral business based on policy-related lending. Since 1994, the Big Four have moved from their original operating mandates into commercial and consumer credit. However, the huge legacy of non-performing loans inherited from the policy lending mandate imposed on them by government instrumentalities continues to constrain their earnings and profitability. In 2006, the CBRC officially defined the Bank of

Communications (BOCOM) as a SOCB, and along with the Big Four formed the new Big Five SOCBs[19]. The CBRC has set up a special supervision department to oversee these five large-scale Commercial Banks. The five large banks' total assets reached RMB 28 trillion in 2007. The Big Five banks' assets as a proportion of total banking industry assets has fallen over the last decade (from 77% of total assets in the banking system in 1997 to 53% at the end of 2007). In spite of this, the presence and influence of the Big Five will continue to dominate China's banking system.

- The Agricultural Bank of China (ABC) was set up in 1949 to facilitate financial operations in the agricultural sector and rural areas. Today, ABC's business has developed from its original brief of rural credit and settlement to a wide range of financial business transactions. ABC has extensive outlets covering urban and rural areas of China. It now (2007) has 447,519 employees across 24,452 branches and banking offices in Mainland China, two overseas branches in Singapore and Hong Kong, and three representative offices in London, Tokyo, and New York. According to information recently released by the Agricultural Bank of China, the ABC has become the third largest bank in China in terms of total assets, which had reached RMB 6.05 trillion at the end of 2007. Its total deposits and total loans had reached RMB 5.28 trillion and RMB 3.48 trillion respectively in 2007. In addition, the operating profit reached a record high of RMB 96.13 billion with a growth rate of 65.30% over fiscal year 2007. In 2007, ABC ranked 65th among the "Top 1000 Banks" in *The Banker*, and 277th among *Fortune's Global 500*.

- The China Construction Bank (CCB) was originally created in 1954 to administer and disburse government funds for construction and infrastructure related projects. Until 1994, CCB had gradually become a full service

[19] The size of BOCOM is much larger then that of JSCBs, and its shares are spread among different state entities.

commercial bank. Its business now consists of corporate banking, personal banking, and treasury operations. It maintains a leading position in infrastructure loans and residential mortgages. Today, it holds about two-thirds of residential mortgages in China. In October 2005, the CCB was publicly listed on the Hong Kong Stock Exchange, and by the end of 2007, the CCB became the nation's second largest bank in terms of total assets, which totalled RMB 6.598 trillion.

■The Bank of China (BOC), founded in 1912, is the country's oldest bank. It originally specialised in international financial transactions such as foreign exchange services and extending trade credit, but now the BOC is mainly engaged in commercial banking, including corporate and retail banking, treasury business and financial institution banking. It also conducts investment banking and insurance activities through its subsidiaries. The BOC is the most international of all the commercial banks in China. At present, it has in excess of 11,000 domestic branches and over 600 overseas branches, and representative offices covering 27 countries and regions. In 2006, the BOC held an initial public offering (IPO), both on the Hong Kong Stock Exchange and the Shanghai Stock Exchange, in which it raised around 22.5 billion U.S dollars of new equity capital. Recently, the BOC has also made further efforts to attract strategic investors from overseas. Foreign shareholders now hold a 20% stake in BOC.

■The Industrial and Commercial Bank of China (ICBC) is the youngest of the "Big Five" banks, and was founded in 1984. ICBC primarily engages in corporate and retail banking and treasury operations throughout China, and has strong profitability. The ICBC followed several other major banking institutions in China in implementing western auditing and accounting procedures in 2003 when it appointed KPMG as its auditors. The compound annual growth rate in ICBC's after tax profits between 2003 and 2007 exceeds

38%. In 2007, the group's after-tax profits amounted to RMB 81.99 billion, representing a 65.9% growth over the previous year. In 2006, ICBC was simultaneously listed on the Hong Kong Stock Exchange and the Shanghai Stock Exchange, and ranked as the world's largest ever initial public offering. At the end of January, 2008, ICBC's market capitalisation had risen to USD 227,514 billion, making it the largest bank in the world in terms of market capitalisation[20].

■The Bank of Communications (BOCOM) was founded in 1908 and is one of oldest banks in China. It was restructured and re-constructed in 1987, becoming China's first state-owned shareholding commercial bank. In 2004, BOCOM further deepened the reform of its shareholding structure by introducing mainland and overseas strategic investors like the National Social Security Fund, China SAFE Investment Ltd (Huijing) and HSBC[21]. Today (2007), the BOCOM is one of the Big Five leading commercial banks in China, and has an extensive network of over 2,600 branches covering over 148 major cities in mainland China. In 2005, BOCOM was listed on the Hong Kong Stock Exchange and in 2007 it was listed on the Shanghai Stock Exchange. Now BOCOM has grown into a well-established modern commercial bank, and has four key business divisions: corporate, personal, fee-based and international business.

4.2.3 Policy Banks

Three policy banks were created in 1994 in order to take over the policy lending obligations that were previously assigned to the original big four stated-owned commercial banks. Each of these policy banks provides credit for specialised sections

[20] http://financialranks.com/?p=69
[21] HSBC bought a stake of 19.9% of Bank of Communications with RMB 14.46 billion.

of the economy. The Agricultural Development Bank of China (ADBC) is mainly engaged in the state policy oriented agricultural finance business and extends credit for agriculture and agricultural economic development. The China Development Bank (CDB) is primarily responsible for providing loans for capital investment projects and large infrastructure projects consistent with national economic objectives. The Export-Import Bank (EXIM) grants trade credit, export insurance, and working capital loans for firms involved in international trade and investment. Policy banks fund themselves primarily through the issuance of bonds, and they accept few deposits. The combined assets of the three policy banks have grown rapidly, and by the end of 2007 represented 8.1% of total bank assets in China. The policy banks are deliberately exempted from many of the prudential controls imposed on Chinese commercial banks, and profitability is only a residual objective for their managers. Therefore, by the end of 2007, its in-balance sheet non-performing loans amounted to RMB 85.5 billion.

4.2.4 Joint-stock Commercial Banks

Since the late 1980s, the Chinese government has granted permission for the establishment of commercial banks with a diverse ownership structure, and there are currently 12 joint-stock commercial banks (JSCBs) with national licenses; these represent the second tier of Chinese banks. These banks are CITIC Bank, China Everbright Bank, China Merchants Bank, Huaxia Bank, China Mingsheng Bank, Shenzhen Development Bank, Shanghai Pudong Development Bank, Guangdong Development Bank, Industrial Bank, Evergrowing Bank, China Zheshang Bank and Bohai Bank. Because they were established more recently than the original Big Four banks, they are not burdened with any historical baggage (in particular, in relation to non-performing loans) and therefore, are more agile and responsive to market requirements. These joint-stock commercial banks constitute an important part of China's banking system. According to statistics maintained by the China Banking Regulatory Commission, by the end of 2007 the total assets of the joint-stock

commercial banks was RMB 72.5 billion, up 33.1 % on a year on year basis, and together accounting for 14% of the total assets in the Chinese banking sector.

Joint-stock commercial banks are allowed to engage in a wide variety of banking services including accepting deposits, extending loans, as well as providing foreign exchange and international transaction services. They regularly finance small and medium sized enterprises (SMEs), an area where the state-owned banks have traditionally been weak. Some of JSCBs have professional advantages in specific business areas: for example, Minsheng Bank emphasises trade finance services, and has the objective of building a domestic first-class bank, strong in trade financing; China Merchants Bank focuses on retail banking services, and has issued more than 10 million credit cards; whilst the Industrial Bank has made great advances in institutional banking services; China Everbright Bank has become a leader in the financing business. JSCBs maintain much smaller branch networks than SOCBs, typically operating in fast growing areas or their region of origin, although they are generally allowed to operate nationwide. Given their smaller size and a corporate culture oriented more to the private sector, they are more "nimble" than their state-owned counterparts and have been successful at increasing market share at the expense of the large-scale (or state-owned) commercial banks.

JSCBs typically have a diverse ownership structure. The equity ownership of these banks is distributed among the state (central government, local government, state-owned enterprises), private, and foreign investors. With the exception for CITIC bank and China Everbright Bank, they have no owners with an outright majority position. But the government still has a controlling stake in many of these joint-stock banks (See Table 4.1 for further dertails). There is a trend at the moment for JSCBs to make private equity issues thereby moving them towards a private ownership structure. For example, China Mingsheng Bank, founded in January 1996, is China's first bank to be owned mostly by non-government enterprises, and China Zheshang Bank, founded in

2004, is 89.66% owned by private individuals and institutions. State-owned enterprise investment in some JSCBs is undertaken purely for the returns (that is, dividends and capital gains) they expect to receive from them because they do not expect to have a controlling interest in the affected banks due to the dispersed nature of the share ownership. Recently, foreign ownership participation in JSCBs has increased substantially as well. The most prominent example was, in 2004, where Newbridge Asia AIV III, L.P. (a U.S. investor group) purchased an 18% stake in Shenzhen Development Bank. As a result, the Shenzhen Development Bank became China's first shareholding commercial bank with a foreign institution as the largest shareholder. By the end of 2007, seven JSCBs had introduced international strategic investors in order to gain advanced international management skills.

In order to improve the banks' management, JSCBs are also encouraged to list on the stock exchange so as to ensure additional external monitoring. Since Shenzhen Development Bank went public in 1991, there have been six other JSCBs listed on the stock exchange, and these are CITIC Industrial Bank, China Merchants Bank, Huaxia Bank, China Mingsheng Bank, Shanghai Pudong Development Bank, and Industrial Bank.

Table 4.1 Ownership Structure of JSCBs (2007)

	Largest Shareholder	*Government Ownership* [a]	*Private Ownership* [b]	*Foreign Ownership*
CITIC Bank	CITIC Group (62%)	64.18%	15.82%	20%
China Everbright Bank	China SAFF Investment Ltd. (Huijin) (70.88%)	84.7%	15.3%	0%
China Merchants Bank	HKSCC Nominees Ltd[C]. (17.88%)	46.53%	53.47%	0%
China Mingsheng Bank	New Hope Investment Co., Ltd. (5.9%)[c]	5.1%	94.9%	0%
Huaxia Bank	Shougang Corporation HQ (10.19%)	38.87%	47.15%	13.98%
Industrial Bank	The Finance Bureau of Fujian Province (20.4%)	46.35%	33.67%	19.98%
Guangdong Development Bank	Citigroup (20%) China Grid Corp (20%) China Life Insurance Group (20%)	75.26%	0%	24.74%
Shenzhen Development Bank	Newbridge Asia AIV III L.P. (16.7%)	0.2%	83.1%	16.7%
Shanghai Pudong Development Bank	Shanghai International Group (23.57%)	46.88%	49.34%	3.78%
China Zheshang Bank	Zhejiang Communications Investment Group CO.,Ltd. (10.34%)	10.34%	89.66%	0%
Bohai Bank	TEDA Investment Holding co., Ltd. (25%)	72.01%	8%	19.99%

Source: Own calculation based on banks' annual reports.
a "Government Ownership" includes central government, local governments, state-owned enterprises.
b "Private Ownership" includes institutional investors, corporate investors, individual investors, etc
c HKSCC Nominees Ltd. is a subsidiary of the Hong Kong Securities Clearing Company Ltd., which acts as the common nominee for the sharers held in the Central Clearing and Settlement System Depository in Hong Kong

4.2.5 City Commercial Banks

Since the mid-1990s, City commercial banks (CCBs) have been created through the restructuring and consolidation of urban credit-cooperatives (UCCs), but they are very

small in terms of market share. Some of the largest CCBs are in a similar position to JSCBs, but the small CCBs still resemble the UCCs. By the end of 2007, there were 124 city commercial banks, with total assets of RMB 33.4 billion, accounting for 6.4% of total banking institution assets in China. Equity ownership of CCBs is mainly distributed between local governments and urban enterprises. For historical reasons it is common for local governments to hold a large bulk of city commercial banks' shares, and as a result, CCBs are often directly controlled by local governments and experience greater pressure to lend for policy purposes. Weak governance and a large proportion of nonperforming loans have been a common feature of CCBs.

The scope of city commercial banks' business tends to be concentrated in the cities where they were founded. Unlike the joint-stock commercial banks, CCBs are not usually allowed to operate at the national regional level, and this impedes their potential for expansion. However, the supervisory authorities are gradually relaxing these limitations for CCBs which are well-managed and performing well, and over time it is expected that CCBs will be allowed to engage in trans-regional operations. For instance, the CBRC gave approval to the Shanghai Bank in 2005 to establish a branch in Ningbo. Promoting trans-regional development and expanding business operations in other regions or cities will help CCBs overcome the negative impact of regional economic fluctuations. In order to improve management and accelerate the restructuring of ownership, some large city commercial banks have invited investment from strategic foreign investors in the last few years, and by the end of 2007, nine city commercial banks featured such investors[22].

CCBs lend to small and medium size enterprises and collective and local residents in their municipalities. However, there are some banks whose operating performance and

22 These nine city commercial banks are Shanghai Bank, Beijing Bank, Nanjing Bank, Ji'nan City Commercial Bank, Xi'an City Commercial Bank, Nancong City Commercial Bank, Tianjing City Commercial Bank, Ningbo City Commercial Bank, and Hangzhou City Commercial Bank.

asset quality has been poor. As the restructuring and reforming of state-owned and other big commercial banks continues, city commercial banks may be marginalised and become acquisition targets for the "big players" in the banking sector.

4.2.6 Rural and Unban Credit Cooperatives

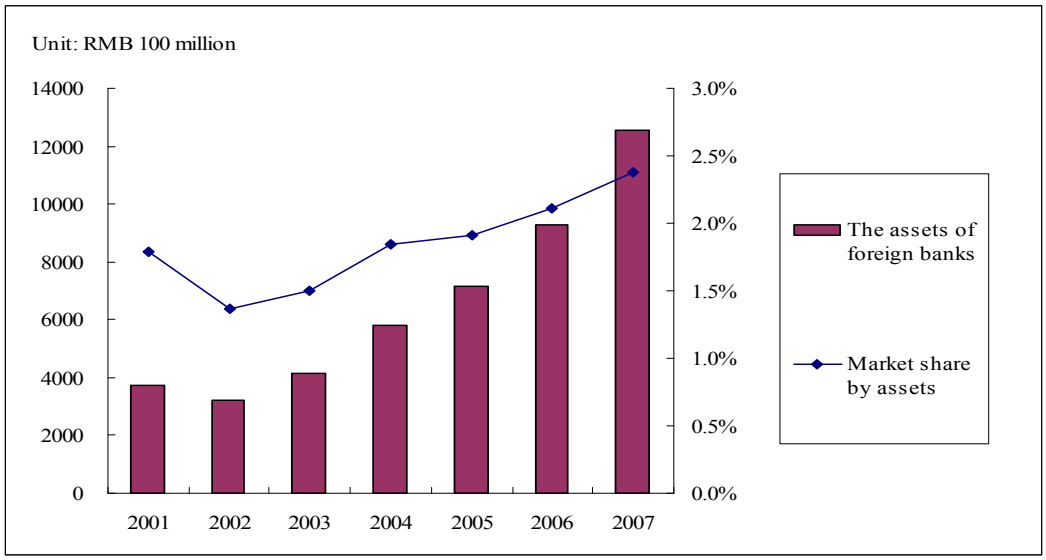
China's banking sector also features other types of banking institutions which are unique to its command economy. These include rural and urban credit cooperatives (RCCs and UCCs respectively), typically providing financial services to small-and medium-sized enterprises and individuals. Together, RCCs and UCCs accounted for 8.5% of the total assets of the Chinese banking sector in 2007.

Nowadays, rural credit cooperatives are more important and numerous then urban cooperatives, after the consolidation of the latter into city commercial banks. Rural credit cooperatives provide financial services for agricultural production, farmers and town and village enterprises. Today, RCCs have become the mainstay of rural financial institutions and provide financial services for around 800 million people living in rural areas (almost two-thirds of the total Chinese population). The agricultural loans granted by RCCs across China stood at RMB 1,399.8 billion, which accounted for about 88% of total agricultural loans from all financial institutions.

4.2.7 Foreign Banks

The entry of foreign banks was expected to bring great benefit to China's financial system. But, to date, they have played a rather minor role in the Chinese banking sector. By the end of 2007, 193 banks from 47 countries and regions had set up 242 representative offices in China. The assets of foreign banking institutions totalled RMB1.25 trillion, only accounting for about 2.4 percent of total banking assets in China (see Figure 4.3 for further details).

Figure 4.3 Total Assets and Market Share for Foreign Banks (2001-2007)



Sources: Almanac of China's Finance and Banking (2001-2006); CBRC annual report 2007

Initially, foreign banks were only allowed to provide foreign-currency intermediation in order to facilitate the operations of foreign investors and enterprises in China. The Chinese currency business has only gradually been opened to foreign banking institutions since 1996 when foreign banks were allowed to provide local currency services for the first time but even then there were restrictions on the cities and provinces in which foreign banks were allowed to trade (geographical coverage). A milestone in the financial liberalisation process was China's accession to the WTO in late 2001. Since December 2001, foreign banks can offer foreign currency transactions to all Chinese enterprises and individuals, and, by December 2006, under the terms of the accession agreement, China removed all geographic and customer-related restrictions on foreign banks. Foreign banks are no longer treated differently from domestic banks, and today there are 25 locally incorporated foreign banks and 57 foreign bank branches which have been licensed to provide RMB business. They have access to the lucrative bank card business and provide Chinese currency business to Chinese nationals. Foreign banks have a distinct advantage over Chinese banks in respect to consortium loans, foreign trade financing, retail business, funds management and financial derivatives because of their broader international trading connections which allow them to spread risk and to secure different types of customers

(Tong, 2005). Foreign banks will expect to play a more important role in attracting foreign capital, intensifying competition in the Chinese banking sector, introducing advanced management techniques and experience, and promoting the improvement of efficiency and the corporate governance of Chinese banks.

4.2.8 Non-banking Financial Institutions:

According to CBRC, there are five major types of non-banking financial institutions; namely, trust companies, finance companies of enterprise groups, financial leasing companies, auto financing companies and money brokerage firms. These institutions increase the amount of credit available in the financial system, and are currently governed by the CBRC's regulations and supervision. Together they account for about 1.8% of the Chinese banking sector's total assets.

4.3 China's Banking Reform

Chinese authorities have embarked on a number of steps to ensure that the banking sector will be able to support continued rapid rates of growth in the real economy. Basically, China's banking reforms can be divided into three distinct periods: first from 1979 until 1993; second from 1994 until China's entry into the WTO in 2001, and third post-WTO accession after 2001.

4.3.1 China's Banking Reform before 1994

Prior to 1979, the Chinese banking system followed a mono-bank model, where the People's Bank of China (PBC) combined the roles of central and commercial banking and thereby sought to assist the government in fulfilling the various state production plans. The changes began in 1979 when China embarked on a series of market-oriented economic reforms. Between 1979 and 1984, the banking system

expanded by establishing four state-owned specialised banks – Bank of China (BOC), Agricultural Bank of China (ABC), Industrial and Commercial Bank of China (ICBC) and China Construction Bank (CCB), with each having its own specific business focus. The big four state-owned banks assumed responsibility for the lending functions of the PBC, and the PBC was left to focus on its central banking responsibilities alone. In addition, nonbanking financial institutions, such as investment and trust corporations and insurance companies, also emerged and multiplied during this period. The mono-banking system has changed into a two-tier banking system consisting of a central bank (PBC) and various kinds of other financial institutions. From 1985 the Big Four were allowed to enter into a variety of commercial banking services, and the segmentation of these four specialised banks gradually diminished (Fu, 2004). However, competition among them was very limited until the mid-1990s, because their lending decisions were based on the government's national credit plan rather than the commercial viability of the banks' investment activities[23]. Stated-owned banks also served as policy-lending conduits for the government, and provided loans to state-owned enterprises (SOEs). The industrial reforms which began in 1984 also meant that the number of loss-making SOEs dramatically increased. As a result, the state-owned banks accumulated an enormous volume of non-performing loans (Kumbhakar and Wang, 2007).

In the mid-1980s, the PBC relaxed barriers to entry for new banks in order to inject competition into the banking sector. Between 1985 and 1993 a number of new medium and small-sized commercial banks were established through merger, restructuring, or incorporation with the objective of providing competition for the Big Four banks. In 1987, the Bank of Communications (BOCOM) was restructured and became China's first joint-stock commercial bank (JSCB). Several JSCBs, including CITIC Bank, China Merchant Bank, Shenzhen Development Bank, China Everbright

[23] In order to maintain control over aggregate credit, the PBC established an annual credit plan for the nation as a whole and for each of the specialized banks, and directed bank financing of enterprise.

Bank, Industrial Bank, Guangdong Development Bank and Hua Xia Bank, followed in the late 1980s and early 1990s. Unlike the Big Four which are wholly owned by the government, these new banks' shareholders included central and local governments as well as other private institutions. This equity structure means they can raise funds from various channels outside of the state and are wholly responsible for their own lending policies. Consequently, their loan portfolios are much healthier than the Big Four (Cousin, 2007).

The early 1990s also saw a rapid expansion in quasi-banking institutions; namely, Rural Credit Cooperatives (RCCs) and Urban Credit Cooperatives (UCCs). These credit cooperatives are depository institutions established primarily for the purpose of encouraging thrift among persons of modest means (Saez, 2004). Both UCCs and RCCs could undertake deposit and lending business with the public. However, the management of these banks is often dominated by local government officials who use their influence to pressure the UCCs and RCCs to make loans of doubtful commercial viability and their loan portfolios are invariably loaded with non-performing loans as a consequence.

As an important part of banking reform, China has also gradually opened its banking operations to foreign competition. Beginning in 1978, foreign banks were allowed back into China for the first time since 1949. However, there were restrictions on the banking activities they are allowed to undertake (business scope) and the cities and provinces in which they were allowed to trade (geographical coverage). In 1985, China promulgated the Administrative Regulations on Foreign Banks and Sino-Foreign Joint-Venture Banks in the Special Economic Zones Regulations. These regulations clearly restricted foreign banks in that they could only provide foreign exchange business to foreign firms and citizens in five special economic zones[24]. In 1990,

[24] Five special economic zones are Shenzhen, Zhuhai, Xiamen, Shantou, and Hainan.

foreign banking institutions were allowed to undertake foreign currency business in Pudong New Zones in Shanghai. In 1992, foreign financial institutions were allowed to expand their operation into 13 other large Chinese cities on the East Coast mainland.

Another important reform in the late-1980s was the introduction of some flexibility into the lending rate so that banks were allowed to adjust the interest rates they charged on commercial loans within a certain margin of the administrated rate set by the PBC. Specially, both UCCs and RCCs were given flexibility with respect to lending rates and could charge rates that are between 30% and 60% higher than the rates set by the Big Four, the JSCBs and many other banks. However, such flexibility was not extended to deposit interest rates.

4.3.2 China's Banking Reform between 1994 and 2001

By the early 1990s, the asset quality of state-owned banks (SOBs) had deteriorated very significantly and so the government was forced to reconsider the wisdom of pervasive political intervention in regards to banks' credit and lending decisions. Policy loans have accounted for more than one third of total loans for SOBs (Chen and Shi, 2004). To ameliorate this problem, the government established three policy banks in 1994 to strip off the SOBs' policy based loans and accelerate the transformation of SOBs into true commercial banks. The three policy banks are China Development Bank (CDB), China Export-Import Bank (EXIM) and China Agricultural Development Bank (ADBC). They are funded by the issue of bonds and all three banks are wholly owned by the state. Thus, they are in charge of specialised lending on behalf of central government, and they are not for profit institutions but are none the less expected to break even.

Two major legislative reforms occurred in 1995. The Law of the People's Bank of China of the People's Republic of China (normally referred to as the Central Bank Law) was enacted in March, 1995. The Central Bank Law further enhanced the legal status

of the Peoples' Bank of China (PBC) and reduced the ability of government instrumentalities to intervene in and even dictate monetary policy in China. According to this law, the PBC is under the leadership of the State Council, but should not be subject to interference by local government, other administrative organs and individuals (Schueller, 2003). The main functions of the PBC are to implement monetary policy, supervise financial institutions and to regulate the financial system in China. The Commercial Banking Law, also promulgated in May 1995, aims to establish a diversified market-oriented and independent modern banking system. It officially defines the major state-owned banks as commercial banks which are to be based on market principles, and the Commercial Banking Law also defines a series of requirements for commercial banks to encourage market-based management and pricing principles. For example, a bank's senior managers must have at least a university degree in finance and eight years' experience in the financial sector. After these reforms, Chinese banking legislation was compatible with the provisions of the Basel Committee on Banking Supervision (Chen, *et al*., 2005).

However, the growing problems which many banks had at this time with non-performing loans and capital adequacy requirements pushed the government to speed up the pace of banking reform. Key reforms consisted of abolishing the loan quotas system, reorganising the PBC, introducing a risk-based loan classification system, recapitalising the state-owned banks and disposing of non-performing loans. By January 1998, the PBC had abolished the credit plan system (for both working capital loans and fixed investment loans) which had previously applied to commercial banks. In lieu of this credit plan, the PBC set an indicative non-binding target as an indirect monetary policy and began the promotion of asset liability ratio management and risk control. In other words, the PBC no longer gave instructions as to how loans should be allocated in each quarter and year, and instead, provided only voluntary guidance (Chen and Shi, 2004). This reform granted banks greater freedom in setting their own lending targets in accordance with their commercial instincts. In order to eliminate the

perverse influence of local government on banks' lending policies and also, to improve the effectiveness of monetary policy, in September 1998 the 31 provincial branches of the PBC were replaced with 9 trans-provincial branches (Mo,1999). Furthermore, the senior managers of the 9 trans-provincial branches of the PBC are now appointed by the PBC itself, rather than local government officials (Fu, 2004).

In the 1980s, the PBC made only a token effort to classify bank loans by their quality, and before 1995, each of the major banks employed its own system and standards for classifying non-performing loans (Lardy, 1998). In 1995, the PBC formally set four-category loan classifications: normal loan, past due loan, doubtful loan and bad loan. According to this system, the past due loan, doubtful loan and bad loan were non-performing loans, although banks were not required to make provisions against any overdue loans. This system is based on the payment status of the loan rather than on any risk assessment. After the Asian financial crisis of 1997, the PBC recognised the importance of risk management in the banking sector and then introduced an internationally accepted loan classification system in 1998. The new credit risk management system was comprised of a five-category loan classifications system: normal, special attention, sub-standard, doubtful, and loss (See Table 4.2 for further details). Non-performing loans consist of sub-standard, doubtful, and loss, and banks make provisions according to the defined risk category of the loans (Mo, 1999). The five-category loan classification system was initially implemented on an experimental basis and was not fully implemented by all banks until the beginning of 2002.

Table 4.2 Four Category and Five Category Loan Classification

	Four-category loan classification		Five-category loan classification	
Performing loans	Normal loans	No problem with repayment of principal after the due date	Normal loans	No reason to doubt borrower's ability to repay the principal and interest of loans in full and in a timely manner
			Special Mention loans	Borrowers are able to serve their loans currently but some specific factors may adversely affect repayment.
Non-performing loans	Past due loans	Missing repayment on the principal not the interest after the due date	Sub-standard loans	The payments on principal and interest can be fully covered by normal operating income and losses possibly (overdue >90 days).
	Doubtful loans	No repayment on principal within two years after the due date.	Doubtful loans	Borrowers cannot pay back the principal and interest in full and significant losses will occur even if the collaterals are exercised (overdue> 180 days).
	Bad loans	Only in the unlikely event that the borrower is declared bankrupt or goes through liquidation proceedings	Loss loans	The principal and interest of loans cannot be recovered or only a small portion can be recovered after exhausting all possible collection efforts and legal procedures

Sources: PBC Annual Report 1995, 2002; Cousin, 2007, p84

In order to rehabilitate the balance sheets of the four largest state-owned commercial banks, the Chinese government injected RMB 270 billion of capital in to the Big Four

in the form of special government bonds. A brief summary of the capital injection procedure was as follow: first, the PBC lowered the legal reserve requirement from 13% to 8%, freeing up about RMB 270 billion of bank liquidity. Then, the Big Four used the additional liquidity to buy government bonds issued by the Ministry of Finance. Finally, the Ministry of Finance transferred the receipts of this purchase to the Big Four as fresh equity capital (Garcia-Herrero, *et al*, 2006). This recapitalisation procedure resulted in a significant improvement in the big four SOCBs' capital adequacy ratios without changing the overall assets and liabilities on the banks' balance sheets. In 1999 the average capital adequacy ratio for the big four SOCBs was 6.19%. However, it is still less than the 8% recommended by the 1998 Basel Accord (Chen and Shi, 2004).

In order to reduce the volume of non-performing loans and rehabilitate the reputation and international competitiveness of the state-owned banks, in 1999 the government created four asset management companies (AMCs) specifically for the purpose of purchasing and managing a substantial amount of non-performing loans from each of the state-owned banks. The original idea was to assign one AMC to each SOCB. Thus, Cinda AMC was assigned to the China Construction Bank (also China Development Bank), Oriental AMC was assigned to the Bank of China, Great Wall AMC was assigned to the Agricultural Bank of China, and Huarong AMC was assigned to the Industrial and Commercial Bank of China. These AMCs were under the supervision of the PBC, with guidance from the State Securities Supervisory Committee of China and the Ministry of Finance, and were given a budgeted life-span of 10 years. In 1999-2000, the four AMCs had purchased RMB 1.4 trillion of non-performing loans at their book values (equivalent to 19 % of the total loans of the state-owned banks). These nonperforming loans were mainly issued before 1995 by the Big Four and the China Development Bank (for further details, see Table 4.3). This asset purchase enabled the Big Four to reduce their average ratio of nonperforming loans to total loans down to 25% (compared to 35% before the purchase of the non-performing loans by the

AMCs) (Shirai, 2002). The AMCs sought to recover the purchased assets as much as possible through asset restructuring, securitisation, debt equity swaps and outright asset sales (Lardy, 2000).

Table 4.3 NPLs Disposals at State-owned Banks

Asset Management Companies	Purchased Value (RMB billion)	NPLs Received From
Hua-rong AMC	407.7	Industrial and Commercial Bank of China
Great Wall AMC	345.8	Agricultural Bank of China
Oriental AMC	267.2	Bank of China
Cinda AMC	350	China Construction Bank China Development Bank

Source: Almanac of China's Finance and Banking 2000.

Interest rate liberalisation is another important pillar of bank reform in China, as it enhances the role of market forces in resource allocation. In 1995, regulations were issued under the title of the PBC Programme of Deepening Interest Rate Reform during the Ninth Five-year Plan Period and marked the beginning of interest rate liberalisation. The approach towards interest rate liberalisation has been gradual in the second wave of banking reform which, as previously noted, began in 1994. Table 4.4 summarises the major developments in the interest rate liberalisation programme during the second stage of banking reform. This table shows that lending rates were liberalised before deposit rates; interest rates on large and long term funds were liberalised before those for small and short term funds and, interest rates on foreign currency were liberalised before those for domestic currency.

Table 4.4 Interest Rate Liberalisation Process between 1993 and 2001

Year	Key Interest rate liberalisation measures
1996	The nationwide inter-bank market was created, and the inter-bank money market rate was freely determined by market forces. Lending rate bands changes were allowed to ± 10% around the reference rate.
1997	The interest rate in the bond repo bank market was liberalised.
1998	The issuing rate of government bonds was determined by market supply and demand. The interest rates on loans to small business by commercial banks were allowed to widen from 10% to 20% of reference rates; RCCs increased the upper limit of lending rates from 40% to 50% of reference rates.
1999	Interest rates on loans to SMEs by commercial banks were allowed to be as high as 30% above the reference rate set by the PBC. Interest rates on long-term large-value deposits by insurance companies started to be liberalised. The interest rate on over RMB 30 million deposits with maturity of about 5 years for insurance companies became negotiable.
2000	The foreign currency interest management system was overhauled. The restrictions on foreign currency loan interest rates were moved; For deposits of over US$3 million, interest rates could be negotiated between the financial institutions and their customers.

Source: PBC Annual report 2005

During the second wave of banking reforms, the Chinese government encouraged greater competition by easing the licensing and entry requirements of new small and medium domestic banks. Two new national joint-stock commercial banks, the Shanghai Pudong Development Bank and the China Mingsheng Banking Corporation, were created in 1993 and 1996, respectively. During this period, most small and medium sized commercial banks, established in the mid-1980s or early 1990s, began to operate nation-wide with a diversified ownership (that included private institutions and not just the government) in direct competition with the state-owned banks (that is the Big Four). For example, the Hua Xia Bank was fully owned by the Capital Iron and Steel Company when it was established in 1992. In 1995, the Hua Xia Bank transformed itself into a national joint-stock commercial bank with thirty-three shareholders.

During the 1990s many urban credit cooperatives (UCCs) incurred severe losses and became insolvent. In order to alleviate this problem, the supervisory authorities (the PBC, local government, etc.) started the reform of UCCs from 1995 onwards. A major instrument used in this process was to transform and merge UCCs into city commercial banks (CCBs). For instance, the Bank of Shanghai was created through the merger of some 110 credit cooperatives. Between 1995 and 2001, about 2,200 UCCs were transformed into 110 city commercial banks (Cousin, 2007). CCBs were established in the first place to provide financial services to small and medium enterprises, individuals and local government.

Between 1993 and 2001, the Chinese government implemented a series of reforms in order to further open up the banking sector to foreign competition. In 1994, the State Council further relaxed geographic restrictions on foreign banks' operations. It allowed foreign banks to trade foreign currency in an additional 11 non-coastal cites, including Beijing. At the end of 1996, the PBC approved nine foreign banks, subject to the prescribed requirements, to engage in local currency business in the Shanghai Pudong New Zone on a trial basis, and soon after six foreign banks were also allowed to undertake RMB business in Shenzhen. Up to 2001, 32 foreign banks obtained permission from the PBC to conduct RMB business in Shanghai, Shenzhen and their adjacent regions. In 1999, the PBC further relaxed geographical restrictions on foreign banks and allowed them to operate in all major Chinese cities. A crucial milestone in the financial liberalisation process was China's accession to the world Trade Organisation (WTO) in December 2001. According to China's WTO commitments, China agreed to gradually lift all geographic, business scope and customer restrictions in relation to foreign banking institutions by 2006. This means that China's banking sector has now been completely opened up to foreign banks. China's admission to the WTO will intensify competition among banks and increase bank internationalisation, thus bringing China to a new stage of development.

4.3.3 Chinese Banking Reform after WTO Entry

China's entry into the WTO at the end of 2001 marked the beginning of a new era. In order to comply with its WTO commitments, the Chinese government progressively removed regulatory obstacles and adopted numerous reforms to open up its banking sector to competition – both domestic and foreign. Over the period from 2002 until 2006, the cities and provinces in which foreign banks were allowed to trade (geographical coverage) as well as the banking activities they were allowed to undertake (business scope) were gradually widened. By the end of 2006, all Chinese cities allowed foreign banks to engage in both local and foreign currency business with all types of customers. Table 4.5 illustrates the major changes during the transition period in relation to the geographical coverage and business scope of foreign banks. However, in late 2006, the CBRC imposed new rules that foreign banks must be locally incorporated as legal entities before they can conduct local currency business for Chinese citizens. The CBRC also encouraged locally incorporated foreign banks to set up independent risk control, accounting and IT systems so that as far as possible, adverse circumstances arising out of their foreign operations would not impact on their Chinese (domestic) operations (that is, to minimise risk overflow). This prudent supervision measure may lead to further delays in foreign banks' access to China's retail banking market (Berger, *et. al*., 2007). By the end of 2007, the CBRC had allowed 21 foreign banks to change their Chinese mainland branches into locally incorporated banks registered in China.

Table 4.5 Opening of China's Banking Sector (2001-2006)

Time	*Business Services*	*customer Restrictions*	*Geographic Restrictions*
Dec. 2001	Foreign currency business	No restriction – Chinese and foreign enterprises and individuals	No restriction – all of China
	Local currency business	Only with foreign enterprises and overseas citizens	Only in Shanghai, Shenzhen, Dalian and Tianjin.
Dec. 2002	Local currency business	Only with foreign enterprises and overseas citizens	As in 2001 plus Guangzhou, Nanjing, Qingdao, Wuhan and Zhuhai
Dec. 2003	Local currency business	With all Chinese and foreign enterprises and overseas citizens	As in 2002 plus Ji'nan, Fuzhou, Chendu and Chongqing
Dec. 2004	Local currency business	With all Chinese and foreign enterprises and overseas citizens	As in 2003 plus Beijing, Kunming Xiamen, Shenyang and Xi'an
Dec. 2005	Local currency business	With all Chinese and foreign enterprises and overseas citizens	As in 2004 plus Ningbo, Shantou, Harbin, Changchun, Lanzhou, Yinchuan and Nanning
Dec. 2006	Local currency business	No restriction –Chinese and foreign enterprises and individuals	No restriction – all of China

Source: CBRC

In order to increase the efficiency of regulatory and the supervisory functions of the banking sector and leave the PBC free to focus on its responsibilities as a central bank (monetary policy issues), it has previously noted that the Chinese government created the China Banking Regulatory Commission (CBRC) in March 2003. The CBRC is a ministerial-level organisation under the control of the State Council and is responsible for supervising banks, asset management companies, trust and investment companies, and other depository institutions. In 2004, the CBRC's legal status was reconfirmed by the Law of the People's Republic of China on Banking Supervision and Administration. Moreover, in 2005 two existing laws, the Law of the People's

Republic of China on the People's Bank of China and the Law of the People's Republic of China on Commercial Banks were revised to accommodate China's commitments on entry to the WTO as well as to improve the efficiency of the banking sector. The exact division of powers between the CBRC and the PBC has been clarified by these laws (Hansakul, 2004). These laws all aimed to improve the level of banking sector supervision. In the last several years, the CBRC has also focused on encouraging Chinese banks to adopt best international banking practices. This involves resolving issues related to capital adequacy, non-performing loans and corporate governance (Cousin 2007).

In order to enhance risk management in the banking sector, the CBRC promulgated new capital adequacy rules, Regulations Governing Capital Adequacy of Commercial Banks, in February 2004. This new regulation is based on the 1988 version of the Basel Capital Accord (Basel I) as well as parts of the New Basel Capital Accord (Basel II) promulgated in 2002[25]. It also allowed for the fact that Chinese banks would face potentially stiff competition when China's WTO commitments opened the Chinese banking sector to foreign banks commencing in December 2006 (Cousin, 2007). The new rules provided a precise mechanism for calculating the capital of commercial banks and required commercial banks to replenish their capital base to meet a minimum capital adequacy ratio (CAR) of 8% on or before January 1, 2007[26]. According to a CBRC spokesman's statement, under the new stricter rules the CAR of commercial banks may actually decrease by an average of 2% when based on the computation procedures implied by the "old" (1995) CAR rules. This in turn means that the "new" (2004) CAR rules will impose more stringent capital adequacy requirements on all Chinese banks. The regulatory authorities also urged Chinese banks to establish risk management structures and rating systems. In response to this the leading three

[25] Three pillars of Basel II were incorporated into the new regulations. They are minimum capital requirements, supervisory reviews and market discipline.

[26] The minimum bank CAR of 8% was prescribed in earlier Commercial Bank Law. However, this earlier Law did not provide any detailed calculation methods or definitions of the CAR's components, and as a consequence, this 8% requirement had not been enforceable.

commercial banks, the Bank of China (BOC), the China Construction Bank (CCB) and the Industrial & Commercial Bank of China (ICBC), have been developing new internal rating and credit risk management systems which are based on the Basel II framework.

The international five-category loan classification system was introduced for Chinese commercial banks in 1998. However, it was not until 2003 that the CBRC required all commercial banks to adopt this risk-based loan classification system - at which point the existing parallel four-category loan classification system was phased out. Under the new system, bank loans are classified as performing (normal and special-mention) and non-performing (sub-standard, doubtful and loss) based on their inherent risks. This loan classification system has facilitated reform by making the actual situation of the banks more transparent to regulators and bank managers.

State-owned commercial banks (SOCBs) play a vital role in China's economic and social development and they also take a leading role in the country's banking system. Therefore, in 2003, the State Council initiated the "pilot state-owned bank-overhaul program" to accelerate reform of its state-owned banks through the process of infusing new capital, resolving problems with non-performing loans and improving corporate governance. The Bank of China (BOC) and China Construction Bank (CCB) were selected as pilot banks for the state-owned banking reforms. In December 2003, the State Council injected USD 22.5 billion in fresh capital into these two banks respectively. This capital injection was accomplished through a new established state-owned investment company, the Central Huijin Investment Co., Ltd (Huijin), which acquired funds from China's official foreign exchange reserves. The two banks used their new capital along with undistributed profits to provision or write-off, the equivalent of USD 23.4 billion in non-performing loans (Brean, 2007). Similar capital injections were extended to other big state-owned commercial banks. Huijin injected RMB 3 billion to the Bank of Communications (BOCOM) in 2004 and USD 15 billion into the Industrial and Commercial Bank of China (ICBC) in 2005. In addition to the

capital injections, the big SOCBs transfer their non-performing loans to the asset management companies (AMCs) referred to earlier. These transfers totalled more than RMB 1,200 billion, some at face value, and some at discounted prices (see Table 4.6 for further details). For example, in June 2004 Cinda AMC won the auction to purchase RMB 278.7 billion of distressed assets from BOC and CCB at 31% of their book values[27]. After the capital injections and transfers of non-performing loans, there was a dramatic improvement in the SOCB's balance sheets (see Table 4.7 for further details). In contrast, there has been little progress in reforming the Agricultural Bank of China (ABC). The ABC's problems were regarded as more serious than those of the other four banks and as inextricably related to rural financial-system reform, so its bailout and restructuring program have required much more consideration.

Table 4.6 SOCB's Capital Injections and Disposal of NPLs since 2003

Bank	*Capital Injections*			*NPLs Transfer to AMCs*			
	Institution	Amount (RMB billion)	Date	AMCs	Face Value (RMB billion)	Actual Paid (% face value)	Date
ICBC	Huijing	124.0	Apr. 2005	Huarong	246.0	100%	May 2005
				Huarong	22.7	100%	June 2005
				Cinda	58.1	100%	June 2005
				Greatwall	257.0	100%	June 2005
				Oriental	121.2	100%	June 2005
BOC	Huijing	186.4	Dec. 2003	Oriental	140.0	100%	May 2004
				Cinda	149.8	31%	June 2004
CCB	Huijing	186.4	Dec. 2003	Cinda	56.9	100%	May 2004
				Cinda	128.9	31%	June 2004
BOCOM	Huijing	3.0	June 2004	Cinda	64.1	50%	June 2004
	Ministry of Finance	5.0	June 2004				
	Social Security Fund	10.0	June 2004				
Totals		514.8			1244.7		

Sources: Almanac of China's Finance and Banking (2003-2006), Okazaki (2007), AMCs press releases.

[27] Unlike the 1999 non-performing loan transfers at face value to the AMCs, on this occasion the bad loans were sold in a bidding process involving the four AMCs.

Table 4.7 Financial Restructuring in SOCBs

	ICBC		BOC		CCB		BOCOM		ABC	
	NPL Ratios (%)	CAR (%)	NPL Ratios (%)	CAR (%)	NPL Ratios (%)	CAR (%)	NPL Ratios (%)	CAR (%)	NPL Ratios (%)	CAR (%)
2003	21.7	-8.8	17.8	5.4	9.3	6.7	13.3	1.9	30.7	-19.6
2004	19.5	-8.3	5.7	8.0	3.8	12.0	3	9.7	26.8	-18.6
2005	4.5	10.0	5.4	10.2	3.8	13.6	2.5	11.2	26.3	-21.7
2006	3.8	14.2	4.8	13.6	3.3	11.1	2.1	11.1	23.6	-17.5
2007	2.7	13.1	3.1	13.3	2.6	12.6	2.7	14.4	23.5	N/A

Sources: CBRC, Bank annual reports.
Notes: Non-performing loan (NPL) ratio = total non-performing loan amount / total loan amount.
Capital adequacy ratio (CAR) = capital / risk weighted assets.

As an important part of the banking reform process, the Chinese government has encouraged foreign strategic investment by foreign financial institutions into Chinese banks in recent years. Its hope is that Chinese banks will acquire risk management, advance technology, international operations experience and fresh capital from their foreign partners and thereby improve their core competitiveness. For their part foreign financial institutions have shown considerable interest in investing Chinese banks because of the favourable opportunities it offers for them to expand into China without the risk and hassles of establishing their own local affiliates. It also allows the foreign financial institutions to form strategic partnerships and to acquire an understanding of Chinese business culture and customers that would not otherwise be possible. Therefore, the introduction of foreign strategic investors is a win-win game.

In December 2003, the CBRC issued a regulation regarding foreign equity investment in Chinese financial institutions. According to the regulations, a single foreign investor can hold up to a 20% ownership stake in a local bank, and total foreign investments in one domestic bank are not permit to exceed 25 % of total equity. Therefore, foreign strategic investors have only been permitted to take a minority stake in Chinese banks and have very little involvement in the direct management of the

affected banks. Most strategic foreign investments took place between 2004 and 2006. Initially, foreign ownership participation was focussed on Chinese small and medium sized commercial banks but eventually spread to big state-owned commercial banks. Since 1996, when foreign strategic investors were first permitted to invest in Chinese banks, 29 foreign institutional investors have acquired a stake in 21 Chinese banks with a total investment of USD19 billion by 2006 (see table 4.8 for further details)[28].

Another strategy used by the Chinese authorities in order to improve Chinese banks' corporate governance and management efficiency is to encourage Chinese banks to list on stock exchanges through the device of an initial public offering (IPO). The Bank of Communications (BOCOM) successfully launched an initial public offering (IPO) on the Hong Kong Stock Exchange in June 2005 and raised USD 2.2 billion in share capital. This successful IPO has been view as a model for shareholding reform. Bank of China (BOC) and Industrial and Commercial Bank of China (ICBC) also completed IPOs on the Hong Kong Stock Exchange in 2005 and 2006 respectively. At first, the government preferred to use offshore markets because the requirements for qualification and disclosure in overseas markets are generally much more stringent than those in Chinese domestic markets. It was expected that by listing on foreign stock markets Chinese banks would be forced to undertake the structural reforms the Chinese governments was hoping for (Okazaki, 2007). However, the government soon recognised that listing bank securities on foreign stock markets limited domestic investor's opportunities to invest in the country's largest national banks. Thus, BOC, ICBC, BOCOM and CCB also carried out IPOs on the Shanghai Stock Exchange. In 2007, several joint-stock commercial banks and city commercial banks also launched IPOs on Chinese stock exchanges (See Table 4.9 for further details). Here it is important to note that shares listed on (both domestic and foreign) stock exchanges are not subject to the 25% restriction on foreign ownership alluded to earlier.

[28] The Asian Development Bank was the first foreign financial institution to purchase an interest in a Chinese domestic bank when in 1996 it purchased a 3.29% stake in the China Everbright Bank for 1.9 million USD.

Table 4.8 Foreign Investments in Chinese Banks (up to 2007)

Bank Name	Invest time	Foreign Investor		Foreign Ownership Stake	100 million U.S.D.
		Name of Financial Institution	Country		
State-owned Commercial banks					
Industrial & Commercial Bank of China	2006.3	Goldman Sachs Group	USA	6.05%	25.822
		Allianz Group	Germany	2.36%	10
		American Express	USA	0.47%	2
Bank of China	2005.12	Royal Bank of Scotland	UK	10%	30.478
		Union Bank of Switzerland （UBS）	Switzerland	1.61%	4.916
		Asian Development Bank （ADB）	International Finance Organisation (IFO)	0.24%	0.737
		Asia Financial Holdings Pte. Ltd (AFH)	Singapore	5%	15.239
China Construction Bank Corporation	2005.8	Bank of America	USA	8.515%	30
	2005.8	Asia Financial Holdings. Ltd (AFH)	Singapore	5.878%	24.66
Joint Stock Commercial Banks					
Bank of Communications	2004.8	HSBC in HK	Hong Kong	19.90%	17.47
Hua Xia Bank	2006.3	Deutsche Bank	Germany	7.02%	1.656
		Deutsche Bank Luxembourg （DBL）	Luxembourg	2.88%	0.679
		Sal. Oppenheim jr. & Cie. KGaA	Germany	4.08%	0.961
China Merchants Bank	2004.11	Asia Financial Holdings Pte. Ltd (AFH)	Singapore	4.55%	1.07
	2003.9	International Finance Corporation (IFC)	IFO	1.22%	0.235

Table 4.8. Foreign Investments in Chinese Banks (up to 2006) (continued)

Bank Name	Invest time	Foreign Investor		Foreign Ownership Stake	100 million U.S.D.
		Name of Financial Institution	Country		
Industrial Bank	2004.3	Hang Seng Bank	Hong Kong	15.98%	2.08
		International Finance Corporation (IFC)	IFO	4%	0.52
		Government of Singapore Investment Co (GIC)（via Tetrad Investment Pte Ltd ）	Singapore	5%	0.65
Guangdong Development Bank	2006.12	Citibank	USA	20%	7.2468
		IBM CREDIT LLC	USA	4.74%	1.7175
Shenzhen Development Bank	2004.9	Newbridge Asia AIV Ⅲ L.P.	USA	17.89%	1.5
Shanghai Pudong Development Bank	2002.12	Citibank（via COIC）	USA	5%	0.6753
China Everbright Bank	1996.10	Asian Development Bank （ADB）	IFO	3%	0.2
Bohai Bank	2005.12	Standard Chartered Bank (Hong Kong)	Hong Kong	19.99%	1.2346
City Commercial Banks					
Bank of Shanghai	1998.8	International Finance Corporation (IFC)	IFO	5%	0.2561
	2001.12	International Finance Corporation (IFC)	IFO	7%	0.2467
		HSBC in HK	Hong Kong	8%	0.6257
		Shanghai Commercial Bank (Hong Kong)	Hong Kong	3%	0.2347
Jinan City Commerical Bank	2004.11	Commonwealth Bank	Australia	11%	0.1735
Xi'an City Commerical Bank	2004.6	International Finance Corporation (IFC)	IFO	2.50%	0.032
		Scotiabank	Canada	2.50%	0.032

Table 4.8. Foreign Investments in Chinese Banks (up to 2006) (continued)

Bank Name	Invest time	Foreign Investor		Foreign Ownership Stake	100 million U.S.D.
		Name of Financial Institution	Country		
Bank of Beijing	2005.3	ING BANK N.V.	Netherlands	19.90%	2.352
	2005.5	International Finance Corporation (IFC)	IFO	5%	0.59
Bank of Nanjing	2001.11	International Finance Corporation (IFC)	IFO	5%	0.0882
	2005.12	BNP Paribas	Finace	19.20%	0.8732
Hangzhou City Commercial Bank	2005.3	Commonwealth Bank	Australia	19.92%	0.77
	2006.11	Asian Development Bank （ADB）	IFO	4.99%	0.2760
Nancong City Commercial Bank	2005.7	DEG finances investments of private enterprises （DEG）	Germany	10%	0.036
		Sparkassen International Development Trust （SIDT）	Germany	3.30%	0.012
Tianjing City Commercial Bank	2006.5	Australia & New Zealand Banking Group (ANZ)	Australia	20%	1.10
Bank of Ningbo	2006.5	Oversea-Chinese Banking Corporation Ltd.(OCBC)	Singapore	12.20%	0.71
21 Banks		29 Financial Institutions			190.15

Source: CBRC

Table 4.9 Publicly Listed Banks since 2005

Bank	Date of IPO	Listed Place	Selling Price per Share	Total Capital before IPO (RMB billion)	Share Capital Raised (RMB billion)
ICBC	Oct. 2006	Hong Kong Shanghai	HK$ 3.07 RMB 3.12	326.2 (June 2006)	126.6 46.6
BOC	June 2006 July 2006	Hong Kong Shanghai	HK$ 2.95 RMB 3.08	233.8 (Dec. 2005)	90.0 20.0
CCB	Oct. 2005 Sep. 2007	Hong Kong Shanghai	HK$ 2.35 RMB 6.45	200.9 (June 2005)	74.6 58.1
BOCOM	June 2005 May 2007	Hong Kong Shanghai	HK$ 2.50 RMB 7.90	52.1 (Dec. 2004)	18.0 25.2
China Merchants Bank	Sep. 2006	Hong Kong	HK$ 8.55	26.0 (Dec. 2005)	20.9
CITIC Bank	April 2007	Hong Kong Shanghai	HK$ 5.86 RMB 5.8	31.7 (Dec. 2006)	31.5 13.34
Industrial Bank	Feb. 2007	Shanghai	RMB 15.98	16.2 (Dec. 2006)	16.0
Beijing Bank	Sep. 2007	Shanghai	RMB 12.5	9.84 (Dec. 2006)	15
Nanjing Bank	July 2007	Shanghai	RMB 11	2.63 (Dec. 2006)	6.93
Ningbo Bank	July 2007	Shenzhen	RMB 9.2	3.2 (Dec. 2006)	4.14

Sources: Annual report of each bank, Okazaki (2007)

4.4 Summary and Conclusion

This chapter briefly outlines the structure of the Chinese banking sector. Currently, the Chinese banking sector is comprised of two regulatory institutions (the Peoples' Bank of China and China Banking Regulatory Commission), both of which are overseen by the State Council (the Cabinet), and four categories of banks, namely: commercial banks (state-owned commercial banks, joint-stock commercial banks, city commercial banks, and foreign banks), policy banks, credit cooperatives and non-banking financial institutions. The most notable characteristic of the Chinese banking system is that it is dominated by the big four state-owned commercial banks (ICBC, BOC, CCB and

ABC).

This chapter also reviews the banking reform process implemented by the Chinese government and which began in 1979. Basically, the Chinese banking reform process can be subdivided into three phases. In 1979 the Chinese government began implementing the first phase of its banking reforms and these continued until 1993. During this period the Chinese banking system moved from a Soviet style mono-banking system towards a two tiered banking system consisting of a central bank and various types of financial institutions (e.g. state-owned specialised banks, medium and small-sized commercial banks and credit cooperatives, etc.). This phase prepared the environmental setting for future banking reforms (Cousin, 2007). The second phase of banking reforms began in 1994 and lasted until 2001. This entailed a progressive movement towards less administrative and more independent banking operations and emphasised the financial stability and systemic risk of the banking sector. Thus, in 1994 the Chinese government established three policy banks in order to separate policy lending from the four existing specialised state-owned commercial banks. Moreover, the promulgation of the Central Bank Law and the Commercial Banking Law in 1995 enhanced the independence of both the PBC and the commercial banks. During this second phase of the reform process, the Chinese government also injected substantial levels of additional equity capital into the state-owned banks. Furthermore, it encouraged all banks to implement the international classification of non-performing loans scheme and for the state-owned banks to transfer non-performing loans into asset management companies established in 1999 specifically for that purpose.

The third and last phase of banking sector reforms occurred from 2002 until 2007 and entailed a progressive implementation of the WTO protocols. The Chinese banking system became much more open subsequent to China's entry into the WTO. The major banking reforms during this period included the creation of the China Banking

Regulatory Commission which has the objective of achieving a more enhanced level of monitoring of the banking sector, the recapitalisation of the state-owned banks and the disposition of non-performing loans to rehabilitate the balance sheets of the major Chinese state-owned banks. Moreover, the introduction of foreign strategic investors and the listing of bank securities on the stock exchange was designed to enhance the effectiveness banking management in China. In the following chapter, we outline the modelling framework used to measure cost efficiency and scale economies of Chinese banks.

Chapter 5 Methodology

5.1 Introduction

The preceding chapter discussed the main structure of the Chinese banking sector and the banking reforms undertaken in China over the last three decades. In recent years the Chinese banking sector has experienced significant institutional, structural and legal changes because of the deregulation and liberalisation programme implemented by the Chinese government. The main objective of this chapter is to describe the modelling framework used to measure the cost efficiency and scale economies of Chinese banks. To the author's knowledge, no previous study has employed both parametric (SFA) and nonparametric (DEA) methods to measure the efficiency of Chinese banks and assess the robustness of results obtained. Thus, we endeavour to fill this gap by applying multiple frontier techniques and specifications on a large data set of Chinese banks.

The remainder of this chapter is structured as follows. Section 5.2 discusses a number of SFA cost efficiency models that have been developed to measure the efficiency of Chinese banks and to account for sample heterogeneity. Section 5.3 defines the variables used in our modelling procedures and presents in detail, the empirical specification of the SFA models. Section 5.4 outlines the DEA methodology that is also employed to estimate the cost efficiency of Chinese banks. The DEA models complement the SFA models employed in our empirical analysis and are valuable device for cross-checking purposes. Section 5.5 proposes a set of consistency conditions in order to compare the efficiency estimates generated by the SFA and DEA models. Section 5.6 provides summary data and descriptive statistics of the variables used in the empirical work. Finally, the last section provides our concluding comments.

5.2 The Stochastic Cost Frontier Function

It is well known that the cost (or profit) function approach for determining the optimal combination of factors of production is the dual of the production function approach[29] and allows for the treatment of multiple outputs, quasi-fixed inputs, behavioural objectives and the analysis of economic efficiency levels. The duality condition between production and cost functions ensures that they contain essentially the same information about a firm's production possibilities. However, the cost function adds the economic dimension of determining the technically efficient combinations of factors of production which minimise the total cost of particular output levels. This latter aspect of cost minimisation is referred to as allocative efficiency. Here Shephard (1953, 1970) demonstrates how cost functions are derived from the production function and input prices of the factors of production. A general version of the minimum cost function (also know as the cost frontier) can be written as:

$$\mathrm{TC_i} \geq \mathrm{TC}^* = f(Q_i, W_i; \beta), \qquad i = 1,\ldots, \mathrm{I}, \tag{5.1}$$

where $\mathrm{TC_i}$ is the observed total cost of the individual bank i; Q_i is a vector of the outputs of bank i; W_i is an input price vector of bank i, $f(Q_i, W_i; \beta)$ is the cost frontier common to all banks representing the minimum cost of producing outputs Q_i when the banks face input prices W_i, and β is a vector of the technology parameters to be estimated. The cost function should satisfy certain properties which are summarised by Coelli *et al.* (2005) as follows[30]:

(i) Nonnegativity: $f(Q, W) > 0$ for $Q > 0$ and $W > 0$. This states that it is not possible to produce a positive output without incurring any costs.

(ii) Nondecreasing in output, Q: if $Q^0 > Q^1$ then $f(Q^0, W) > f(Q^1, W)$. This states that cost cannot decreases as output rises.

[29] The production function summarises the technology of a bank; that is, the relationship between outputs and inputs under which it operates.

[30] For a more detailed discussion of these properties, see Chambers (1998).

(iii) Nondecreasing in input prices, W: if $W^0 > W^1$ then $f(Q, W^0) > f(Q, W^1)$. This implies that an increase in input prices will not lead to a decrease in costs.

(iv) Homogeneity of degree one in input prices, W: $f(Q, kW) = kf(Q, W)$ for $k > 0$. This implies that a proportional increase or decrease of all input prices will cause the same proportional change in total costs.

(v) Concavity in input prices, W: $f(Q, \theta W^0 + (1-\theta) W^1) > \theta f(Q, W^0) + (1-\theta) f(Q, W^1)$ for all $0 \leq \theta \leq 1$.

Cost efficiency (CE) is measured relative to the efficient cost frontier, which is defined as the ratio of the minimum cost to the cost actually incurred. Thus, if the cost incurred in producing a given output level turns out to be TC but that the technically efficient combination of factors of production which minimise costs for this output level is TC* then the cost efficiency of the firm will be CE = TC*/TC. This in turn implies that it would be possible to produce the same output bundle under the same conditions with a saving in costs of (1-CE)%. Failure to attain the cost frontier may be due to either technical or allocative inefficiency (or both). Because the cost frontier is deterministic, such a formulation ignores measurement errors and other sources of statistical noise and all deviations from the frontier are attributed to inefficiency.

To overcome this drawback, Aigner, Lovell and Schmidt (1977) and Meeuse and van den Broeck (1997) simultaneously proposed the stochastic frontier model (that is, SFA). Their model adds a symmetric error term to the deterministic frontier, which accounts for statistical noise. The original models are defined as stochastic production frontiers, but the same framework can be used to define the stochastic cost frontier. Considering the characteristics of our data set and the purposes of this study, we decided to apply this classical frontier model to the panel of China banking data on which our empirical analysis is based. The single equation stochastic cost function for a panel data set can be written as:

$$\ln TC_{it} = f(Q_{it}, W_{it}; \beta) + v_{it} + u_{it} \quad i = 1,\ldots,I, \quad t = 1,\ldots T \tag{5.2}$$

where $\ln TC_{it}$ is the logarithm of the total cost of bank i at time t; $f(Q_{it}, W_{it}; \beta)$ is the deterministic kernel of the cost frontier; Q_{it} and W_{it} are a vector of outputs and of input prices in logarithmic form at time t; v_{it} is a two-sided normal disturbance term with zero mean and variance σ_v^2 representing the effects of noise, and u_{it} is a non-negative random disturbance term capturing the effects of cost inefficiency and is usually assumed as a half-normal distribution, $N^+(0, \sigma_u^2)$. Additionally, v_{it} and u_{it} are independently distributed from each other. Because the cost frontier is specified as being stochastic, the appropriate measure of cost efficiency becomes:

$$CE_{it} = \frac{f(Q_{it}, W_{it}; \beta)\exp(v_{it})}{f(Q_{it}, W_{it}; \beta)\exp(v_{it} + u_{it})} = \exp(-u_{it}) \tag{5.3}$$

Note that the value of u_{it} cannot be observed directly from the above equation; only the composite error term $\varepsilon_{it} = v_{it} + u_{it}$ can be observed. A solution to this problem is obtained by using the distribution of the inefficiency term condition on the estimation of the composite error term. For the half-normal case, Battese and Coelli (1988) proposed an appropriate point estimator for cost inefficiency which involves the conditional expectation of $\exp(-u_{it})$ given the entire error term[31]. This is given by:

$$CE_{it} = \mathrm{E}\left[\exp(-u_{it}) \middle| \varepsilon_{it}\right] = \left[\frac{1 - \Phi(\sigma_* - \varepsilon_{it}\gamma / \sigma_*)}{1 - \Phi(-\varepsilon_{it}\gamma / \sigma_*)}\right] . \exp\left\{-\varepsilon_{it}\gamma + \frac{1}{2}\sigma_*\right\} \tag{5.4}$$

where $\Phi(.)$ is the standard normal cumulative distribution function and $\sigma = \sqrt{\sigma_v^2 + \sigma_u^2}$, $\sigma_* = \sigma_v^2 \sigma_u^2 / \sigma^2$ and $\gamma = \sigma_u^2 / \sigma^2$. The value of γ must lie between zero and one. A value of one indicates that the deviation from the frontier is due to

[31] An alternative point estimator for efficiency is given by Jondrow *et al.*(1982) (JLMS). Battese and Coelli (1988) and Kumbhakar and Lovell (2000) point out that Battese and Coelli (1988)'s estimator is to be preferred, particularly when u_i is not close to zero. This is because the JLMS estimator includes only the first term in the power-series expansion of exp (-*u*).

cost inefficiency, while a value of zero indicates that the deviation is explained by pure noise. The estimates of efficiency are unbiased but inconsistent, because the variation associated with the distribution of the estimator ($u_i|\varepsilon_i$) is independent of i and remains non-zero (Greene, 1991)[32]. The efficiency measure from equation (5.4) takes values over the interval $[1,\infty)$ and a value equal to one means fully efficient. Given this, the cost efficiency score can be calculated as $1/CE_{it}$. In this study, we employ maximum likelihood techniques to obtain estimates of β and the parameters of the two error components (see equation 5.2). Firstly, the likelihood function should be defined. Then the log likelihood function can be maximised with respect to the parameters in order to obtain maximum likelihood estimates of all parameters[33].

In Aigner, Lovell and Schmidt (1977), the original model assumes efficiency follows a half-normal distribution with mean zero. This specification implies that the likelihood of inefficient behaviour monotonically decreases for increasing levels of inefficiency and most units are likely to be concentrated close to the cost frontier causing artificially high efficiency levels. But there is no theoretical reason to support the ex ante monotonicity assumption invoked by Aigner, Lovell and Schmidt (1977). Given this, Stevenson (1980) argues that inefficiency is not likely to be distributed with such a monotonically declining density function. He also argues that the half-normal distribution assumption used by Aigner, Lovell and Schmidt (1977) is unnecessarily restrictive. Instead Stevenson (1980) introduces a normal-truncated formulation that assumes u to be normally distributed with a nonzero (constant) mean truncated at zero from above. Thus the truncated normal distribution introduced by Stevenson (1980) requires one more parameter μ (its mean) to be estimated and the point estimate of cost efficiency for each bank is given by the formula:

[32] An estimator is consistent if its values approach the true parameter value and if its variances get smaller as the sample size increases indefinitely.

[33] See Kumbhakar and Lovell (2000) for the derivation of the likelihood function and its partial derivatives with respect to the parameters of the model.

$$CE_{it} = \mathrm{E}\left[\exp(-u_{it})\middle|\varepsilon_{it}\right]$$

$$= \left[\frac{1-\Phi(\sigma_* - (-\sigma_u^2\varepsilon_{it} + \mu\sigma_v^2)/\sigma\sigma_*)}{1-\Phi(-\sigma_u^2\varepsilon_{it} + \mu\sigma_v^2/\sigma\sigma_*)}\right].\exp\left\{-\frac{-\sigma_u^2\varepsilon_{it} + \mu\sigma_v^2}{\sigma} + \frac{1}{2}\sigma_*\right\} \qquad (5.5)$$

This model also can be estimated using maximum likelihood techniques. We prefer the truncated specification to the half-normal model, because the former provides a somewhat more flexible representation of the pattern of efficiency in the data. But both models face an important limitation which fails to account for heterogeneity across banks, an issue we now develop[34].

The Aigner, Lovell and Schmidt (1977) and Stevenson (1980) models both assume that banks operate in perfectly competitive input-output markets. Thus, banks' input prices are taken as exogenous. However, this assumption may not be valid when banks are heterogeneous. Some of the factors contributing to banks' heterogeneity (e.g. output quality) could make their input prices partially endogenous and thus influence both their technical and allocative efficiencies. Therefore, the potential endogeneity of input prices should be controlled for in the measurement of banks' cost efficiency. Additionally, under the conventional frontier model, different banks are assumed to produce equivalent quality in terms of output. However, there are likely to be differences across banks in the quality of outputs. Because the traditional output variables do not fully capture heterogeneity in bank outputs differences in production quality may be incorrectly measured as differences in cost inefficiency (Berger and Mester, 1997). Some banks might be incorrectly labelled as inefficient merely because they produce higher quality outputs than other banks. Thus, failure to recognise this heterogeneity in bank outputs may bias estimates of cost efficiency.

To overcome these problems, we try to incorporate these differences into the specification of the cost function. Formally, it is appropriate to include control variables, Z_{it}, along with the outputs and input prices in a stochastic cost frontier model,

[34] These models absorb all unmeasured heterogeneity through the inefficiency term (u_{it}).

which can be written as follows:

$$\ln TC_{it} = f(Q_{it}, W_{it}, Z_{it}; \beta) + v_{it} + u_{it} \quad i = 1,\ldots,I, \quad t = 1,\ldots T \tag{5.6}$$

Apart from including control variables in the deterministic kernel of the stochastic cost frontier, the model given by equation (5.6) is structurally indistinguishable from the conventional stochastic cost frontier model given by equation (5.2). In this formulation, Z_{it}, are assumed to directly influence the cost of production, and alter the shape of the cost frontier. However, the model still estimates a common benchmark. Although, this model may be more precise in its estimates of the parameters and cost efficiency, it does not account for heterogeneity due to the exogenous variables which either change the position of the frontier or influence the inefficiency term.

Up to now, all the models we have presented assume that all banks in an industry use the same production technology to convert inputs into outputs and that all banks face similar environmental conditions; that is, the shape of the cost frontier is the same across all banks. We know, however, that some heterogeneous environmental variables (or exogenous variables), which are neither inputs to the production process nor outputs of it, may influence the performance measures obtained. For example, variations in market structure, regulation and ownership form, etc. may cause variations in bank performance. Thus, the omission of such heterogeneity leads to biased estimates of the parameters describing the cost frontier and misstates cost inefficiency as a consequence. According to Kumhakar and Lovell (2000), three main approaches exist in the efficiency measurement literature regarding the way in which to incorporate environmental variables into efficiency measurement models. The environmental variables may be considered as the observed factors that can explain differences in (cost) efficiency across firms.

In the simplest case, if the environmental variables which are not under the control of management directly influence the structure of the production process itself, it is appropriate to incorporate these variables into the cost function as regressors (e.g., Good

et al., 1993). In this case we write stochastic cost function as:

$$\ln TC_{it} = f(Q_{it}, W_{it}, Z_{it}, E_{it}; \beta) + v_{it} + u_{it} \quad i = 1,\ldots,I, \quad t = 1,\ldots T \tag{5.7}$$

where E_{it} is a vector of exogenous variables in the deterministic kernel of the stochastic production frontier accounting for systematic differences across banks due to ownership structure, size and market structure etc.. By including the additional variables, the cost frontier incurs a parallel shift. This is different from the influence of incorporating control variables, which changes the shape of frontier. In other words, each bank faces a different cost frontier, but we still assume that the shape of the frontier is the same for all banks. One limitation of this model is that the additional variables do not explicitly explain the variations in the efficiency levels of banks.

Kalirajan (1981) and Pitt and Lee (1981) propose a two-stage approach, in their empirical papers, which seeks to explain the variation in estimated inefficiencies. In the first stage, a cost frontier and banks' efficiency levels are estimated, ignoring the exogenous variables. In the second stage, the estimated efficiency scores are then regressed against the exogenous variables. Thus the variation in estimated efficiency is explained by the exogenous variables. Unfortunately a two-stage approach suffers from serious econometric problems. The first of these emanates from the fact that in order to avoid biased ML estimates in the first-stage, it must be assumed that exogenous variables are uncorrelated with the cost model regressors (outputs and input price). However, in the second-stage our expectation would be that the exogenous variables will be correlated with the inefficiency term. This relationship will cause parameter estimates and efficiency scores to be biased, due to the omitted variables problem. In this circumstance, any inferences from the second-stage are problematic. Second, it is assumed that the efficiency term is independent and identically distributed in the first-stage estimation. But in the second-stage, it is assumed that the estimated efficiencies are normally distributed and dependent on the exogenous variables, and this conflicts with the assumption that the inefficiencies are independent and identically

distributed in the first stage[35]. Thus, the two-stage approach seems inappropriate under the stochastic frontier framework and we do not use this approach in the empirical work on stochastic frontier analysis summarised in later sections of this thesis.

Another way to account for heterogeneity and to achieve an explicit explanation of efficiency is to estimate the parameters of the stochastic frontier and inefficiency models simultaneously. This approach assumes that the environmental variables influence the degree of cost inefficiency (the distribution of inefficiency) and hence that cost efficiencies are expressed as a function of these factors and are integrated into the stochastic frontier model. By comparing this with the incorporation of exogenous variables into the cost function, this method allows the adjustment of the raw efficiency scores to reflect the nature of the operational environments which banks face (Kumhakar and Lovell, 2000). This approach also avoids the omitted variables and independence problems which plague the two-stage estimation procedure. Thus, we also employ the one-stage stochastic frontier model of Battese and Coelli (1995) to estimate bank efficiency. The Battese and Coelli (1995) model extends the ideas of Kumbhakar *et al* (1991), Reifschneider and Stevenson (1991) and Huang and Liu (1994) to panel data. The general Battese and Coelli (1995) model is specified in the same way as equation (5.6) with one exception; and that is that the inefficiency term u_{it} is expressed as an explicit function of a vector of exogenous variables, $E_{it,}$ and a random error term. Thus, the Battese and Coelli (1995) model can be expressed as follows:

$$\ln TC_{it} = f(Q_{it}, W_{it}, Z_{it}; \beta) + v_{it} + (\delta E_{it} + w_{it}) \quad i = 1,\ldots,I, \quad t = 1,\ldots T \tag{5.8}$$

where the random error term w_{it} captures the effect of the 'unobserved' factors and is defined by a truncated normal distribution with zero mean and constant variance; E_{it} captures the observed factors which explain differences in cost efficiency across banks and δ is a vector of parameters to be estimated. Since the inefficiency term u_{it} is nonnegative, the truncation point is $-\delta E_{it}$.

[35] See Kumhakar and Lovell (2000) and Wang and Schmidt (2002), for a more detailed discussion of this issue.

In above model, the truncated inefficiency term u_{it} is independently but not identically distributed and takes the form: $u_{it} \sim (\delta E_{it}, \sigma_u)$. The cost efficiency of the *i*th bank is then given by:

$$CE_{it} = \exp(-u_{it}) = \exp(-\delta E_{it} - w_{it}) \tag{5.9}$$

Here, we also use maximum likelihood estimation to determine values of the unknown parameters in the above model. The expressions for the likelihood function and efficiency point estimator are presented in Battese and Coelli (1993).

Table 5.1 SFA Model Specifications

Models	*Specification*	*Inefficiency u*	*Heterogeneity*
Baseline (M1)	$f(Q_{it}, W_{it}; \beta)$	$u_{it} \sim N^+(0, \sigma_u^2)$	• None.
Truncated (M2)	$f(Q_{it}, W_{it}; \beta)$	$u_{it} \sim N^+(\mu, \sigma_u^2)$	• None.
Controlled (M3)	$f(Q_{it}, W_{it}, Z_{it}; \beta)$	$u_{it} \sim N^+(\mu, \sigma_u^2)$	• Bank specific observed factors in cost function.
Kernel (M4)	$f(Q_{it}, W_{it}, Z_{it}, E_{it}; \beta)$	$u_{it} \sim N^+(\mu, \sigma_u^2)$	• Bank specific observed factors in cost function.
Error effects (M5)	$f(Q_{it}, W_{it}, Z_{it}; \beta)$	$u_{it} \sim N^+(\mu + \delta\ E_{it}, \sigma_u^2)$	• Bank specific observed factors in cost function. • Heterogeneity in the mean of inefficiency distribution.

When considering the different models summarised above, we cannot find a convincing theoretical argument which suggests that one particular specification for assessing efficiency is better than another. Hence, the choice of frontier models is "frequently a judgement call" (Kumhakar and Lovell, 2000, p266). It thus turns out that the specification of inefficiency in frontier modelling is usually ad hoc and is based on tractability rather than on any optimal theoretical criteria for assessing efficiency (Kumhakar *et al*., 1997). Given this, in this study, we employ the different stochastic

cost frontier models briefly summarised in Table 5.1. These models use different assumptions for the distribution of (in)efficiency terms, and different ways to incorporate control and environmental variables. Importantly, however, we also compare the results obtained from each model in order to assess the reliability and robustness of our results and in particular, to determine the most appropriate model with which to measure Chinese banking efficiency.

5.3 Empirical Specification for SFA

5.3.1 Inputs and Outputs Variables

Following the discussion on the stochastic cost frontier models which will be utilised to estimate efficiency levels for the Chinese banking sector, this section defines the output and input (price) variables which are used in our modelling procedures. Although the multiproduct nature of banking firms is widely recognised, there is still no consensus about how the "production process" characterising a bank's outputs and inputs should be defined. There are two main approaches in banking theory about the choice of how to measure the flow of services banks provide: the production approach and the intermediation approach. These two approaches differ in their view of the role of banks and neither fully captures the dual roles of financial institutions. Berger and Humphrey (1997) note that the production approach may be more appropriate for evaluating branch level efficiency while the intermediation approach is better for measuring the efficiency of banks as a whole.

Under the production approach, banks are thought of as production units, which utilise physical inputs such as capital and labour to produce transactions and document processing services for their customers such as keeping customer deposits, issuing loans, and cashing cheques. This approach generally employs the number of deposit accounts, loan transactions and documents processed as outputs. The associated total costs are made up only of the costs of the physical inputs and exclude interest expenses.

An alternative approach to classifying a bank's inputs and outputs is the intermediation

approach, which was originally suggested by Sealey and Lindley (1977). This approach treats a bank as an intermediary, which collects funds from savers and transforms those funds into profitable projects (loans and other earning assets). This transformation activity originates from the different characteristics of deposits and loans[36]. Sealey and Lindley (1977) argue that earning assets (loans, investments, etc.) make up bank outputs, in which case deposits are viewed as inputs, along with capital and labour. Total banking costs include both operating expenses and financial costs. Bank outputs and inputs are treated as a stock, showing the given amount of output at one point in time, since service flows are not usually available.

There is a continuing debate about the definition of the outputs and inputs to be used in cost efficiency studies. We tend to follow the intermediation approach, due to the advantages of this approach (see below) and the easy availability of the data necessary to implement approach. This approach treats deposits as an input, which is more convincing than the production approach (which treats deposits as an output) since they are paid for in part by interest payments and the funds raised provide the bank with its basic "raw material"; namely, investable funds. Furthermore, the intermediation approach emphasises the overall costs of banks, and is appropriate for addressing questions related to cost minimisation by the affected banks (Ferrier and Lovell, 1990). Moreover, the intermediation approach uses money value as a measure output (for loans, other earning assets and non-interest income, etc.) and the necessary information is generally available from a bank's financial statements or from other sources (e.g. Almanac of China's Finance and Banking). Against this, the production approach requires information such as the number of accounts, loans, etc., which is generally not publicly available. Finally, the intermediation approach is also the most widely used in the empirical bank efficiency literature. In this study, we suggest that operating expenses and interest payments comprise total costs; labour, total borrowed funds, and physical capital are the bank's inputs; three outputs are total loans, other earning assets (e.g. investments, interbank assets), and non-interest income which acts as a proxy for nontraditional activities; that is, off-balance sheet items. Although off-balance sheet

[36] Deposits are typically divisible, liquid and riskless, whilst loans are indivisible, illiquid and risky.

items are technically non-earning assets, they increase the bank's income and are an important component of banking business. Therefore, it should be included when modelling a bank's cost characteristics; otherwise, total output would be understated (Jagtiani and Khanthavit, 1996, Rogers, 1998 and Clark and Siems, 2002).

5.3.2 Control Variables

In addition to the above input and output variables, this study also incorporates several control variables which have the potential to influence a bank's costs in a variety of ways. The control variables enter into the stochastic frontier model in the same way as the output (or input price) variables and these variables are fully interactive with the other parameters of the model. The control variables included in our model – namely, the level of equity, the amount of non-performing loans and the time trend – are used to help in addressing the omitted variables problem and the heterogeneity of our sample of banks. Omitting these control variables may result in some efficient elements of banking operations being incorrectly measured as differences in cost inefficiency.

The first control variable is the level of equity which is included as a quasi-fixed input in the banking cost function. Here it needs to be emphasised that the level of equity is an important aspect of efficiency measurement. For example, Berger and Mester (1997) argue that a bank's insolvency risk depends on the level of its equity capital since it provides a cushion against portfolio losses and financial distress. Insolvency risk (non-performing loans) influences the bank's costs through the risk premium which the bank has to pay for its borrowings. This issue is particularly important in the Chinese banking sector where the insolvency risk of a bank could be very high because of a large proportion of non-performing loans in its asset portfolio. However, equity capital is more than just a cushion against insolvency. The level of a bank's equity capital also provides an alternative to deposits and other borrowed funds as a source of loanable funds. Thus, the level of a bank's equity capital may have a direct impact on the bank's other borrowing costs and therefore, the level of equity capital should be considered as an input into the bank's production process. On theoretical grounds, many previous studies which omit the level of equity capital from the cost function, implicitly assume that equity capital is not used as a source of loanable funds; or that

the cost of equity capital is perfectly correlated with the costs of other inputs; or that the cost of equity capital is the same across all banks. However none of these assumptions seems plausible. Therefore, the level of equity capital will affect a bank's cost structure and thus the level of equity capital should be included in a bank's cost function.

Incorporating the level of equity capital into the estimated cost function is also intended to control for a bank's different risk preferences[37]. Banks lever their equity capital with demandable debt to reflect their attitudes toward risk. If some banks are more risk averse than others, they may choose a higher level of equity capital than other banks. Since a bank's equity capital is typically more expensive than deposits, this could lead one to conclude that the risk averse bank is producing its outputs in an allocatively inefficient manner; that is, using the wrong input mix. But an alternative explanation is that the relative levels of equity capital across banks are actually due to different risk preferences (Mester, 1996). So failure to control for the level of equity capital could lead to biases in efficiency measurement. Following Hughes and Mester (1993), this study includes the level of equity rather than the estimated cost of equity capital as a component of the cost function. Here we need to emphasise that banks may not hold the optimal level of equity capital (which minimises its operating costs) if that implies a degree of risk which is unacceptable (banks might be risk averse) and/or regulations set minimum capital requirements.

Following Hughes and Mester (1993) and Mester (1996, 1997), another important control variable included in the cost function is nonperforming loans. This captures the quality of a bank's assets as well as the probability of bank failure and this can influence a bank's costs in a number of ways. On the one hand, problem loans would be endogenous to the bank. A large proportion of problem loans may due to "bad management". Inefficient banks do not practice adequate loan underwriting and monitoring and hence will have higher losses due to non-performing loans. Problem loans may also be caused by short-run cost savings on the initial credit evaluation and

[37] Hughes and Mester (1993), Hughes *et al.* (1995) and Hughes *et al* (1996) tested and rejected the assumption of risk neutrality for banks.

loan monitoring ("skimping"). This would produce short term cost efficiencies artificially higher than a bank which spends adequate resources to ensure its loans are of higher quality. On the other hand, problem loans are likely to be exogenous to the bank due to negative economic shocks ("bad luck"). That is, exogenous events can increase problem loans. As a consequence, the bank incurs extra administrative expenses and managerial efforts in order to alleviate the effects that these problem loans have on their operating activities. These extra operating costs lead to a reduction in cost efficiency. Controlling for non-performing loans in cost functions helps remove, by statistical means, the costs of dealing with problem loans. Berger and DeYoung (1997) tested the bad management, skimping and bad luck hypotheses and found mixed evidence for the exogeneity of nonperforming loans (see Berger and DeYoung (1997) for further discussion).

Finally the time trend variable is included in the stochastic cost function in order to control for the effects of technical progress over time. The time trend is a "catch all" variable which captures the effect of technological factors, such as learning by doing and organisational changes allowing for the more efficient use of existing inputs.

5.3.3 Environmental Variables

In our study, the environmental variables are also incorporated in the model to account for heterogeneity and to investigate the determinants of the cost efficiency of banks. Environmental variables cannot generally be controlled by bank managers, or at least are partially exogenous. These variables fall into five broad categories: bank ownership structure, bank size, market structure characteristics, banking deregulation and market discipline.

The first category of environmental variables included in our analysis is the ownership structure of banks. In particular, the ownership structure variable is designed to capture differences that may arise between state-owned, domestic private and foreign banks. Foreign-owned banks may possess comparative advantages over domestic banks, especially in a developing country like China. These potential advantages

include superior managerial skills, high quality human capital, lower cost of funds, adequate capital supply, etc. (McCauley and Seth, 1992, Terrell, 1993, Berger *et al*., 2005) and might help foreign banks to reduce their costs in comparison to domestic banks. As a result, it has often been argued that majority-owned of foreign banks are likely to be more efficient than their domestic counterparts (Hasan and Marton, 2003, Bonin *et al.*, 2005a, Berger *et al*., 2009). On the other hand, foreign ownership was also found to be negatively related to banking efficiency by DeYoung and Nolle (1996) and Chang *et al.*, (1998) amongst others. Some adverse factors, such as organisational operating diseconomies and monitoring banks from a distance, could prevent foreign-owned banks from achieving the same levels of efficiency as domestically-owned banks. Moreover, the different types of banks in China may have different operating objectives and face different regulatory environments. For example, state-owned banks are often obliged to conduct projects which assist in fulfilling social welfare objectives while private banks and foreign banks operate predominantly on a purely commercial basis and thereby have a primary focus of profit maximisation. Furthermore, majority foreign-owned banks have only a recent history of competing in the retail banking market in China because before 2006, they were not been permitted to collect Chinese currency (RMB) deposits from Chinese individuals. Therefore, the constructional basis under which a bank operates in China can have a significant impact on its structure and performance and so failing to include ownership types in efficiency analysis can be problematic and lead to biases in efficiency scores.

The second environmental variable included in our efficiency models is the size of banks. We do this in order to control for potential scale biases in the estimating process. Bank size may be an important determinant of net interest margins and spreads if there are economies of scale in the Chinese banking sector. In other words, one bank may be more efficient than another as a result of the economies of scale that arise from size rather than because of better management. Beck and Hesse (2006) argued that small banks may be less able to diversify risks, which results in a higher risk premium in the rates at which they can borrow. Therefore, there is a potentially negative relationship between bank size and operating costs. Hunter, Timme, and Yang (1990) and Casu and Girardone (2006) find that larger banks might reap efficiency benefits from economics of scale or/and scope. Furthermore, larger banks

may have more professional management teams which are more effective in cost control, thereby resulting in higher profits. (Evanoff and Israilevich, 1991). In contrast, Bauer, Berger, and Humphrey (1993) and DeYoung and Nolle (1996) found that efficiency was inversely related to bank size and that the smallest banks showed the greatest efficiency. However, Pi and Timme (1993), Mester (1996), Berger and Mester (1997) and Avkiran (1999) did not detect a significant relationship between size and efficiency. Consequently, we analyse the impact that size can have on banking efficiency, which in turn provides useful information for regulators and allows bank managers to assess the optimal scale at which to conduct their operations. Instead of introducing bank size categories (big, medium and small) as dummy variables into our modelling procedures, we use the logarithm of total assets as a proxy for bank size. The advantage of doing so is to capture the effects of scale on cost efficiency while avoiding potential misspecification by using inappropriate break points for dividing our range of banks into different size groups.

The next variable characterises the competitive conditions of the market in which banks operate. The degree of concentration, as an indicator of the characteristics of market structure, may influence a bank's profitability and operational efficiency. The degree of concentration of the banking industry is usually measured by the Herfindahl-Hirschman index (HHI) or n-bank concentration ratio (CRn) which proxies for the bank's market power or the intensity of the competition between banks. The higher the value of the HHI or CRn, the more concentrated the banking system, and the lower the degree of competition. Banks in higher concentrated (less competitive) markets exercise market power by charging higher spreads than is the case in less concentrated markets. They may find less pressure to control their costs as a consequence of this and thus may be able to enjoy the "quiet life" hypothesized by Hicks (Berger and Mester, 1997). It is thus suggested that high market concentration is negatively related to cost efficiency. On the other hand, Demsetz (1973) argued that the relationship between efficiency and concentration could be positive. High concentration may be the result of greater production efficiency by banks. In other words, relatively efficient banks with lower costs can compete more aggressively, earn higher profits and ultimately gain bigger market shares. The *relative-market power hypothesis* asserts that only banks with large market shares and well-differentiated

products are able to exercise market power and earn supernormal profits (see Shepherd, 1982 and Berger, 1995). Thus, market share for each bank in each year proxies for relative market power and is considered as another measure of market structure. In order to investigate the relationship between market structure and cost efficiency, we incorporate both the Herfindahl-Hirschman index (HHI) and market share into the estimating equation[38]. The HHI is defined as the sum of the squared asset market shares of all banks. The market share is calculated as the fraction of bank assets to total assets of all banks. We include both HHI and market share in our estimating equations because the HHI is an aggregate measure that only changes over time whereas the market share variable differs from bank to bank and over time.

We also include a dummy variable to capture the impact of bank deregulation on Chinese banking efficiency. A key objective of deregulation and liberalisation of banking operations is to improve resource allocation and bank performance (Berger and Humphrey, 1997). There have been two important banking reform time points in China during the last twenty years: 1994 and 2001. Before 1994, Chinese banks operated within the confines of a central economic plan and remained subject to administrative controls and the process of deregulation was slow. However, from 1994, the Chinese government implemented a series of regulatory reforms which strengthened the legal status of commercial banks, and stipulated that banks operate independently so that there would be increased competition between banks. Since China's entry into the WTO at the end of 2001, the Chinese government has accelerated banking reform in order to modernise the banking system. Hence, after 2001 the government accelerated the process of bank privatisation, actively encouraged foreigners to purchase equity holdings in domestic Chinese banks, enhanced the corporate governance of the Chinese bank sector and so on. Therefore, it is useful to divide the sample into two sub-periods; the first covering the reform period from 1994 until 2001, and the second the reform period from 2002 until 2007.

[38] We prefer the Herfindahl-Hirschman index to the n-bank concentration ratio because the former takes into account both the number of banks and the inequality of market shares, while the latter does not take into account the number of banks in the industry.

Finally, we include a dummy variable indicating whether a bank's shares are publicly traded on a stock exchange. This environmental variable is included in order to capture the fact that listed banks may improve their efficiency because of the market discipline mechanism and better corporate governance imposed by listing on the stock exchange. Once a bank goes public, it becomes subject to legal, regulatory, and disclosure requirements which usually lead to better corporate governance and which impose additional external monitoring procedures on the management of the bank. Therefore, it might be expected that banks with shares listed on the stock exchange might be more efficient, all else being equal. Berger and Mester (1997), Laurenceson and Qin (2008), and Ray and Das (2009) find that publicly listed banks do indeed tend to be more efficient than banks whose shares are not listed on the stock exchange.

5.3.4 Specification of Cost Function Models

This section begins with the choice of a functional form for the cost function. Then we present a number of specifications which have been developed to estimate cost efficiency. Some models may be considered better than others because to some extent they take into account observed heterogeneity. A preferred specification for estimating efficiency for our sample can be obtained by comparing the different efficiency models with respect to the results they generate in terms of the significance of statistical tests, estimated efficiency scores and estimated efficiency rankings.

When parametric methods are used to estimate efficiency, we should first consider the choice of a functional form for the cost function. The transcendental logarithmic (translog) cost function developed by Christensen *et al*. (1973) is the most commonly used cost function in the bank efficiency literature. The translog cost function provides a second-order logarithmic approximation to an arbitrary continuous transformation surface. It gives a better fit to the frontier than the Cobb-Douglass form (Kumbhakar and Lovell, 2000). However, some recent studies argue that compared to the translog functional form, the Fourier Flexible (FF) functional form provides a better approximation for banking data located far from the mean scale and product mix of the given bank (McAllister and McManus, 1993, Mitchell and Onvural, 1996 and Altunbas *et al*., 2001). However, Berger and Mester (1997) find that the

results from both the translog and FF functional specifications are essentially the same and the improvement in goodness of fit from using the FF functional form appears to be negligible. Furthermore, the FF specification needs to estimate additional parameters for the Fourier trigonometric terms on which it is based, and this requires more degrees of freedom than for the translog functional form. Moreover, the FF specification is more difficult to apply in our empirical research because the number of observations in our sample is relatively small. For the above reasons we employ the translog functional form to derive our efficiency estimates.

In this study, the baseline model, model 1(M1), mimics the traditional approach which is given by equation (5.2) above. Under the intermediation approach, we assume that banks have three output variables and three input prices. The translog specification gives our empirical cost frontier model as follows:

$$\ln\frac{TC}{W_3} = \beta_0 + \sum_{i=1}^{3}\beta_i \ln(Q_i) + \sum_{m=1}^{2}\chi_i \ln(\frac{W_i}{W_3}) + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\varphi_{ij}\ln(Q_i)\ln(Q_j)$$

$$+\frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\eta_{mn}\ln(\frac{W_m}{W_3})\ln(\frac{W_n}{W_3}) + \sum_{i=1}^{3}\sum_{m=1}^{2}\iota_{im}\ln(Q_i)\ln(\frac{W_m}{W_3}) + u_{it} + v_{it} \qquad (5.10)$$

where ln TC is the natural logarithm of total (operating and financial) costs; Q_i are output quantities which are total loans, other earning assets and non-interest income, respectively; W_1 is the price of labour, W_2 is the price of deposits and W_3 is the price of physical assets; $\beta, \chi, \varphi, \iota, \eta$ are parameters to be estimated; and the inefficiency term and error term are as defined in equation (5.2). The duality theorem requires that the cost function must be linearly homogeneous in input prices and continuity requires that the second order parameters must be symmetric. Thus, the total costs and input price terms are normalised by the last input price W_3, in order to impose a linear homogeneity restriction on the model. In addition, the standard symmetry restrictions $\varphi_{ij} = \varphi_{ji}$ and $\eta_{mn} = \eta_{nm}$ apply to the above cost function.

The model 2 (M2) is a minor extension of the baseline model given above. Following

Stevenson (1980), we relax the implicit assumption that the majority of banks are highly efficient and allow the inefficiency term (u_{it}) to follow a truncated normal distribution (truncated below at zero).

In the model 3 (M3), we seek to account for heterogeneity by including the control variables which may significantly affect the structure of the cost frontier. The control variables consist of the level of equity capital (Z_1), the level of non-performing loans (Z_2) and a time trend (Z_3 or T). Under this framework, the control variables and their interactions with the outputs and prices of inputs are incorporated into the cost frontier function in the following specification:

$$\ln(\frac{TC}{W_3}) = \text{M2} + \sum_{k=1}^{3} \rho_k \ln Z_k + \frac{1}{2}\sum_{r=1}^{3}\sum_{s=1}^{3} \xi_{rs} \ln(Z_r)\ln(Z_s)$$

$$+ \sum_{k=1}^{3}\sum_{m=1}^{2} \theta_{km} \ln(Z_k)\ln(\frac{W_m}{W_3}) + \sum_{k=1}^{3}\sum_{i=1}^{3} \psi_{ki} \ln(Z_k)\ln(Q_i) \qquad (5.11)$$

The distribution of the inefficiency term in this model is identical with the distribution of the inefficiency term in model M2. It is obtained by truncation (at zero) of the normal distribution. However, one more restriction is imposed to ensure symmetry, that is, $\xi_{rs} = \xi_{sr}$. Furthermore, in order to investigate the impact of the level of equity capital, output quality and time trend on Chinese banks' cost characteristics, in Chapter 6 we summarise results from estimating a number of different specifications with a different combination of control variables; i.e. in Chapter 6 we propose a series of models which exclude one control variable and then two control variables from equation (5.11). We then compare the results of these more parsimonious models with results obtained from M3 (that is, equation 5.11) to assess whether a more parsimonious specification can return a reasonable description of our data.

To allow for the impact of exogenous (environmental) factors on banks' performance, we include five broad environmental variables thereby giving a total of seven variables

in the model for estimating cost efficiency. As we discussed earlier, there are two alternative ways to account for environmental influences. The first way assumes that environmental factors affect costs directly through the cost frontier. The second approach assumes that these variables influence the degree of cost inefficiency.

Under Model 4 (M4), the environmental variables are included directly in the cost function as regressors. Because this model does not include interaction terms for the environmental and other production variables, each group of banks faces a different (parallel) cost frontier. Thus, in this case, we estimate the following cost function:

$$\ln(\frac{TC}{W_3}) = \text{M3} + \delta_1^{'} STATE_{it} + \delta_2^{'} FOREIGN_{it} + \delta_3^{'} SIZE_{it} + \delta_4^{'} LIST_{it}$$

$$+ \delta_5^{'} REFORM + \delta_6^{'} HHI_t + \delta_7^{'} MS_{it} \qquad (5.12)$$

where M3 represents model 3; $STATE_{it}$ is a dummy variable that takes a value of one if bank *i* in year *t* is a state-owned bank and zero, otherwise. The dummy variable $FOREIGN_{it}$ is a dummy variable which has a value of one if bank *i* in year *t* is a foreign bank and zero otherwise. The private domestic bank dummy is dropped from the model (used as a reference group) to avoid problems with multicollinearity. $SIZE_{it}$, representing the size of bank *i* in year *t*, is taken to be the natural logarithm of total bank assets. $LIST_{it}$ is a dummy variable which takes a value of 1 if bank *i* was publicly listed in year *t*, zero otherwise. A reform (deregulation) dummy variable, $REFORM$, is equal to one for banks in the post deregulatory period (the second reform stage) and zero for banks in the pre-deregulatory period (the first reform stage). HHI_t is a proxy for market concentration in year t. Finally, MS_{it} is the market share of bank *i* in year *t*[39].

[39] We also modelled market share by taking the natural logarithm of MS_{it}. However, there were no significant differences in the results of our analysis from using the logged value of MS_{it} or the raw value of MS_{it}

A second way to account for the effects of environmental factors is suggested by Battese and Coelli's (1995) inefficiency effects model, also called a one stage efficiency model. An important implication is that exogenous factors influence only the distance of each bank from the best practice cost function. This model is suitable for estimating an unbalanced panel dataset and has the ability to model the determinants of inefficiency as well. Following the Battese and Coelli (1995) model, model 5 (M5) is identical to model (M3) with the one exception that the inefficiency term is made an explicit function of a vector of environmental variables. To derive cost efficiency, the cost function and the inefficiency effects equation are estimated simultaneously. The cost inefficiency term is specified as:

$$u_{it} = \delta_0 + \delta_1 STATE_{it} + \delta_2 FOREIGN_{it} + \delta_3 SIZE_{it} + \delta_4 LIST_{it}$$
$$+ \delta_5 REFORM + \delta_6 HHI_t + \delta_7 MS_{it} \qquad (5.13)$$

where the environmental variables are identical to model 4 (M4) defined earlier (equation 5.12). The inefficiency term u_{it} is obtained by truncation (at zero) of the normal distribution with mean, δE_{it}. Here $\delta_{.}$ is the vector containing the coefficients associated with the seven environmental variables in equation (5.13) and E_{it} is the vector containing the numerical values associated with the seven environmental variables.

Using this model, we can proceed from general to specific by imposing one or more restrictions. For example, if δ_0 has a nonzero value and the coefficients of all other variables in equation (5.13) are zero, then it provides the truncated model (M3) (equation 5.11). If all elements of the δ-vector and all coefficients related to control variables are equal to zero, then the baseline model (M1) (equation 5.10) would be obtained.

5.3.5 Estimation of Scale Economies

Apart from estimating cost efficiency, the estimation of a cost function also enables us to investigate how changes in bank outputs affect cost; that is, it allows us to estimate scale economies (scale elasticities) for banks. According Baumol *et al.* (1982), the overall scale economies (SCALE), also called ray scale economies, can be measured in terms of the relative changes in costs attributable to an increase in output; namely, the inverse of the elasticity of cost with respect to output. It is defined as follows:

$$\text{SCALE} = 1 / \sum_{i=1}^{n} \frac{\partial \ln TC}{\partial \ln Q_i} \tag{5.14}$$

where $\partial \ln TC / \partial \ln Q_i$ is the partial derivative of the logarithm of the cost function with respect to logarithm of output *i*. The sum of individual cost elasticites measures the proportional change in total cost due to a small proportional change in all of a bank's output when all other factors are held constant. It is should be noted here that the change in output alters the scale of output but not the composition of output bundles. The bank operates at decreasing, constant or increasing returns to scale depending on whether the elasticity is greater than, equal to or less than the unity, respectively. In other words, if SCALE >1, then an equal proportionate rise in all outputs leads to a less than proportionate rise total costs, implying economies of scale. If SCALE < 1, then total costs increase more than proportionately with the increase in outputs, implying diseconomies of scale. Hence, banks operating under decreasing, or increasing returns to scale imply scale inefficiency. However, if SCALE = 1, then the bank operates at the optimal production level in the sense that it exhibits constant returns to scale.

In our empirical work economies of scale can be measured by differentiating a specific interpretation of the translog cost function with respect to outputs. For example, in the case of model 3 (equation 5.11), the economies of scale is given by:

$$\text{SCALE} = 1/\sum_{i=1}^{3}\frac{\partial \ln TC}{\partial \ln Q_i} = \sum_{i=1}^{3}\beta_i + \sum_{i=3}^{3}\sum_{j=3}^{3}\varphi_{ij}\ln Q_j$$

$$+\sum_{i=1}^{3}\sum_{m=1}^{2}\iota_{im}\ln(\frac{W_m}{W_3}) + \sum_{i=1}^{3}\sum_{k=1}^{3}\psi_{ik}\ln Z_k \qquad (5.15)$$

5.4 Utilising DEA to Measure Cost Efficiency

The SFA approach is a useful and powerful tool for determining efficiency frontiers and thereby estimating efficiency levels. But a serious drawback associated with this approach is that the specifications of the cost function and error term may not be capable of reflecting the real characteristics of the industry. For example, the inefficiency factor may not be distributed in terms of the half normal or truncated normal distribution. Here the Data Envelopment Analysis (DEA) (non-parametric) model represents a more flexible approach for estimating efficiency because it does not involve explicit estimation of a bank's cost function and the error term associated with it and thereby avoids the risk of mis-specification. However, against this DEA is a purely deterministic model of cost efficiency and as such takes no account of potential random errors in the data. Thus, the DEA approach is superior in terms of the specification problem while the SFA approach is superior in terms of the noise (that is, random error) problem. Moreover, the efficiency scores obtained from different techniques contain different information which is important for policy analysis and decision making (Eisenbeis *et al*, 1999). Therefore, we also employ two DEA models (traditional cost DEA and new cost DEA) as a complement to the SFA model employed in our study. The two DEA models applied in our empirical analysis use the same efficiency concept (cost efficiency), the same sample of banks, the same specification of variables and the same time interval as the SFA approach used in our empirical analysis. By comparing these two approaches, the robustness and accuracy of the results can thus be used for methodological cross checking purposes.

5.4.1 Traditional Cost DEA

Data Envelopment Analysis (DEA) was first developed by Charnes *et al.* (1978) under

the constant return to scale (CRS) assumption. It was later extended to consider alternative sets of assumptions, such as variable returns to scale (VRS), cost minimisation (Färe *et al*., 1985) and profit maximisation (Lovell, 1993). DEA is a nonparametric technique for generating a piecewise linear convex frontier which is formed by enveloping the decision making units (DMUs). Under the DEA approach, cost efficiency refers to a bank which minimises the cost of producing a given set of output quantities, given the input prices it faces. Following Färe *et al.* (1985), a sequence of linear programmes is applied to construct efficient cost frontiers from which the measures of cost efficiency are calculated for this study. The variable returns to scale cost minimisation DEA model is defined in the following terms:

$$
\begin{aligned}
&\min_{\lambda, x_i} \quad w_{i0} x_{i0}^* \\
&subject \quad to \\
&\sum_{j=1}^{n} \lambda_i y_{ri} - y_{r0} \geq 0, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_i x_{ij} - x_{i0}^* \leq 0, \quad i = 1,2,\ldots,m \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{5.16}
$$

where n is the number of the bank; x_{j0}^* is the cost minimising vector of input quantities for the evaluated firm, given the vector of input prices w_{j0} and output levels y_{r0}. This constrained optimal minimisation is obtained from a linear combination of banks that produces at least as much of each of the outputs using the same or less amount of inputs as calculated for each bank in the sample. If the hypothetical bank had the same input price vector as evaluated bank *j*, it would have a cost $w_{j0} x_{j0}^*$. In the case of the DEA approach, the variables for outputs and input prices are identical with the SFA model. As mentioned earlier, the cost efficiency of evaluated banks is defined by measuring the distance of its observed cost point from an idealised cost frontier. In

other words, the cost efficiency of the evaluated bank is calculated as the ratio of the minimum cost to the actual cost, that is, $CE_i = {w_{ij}x_{ij}^*}/{w_{ij}x_{ij}}$. The measure of cost efficiency is bounded between zero and one. A cost efficiency of one represents a fully cost efficient bank; (1-CE) represents the amount by which the bank could reduce its costs and still produce at least the same amount of output.

5.4.2 New Cost DEA

In the traditional cost efficiency DEA models (e.g. Fare *et al.*, 1985), it is assumed that input prices are the same across all Decision Making Units (DMUs). However, actual markets do not necessarily function under perfect competition and unit input prices might not be identical across DMUs. Thus, as pointed out by Tone (2002) the traditional DEA cost efficiency model (equation 5.16) does not take account of the fact that costs can obviously be reduced by reducing the input factor prices. To cite an obvious example, if two banks have the same inputs and outputs while the unit input prices for one bank are twice those of the other bank, then the total costs of the bank with the higher unit input prices will be greater than those of the bank with the lower unit input prices. Now under the traditional DEA model the cost function is homogenous of degree one in input prices and the scaling factor cancels out in the cost efficiency ratio. Thus, the two banks will be assigned the same measure of cost efficiency irrespective of the fact that they have significantly different input prices. This represents a serious drawback for assessing relative efficiency levels under the traditional DEA model. This strange outcome is caused by the peculiar structure of the traditional DEA model which is exclusively focused on the technical efficiency of the two banks and cannot take account of variations in unit input prices between the banks. In order to avoid this shortcoming Tone (2002) proposed the New DEA Model under which the production technology is homogeneous of degree one in the total costs as distinct from being homogeneous of degree one in the input prices under the traditional DEA model. This means that under the New DEA model banks with different input prices will return different measures of cost efficiency. In particular, under the Tone (2002) model efficiency levels are determined in terms of the following linear programming problem:

$$
\begin{aligned}
&\min_{\lambda,\bar{x}} \quad e\bar{x}_{i0}^{*} \\
&subject \quad to \\
&\sum_{j=1}^{n} \lambda_j y_{rj} - y_{r0} \geq 0, \quad r = 1,2,\ldots,s \\
&\sum_{j=1}^{n} \lambda_j \bar{x}_{ij} - e\bar{x}_{i0}^{*} \leq 0, \quad i = 1,2,\ldots,m \\
&\sum_{j=1}^{n} \lambda_j = 1 \\
&\lambda_j \geq 0, \quad j = 1,2,\ldots,n
\end{aligned}
\tag{5.17}
$$

where $e \in R^m$ a row vector with all elements is equal to 1 and $\bar{x}_{ij} = (w_{1j}x_{1j},...,w_{ij}x_{ij})^T$. Tone (2002) also assumes that the elements of $\bar{x}_{ij}$ are denominated in homogeneous units in monetary terms, so that the sum of the elements of the vector $\bar{x}_{ij}$ have meaning. In the traditional model, keeping the unit cost of bank j fixed at w_{i0}, we search for the optimal input mix x_0^* for producing y_0. In the new model, the optimal input mix $\bar{x}_0^*$ that produces the output y_0 can be found independently of the bank's current unit price w_0. Then, the new cost efficiency (NCE) is defined as NCE $= e\bar{x}_0^* / e\bar{x}$.

In order to identify the returns to scale under which Chinese banks operate, we also employ the non-increasing returns to scale (NIRS) DEA model which extends the variable returns to scale (VRS) model (as given in equations 5.16 and/or 5.17) by relaxing the convexity condition $\sum_{j=1}^{n} \lambda_j = 1$ so that it becomes $0 \leq \sum_{j=1}^{n} \lambda_j \leq 1$. Then we compare the estimated efficiency scores generated by the VRS model with those generated by the NIRS model. If the cost efficiency scores are the same under the two different constraint sets then the scale inefficient banks will be operating under decreasing returns to scale. Alternatively, if the two resulting measures are different then the bank will be deemed to operating under increasing returns to scale.

5.4.3 Second Stage Regression

The non-parametric DEA model, unlike the SFA model, may be inappropriate for including control and environmental variables directly into the linear programming analysis on which DEA is based. The inclusion of environmental variables directly into the DEA model requires that those variables are treated as conventional inputs or outputs prior to analysis. However, environmental factors are, by definition, beyond the control of the bank. Hence such a prior classification assumption is untenable. In addition, it is problematic whether the control and environmental variables are fixed or semi-fixed as inputs or outputs in the DEA model. DEA provides the radial efficiency measure which assumes that the inputs are shrinkable or the outputs are expandable. So holding the control and environmental variables constant in the calculation of the radial efficiency makes little sense. Therefore, following Isik and Hassan (2003), Ariff and Can (2008) and Pasiouras (2008) we employ a two stage procedure to further explore the effects of the environmental variables on DEA cost efficiency.

In the first stage, we employ DEA models which include only the traditional input prices and outputs to compute cost efficiency (that is, the environmental variables are excluded from the analysis). In the second stage, we regress the cost efficiency scores on the environmental and other factors which potentially affect the computed DEA efficiency scores. Many studies have used a censored Tobit regression rather than OLS regression to investigate the key determinants of banking efficiency (e.g., Maudos *et al*., 2002, Casu and Molyneux, 2003, and Weill, 2003). This is because the Tobit regression takes into account the censored nature of the dependent variable (that is, cost efficiency estimates are bounded between zero and one). Hence, unlike OLS the Tobit regression procedure returns efficient estimates of all parameters. Therefore, we also use the Tobit regression procedure with a left censored bound of zero and right censored bound of one to regress cost efficiency scores against the set of environmental factors (ownership structure, bank size, market structure, etc.) defined earlier. The second stage regression is specified as follows:

$$CE_{it} = \delta_0'' + \delta_1'' STATE_{it} + \delta_2'' FOREIGN_{it} + \delta_3'' SIZE_{it} + \delta_4'' LIST_{it}$$

$$+ \delta_5'' REFORM + \delta_6'' HHI_t + \delta_7'' MS_{it} + \omega_{it} \qquad (5.18)$$

where the dependent variable CE_{it} is the cost efficiency of the ith bank calculated in the first stage. The definitions of the independent variables on the right hand side of this equation are the same as those given earlier in the SFA model and are summarised in the discussion surrounding equation (5.12). The results from this second stage regression enable one to analyse the potential determinants of cost efficiency, and are complementary to the SFA model M5 (equation (5.13)).

5.5 Comparison of SFA and DEA

As one would expect, SFA and DEA both have advantages and disadvantages. The efficiency scores derived from different techniques contain different information. Thus, it is not necessary to achieve consensus on a single best frontier approach for measuring efficiency. Instead, following Bauer *et al.* (1998), this study compares the preferred SFA model and DEA model by checking five consistency conditions for the efficiency measures. Specifically, (1) the cost efficiency estimates derived from the different approaches should have comparable distributional properties for the efficiency scores (e.g. means, standard deviations, etc.); (2) the different frontier approaches should provide similar rankings for the efficiency scores; (3) the different approaches should be consistent in identifying which are the most and least efficient banks; (4) the efficiency scores generated by the different methods should be relatively stable over time, and (5) the estimated efficiency scores should be consistent with traditional non-frontier performance measures (e.g. the return on equity, the ratio of total operating cost to total assets, etc.). The first three consistency conditions may be thought of as measuring the degree to which the different approaches are mutually identical. Conditions (4) and (5) may be thought of as measuring the degree to which the efficiencies estimated by the different techniques are consistent with reality or are believable (Bauer *et al.*, 1998). In addition, we also examine whether the different frontier models identify the same key determinants of cost efficiency. This is helpful

in identifying the significant environmental (and/or other) factors which impact on bank efficiency scores. If all of the consistency conditions are met, the results from the efficiency frontier models will be much more useful and reliable to decision and/or policy makers.

5.6 Data

Our sample is an unbalanced panel which covers 41 Chinese banks over the period from 1994 to 2007, and totals 397 observations. The sample comprises the big four state-owned banks, three policy banks, twelve national and regional joint-stock banks, sixteen city commercial banks and six foreign banks. At the end of 2007, these 41 banks owned almost 80% of total assets of Chinese banking institutions. The fourteen year period on which our study is based corresponds to the period over which the Chinese government implemented vigorous banking reforms and is also, post-WTO accession. These changes are expected to have a significant impact on Chinese banking performance. The data are mainly drawn from the Almanac of China's Finance and Banking issued by the China Finance Society (1994-2007) and BankScope–Fitch's International Bank Database. Additional data and double checks were made from other data sources, such as individual banks' statutory annual financial reports, the China Banking Regulatory Commission's database, the China Economic Information Network (www.cei.gov.cn), the China Statistical Yearbook and the China Labour Statistical Yearbook.

This study adopts the intermediation approach in defining the outputs and inputs (price) of banking services (see Sealey and Lindley, 1977). More specifically, Chinese banks collect deposits and use labour and fixed capital to transform these inputs into loans, investments and non-interest income. Under this treatment, the outputs are specified as total loans (Q_1), which include short term customer loans, medium and long term customer loans, trade bills, bills discounted, entrusted loans and impaired loans, but excludes loan loss reserves. The other earning assets (Q_2) are comprised of balances due from the central bank and other depository institutions, inter-bank loans, short term investments, long-term investments, trading securities and securities held under Repo

agreements, but exclude investment loss reserves. The non-interest income (Q_3) is comprised of net fees and commissions, gains on foreign exchange transactions, gains on investment and other operating income. The inputs are specified as the total deposits plus other borrowed funds (X_1) which include short and long term deposits, short and long term saving deposits, deposits from the central bank, deposits from commercial banks and other depository institutions, inter-bank funds purchased, securities sold under agreement of repurchase, government deposits, and short and long term bonds. Total physical capital (X_2) is the book value of total fixed assets less the book value of accumulated depreciation and labour input (X_3) is proxied by the total number of employees[40]. Data for state-owned and nationwide banks are complete. But data on the number of employees are not available for some city commercial banks and foreign banks in some years. Hence, in years where data on the number of employees is not available, we estimate the number of employees by assuming that the growth rate of the number of employees is the same as the growth rate of the total assets for the affected banks[41].

The methods for measuring cost efficiency also require the total costs and the market prices of inputs for all banks. Total costs include the costs of borrowed funds, deposits and wages and salaries and other operating expenses. A major problem concerning price data is that banks do not often record prices paid for purchased inputs. Instead they normally record the total expenditure on each input category. However, it is normally possible to derive estimates of unit prices by taking the average prices of a broadly-defined group of inputs (Coelli *et al*., 2005). The input prices are defined as the following three variables. First is the price of deposits plus other borrowed funds (W_1) which is calculated by the ratio of total interest expenses on borrowed funds to total borrowed funds. Total interest expenses consist of interest paid on total deposits and interest on interbank borrowing. Second is the price of physical capital (W_2), also called the user cost of capital, which is defined as the ratio of other operating expenses

[40] The measurement of the quantity of physical capital (assets) is quite difficult, because, unlike labour input, capital assets are a durable input used in the production process throughout the life of the asset. It is typically assumed that the net book value of productive capital stock at any given time reflects the quantity of capital services used in production. See Isik and Hassan, (2002), Kumbhakar and Wang, (2007) and Kyj and Isik, (2008).

[41] This assumption is widely used and accepted in banking efficiency studies; see Altunbas, *et al*, (2001), Vander Vennet (2002) and Rezvanian and Mehdian (2002) and Fu and Heffernan (2007).

to the book value of fixed assets (net of depreciation). Other operating expenses are calculated as the operating expenses less expenses on employees (that is, wages, salaries and other benefits provided to employees). Last is the price of labour (W_3). It is measured by the ratio of personnel expenses (that is, wages, salaries and other benefits paid to employees) to the number of employees. Many of the banks included in our sample prepare their statutory published financial statements using Chinese Accounting Standards (CAS). The CAS have been developed only in recent years and are consistent with the accounting standards issued by the International Accounting Standards Board (IASB). Under CAS and IASB standards statutory published financial statements must include details of the total remuneration paid to employees (that is, wages, salaries and other benefits paid to employees). However, early in our sample period banks were not required to prepare their published statutory financial statements in accordance with CAS and IASB standards. This often meant that personnel employee expense figures were not available in the early years of the sample period. Hence, when the personnel employee expense figure is not available from a bank's financial statements we assume that the growth rate in the unit price of labour matches the growth rate in the average wage rate for the Chinese finance sector[42]. Detailed information about average wages and salaries in the Chinese finance sector is published in the China Statistical Yearbook and the China Labour Statistical Yearbook. Hence, data from these two yearbooks was used to estimate the unit price of labour for all missing years. All data are in real 1994 terms and they have been converted using the GDP implicit price deflator. Data relating to input price and output variables are summarised in Table 5.2.

Table 5.2 shows the mean, standard deviation and other statistics of the total costs across the 41 banks at various points in time as well as the equivalent statistics for the period from 1994 until 2007. Thus, the first element of the first row of Table 5.2 gives the average (mean) total cost across the sample banks for the year 1994 (RMB 75,985 million). The second element of the first row gives the standard deviation of the costs across the sample banks, also for the year 1994 (150,239 million). The next four

[42] Other studies such as Fu and Heffernan (2007), Ariff and Can (2007) adopt the average wage paid by financial institutions as a proxy for the price of labor.

elements of the first row give the equivalent statistics for the years 2001 and 2007. Thus, the average of total costs has decreased from RMB 75,985 million in 1994 to RMB 23,818 million in 2007 or by about 320% over our sample period. Finally the last four elements of the first row summarise the average total cost (RMB 24,584 million), the standard deviation of the total costs (RMB 65,577 million) the minimum total cost (RMB 13 million) and the maximum total cost (RMB 633,080 million) across all 41 banks for the entire from 1994 until 2007. The other entries in this table are to be similarly interpreted.

Table 5.2 Descriptive Statistics of Input Price and Output Variables

Variables	1994		2001		2007		1994-2007			
	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Min	Max
Total Cost (TC)*	75985	150329	14111	28171	23818	45108	24584	65577	13	633080
Total loans (Q_1)*	339386	456490	249922	489596	358403	639552	296686	530281	182	2572235
Total other earning assets (Q_2)*	221020	334698	137504	286640	291550	622114	176090	377239	77	2887446
Non-interest income (Q_3)*	3192	5077	1387	2571	3675	8732	2270	4863	1	43680
Price of funds (W_1)	0.0767	0.0570	0.0252	0.0114	0.0238	0.0127	0.0331	0.0311	0.0052	0.2421
Price of physical capital (W_2)	0.6541	0.2899	0.3619	0.1347	0.7116	0.3213	0.5612	0.5084	0.0852	6.9304
Price of labour (W_3)*	0.0333	0.0189	0.0689	0.0336	0.1185	0.0533	0.0736	0.0441	0.0114	0.2611
Total assets*	691863	931372	417161	821327	670886	1277010	513063	958968	291	5465969

Notes all financial values are inflation-adjusted to the base year 1994
* Unit: RMB one million

In addition to the above input price and output variables, this thesis also employs a variety of control and environmental variables to account for heterogeneity in the sample and to explain differences across the cost efficiency estimates. The first of these is the total equity of the individual banks and this is used to control for different risk preferences across banks. The quality of output is proxied by the gross monetary value of nonperforing loans (that is before any write-offs). The time trend is defined as follows: T=1 for 1994, T=2 for 1995,……, T=14 for 2007. This proxies for aggregate technical progress across time for the banks included in our sample.

As previously noted we also employ several environmental variables in our empirical analysis. Hence, we classify a bank as stated-owned when government agencies control at least 50% of its total capital. Domestic private banks are defined as those banks whose private domestic ownership is greater than 50% of total capital. Banks are classified as foreign banks if foreign institutions and/or shareholders control at least 50% of the affected bank's total capital. Moreover, the domestic private bank dummy is dropped from the regression equations employed in our analysis in which case the constant term in the affected regressions captures any domestic private bank effects. Bank size is measured by the natural logarithm of total assets. The Herfindahl-Hirschman index (HHI), the proxy for market concentration, is defined as the sum of the squared asset market shares of all banks. The HHI is slightly greater than zero for a perfectly competitive market and assumes a unit value for a monopoly. Market share is defined as the ratio of an individual bank's total assets to the total assets of all banks in a given year. Moreover, we define the period from 1994 until 2001 as the pre-deregulatory period (the first reform stage) and the period from 2002 until 2007 as the post-deregulatory period (the second reform stage). Table 5.3 summarises descriptive statistics of all control and environmental variables across the 41 banks covering the period of our analysis from 1994 until 2007.

The first and second elements of the first row in the control variables panel give the average (mean) of equity (RMB 24,592 million) and the standard deviation of equity (RMB 55,867 million) across the 41 banks over the period from 1994 until 2007. The last two elements of the first row summarise the minimum and maximum values of

equity over the period from 1994 until 2007. Thus equity value ranges from RMB 79 to 571,795 million across all 41 banks for the period from 1994 until 2007. The environmental variables panel shows that the mean of the dummy variable for state owned banks is 0.5202 and the standard deviation is 0.5002 over the period from 1994 until 2007. As previously noted, our analysis is based on a total of 397 banks and so, the mean value for the state-owned bank dummy variable implies that our sample is comprised of $0.5202 \times 397 = 206$ sate-owned banks and $397 - 206 = 191$ domestic private and foreign-owned banks. The other entries in table 5.3 are to be similarly interpreted.

Table 5.3 Descriptive Statistics of the Bank's Control and Environmental Variables

Variable	Description	Mean	St. Dev	Min	Max
The control variables					
Z_1	Equity	24592	55867	79	571795
Z_2	Nonperforming Loans	52723	128523	0	644503
$Z_3(T)$	Time trend	8.751	3.758	1	14
The environmental variables					
STATE	Dummy variable for state-owned banks	0.5202	0.5002	0	1
FOREIGN	Dummy variable for foreign banks	0.4116	0.4931	0	1
PRIVATE	Dummy variable for foreign banks (as a reference group)	0.0682	0.2524	0	1
SIZE	Log of total bank assets	5.7102	5.9818	2.4634	6.7377
REFORM	Dummy variable for second stage reform (2002-2007)	0.5592	0.4971	0	1
HHI	Herfindahl-Hirschman index (the sum of the squared asset market shares of all banks)	0.1489	0.0307	0.1133	0.2405
MS	Asset market share	0.0353	0.0664	0.00002	0.3460
LIST	Dummy variable for listed banks	0.1607	0.3677	0	1

5.7 Summary and Conclusion

This chapter summarises the methodological approaches that will be taken to estimate cost efficiency and scale economies in the Chinese banking sector over the period from 1994 until 2007. We employ both the SFA and DEA methodologies to estimate the cost efficiency of Chinese banks and then use methodological cross checking in order to assess the robustness of the results obtained. We commenced this Chapter by outlining a baseline cost minimisation model, M1, which uses the SFA technique to determine the relative cost efficiency of firms (see equation (5.10)). Then we discussed four alternative SFA cost models which can be used to capture heterogeneity across the sample banks on which our empirical analysis is based. The translog functional form will be used to estimate cost functions for the Chinese banks comprising our sample. Scale economies will be estimated by differentiating the estimated cost function with respect to output. With regard to the DEA methodology, we use both the traditional DEA cost and New DEA cost models to estimate the relative efficiency of banks in the Chinese banking sector. Moreover, information on returns to scale for Chinese banks can be derived from the non-increasing returns to scale (NIRS) DEA models. We also employ the Tobit regression model and efficiency scores computed using the DEA models, to further explore the possible drivers of Chinese banking efficiency. Furthermore, following Bauer *et al*. (1998), this chapter proposes five conditions through which to assess the potential consistency of the SFA and DEA models. We argue that if all five consistency conditions are met, then the results from the different efficiency frontier models will be more useful and reliable to decision and/or policy makers.

This chapter also describes the variables and the dataset used in our empirical analysis. We use the intermediation approach to define the outputs, inputs and their associated unit prices on which the estimation of the cost functions for Chinese banking institutions will be based. Moreover, three control variables (equity, nonperforming loans and time trend) are included in some SFA models in order to control for such factors as the risk preferences of bank's senior management, output quality and potential changes in technology. Furthermore, five environmental variables are used in our regression models as potential drivers of banking efficiency: ownership structure, size,

market structure, banking deregulation and market discipline. Our empirical analysis is based on a sample of 41 Chinese banks over the period from 1994 until 2007. At the end of 2007 these 41 banks represent roughly 80% of the total assets of Chinese banking institutions. The following two chapters will report the empirical results obtained from analysing the efficiency of these banks.

Chapter 6 Empirical Results: A Comparison of SFA and DEA

6.1 Introduction

In order to provide more accurate and useful information for regulatory policy purposes, it is important to have reliable methods for measuring banking efficiency. The previous chapter outlines the stochastic frontier approach (SFA) and the data envelopment approach (DEA) methodologies used in this study to evaluate Chinese banking cost efficiency over the period from 1994 until 2007. Because considerable systematic differences may exist across banks, a number of well-established SFA cost specifications are employed to estimate Chinese banks' cost efficiency. In addition, non-parametric methods (traditional DEA and New DEA models) will also be used to estimate banking efficiency. This chapter provides part of the main empirical results of this thesis and aims to report and compare the results from the various efficiency methodologies summarised in the preceding chapter. It is expected that accounting for heterogeneity across banks is important for the SFA methodology and methodological cross-checking will provide robust information on the efficiency of the Chinese banking sector.

The rest of this chapter is organised as follows: Section 6.2 reports the maximum likelihood parameter estimates for the stochastic frontier cost functions discussed in the previous chapter. Section 6.3 further analyses some other key estimation results for all five specifications of the cost frontier in order to highlight the effects of heterogeneity on the estimated parameters. Section 6.4 explains the structural tests we employed to obtain the best-specified cost frontier model that estimates efficiency levels for the banks under study. Subsequently, in Sections 6.5 and 6.6 we compare efficiency

levels and the ranks of efficiency scores across five alternative SFA specifications. This comparison helps shed light on the effects of sample heterogeneity on bank efficiency scores.

Section 6.7 investigates the robustness of the cost efficiency scores derived from the preferred SFA, traditional DEA, and New DEA models. The rationale for using different methods is well described by Berger and Humphrey (1997), who suggest that policy and research issues relying upon bank efficiency scores may be more convincingly addressed if more than one frontier technique is employed to demonstrate the robustness of the results obtained. Hence, in the spirit of Bauer *et al*. (1998) we examine five consistency conditions. Specifically, we deduce whether the efficiency estimates are consistent regarding the properties of the distribution of the efficiency scores, the rankings of efficiency scores, the identification of best and worst banks, stability over time and the relation to standard non-frontier performance measures. Finally, section 6.8 concludes this chapter.

6.2 Cost Frontier Estimates

The five SFA models discussed in the last chapter are used to estimate the cost stochastic frontier and cost efficiency of the 41 Chinese banks for which we have (unbalanced) data over the period form 1994 until 2007. All the stochastic frontier models are estimated u
sing maximum likelihood techniques, based on the computer program FRONTIER 4.1 (Coelli, 1996). The maximum likelihood estimates of parameters of the stochastic frontier cost functions are presented in Table 6.1. Model 1 contains parameter estimates of the translog function (without control and environmental variables) and where efficiency follows a half-normal distribution. In Model 2, efficiency is assumed to follow a truncated normal distribution. Model 3 incorporates three control variables in the cost function (equity level, non-performing loans and time trend). Model 4

allows banks' production technology to be af fected by environmental factors by incorporating these environmental factors (e.g. ownership, bank size and market share) into the deterministic kernel of the banks' cost frontiers. Model 5 introduces environmental factors as explanatory variables of cost efficiency. Before proceeding to analyse the parameter estimates of the various cost functions, it is worth noting that although the translog cost function is more flexible than other functional forms, multicollinearity may exist among the variables thereby leading to inconsistent parameter estimates[43]. However, multicollinearity may not be a severe problem when efficiency scores are used purely for forecasting purposes.

The estimated individual coefficients in the stochastic frontier given by the translog functional form are due to many interactions between output and input price variables but unfortunately, they are not directly interpretable unlike the Cobb-Douglas cost function where all parameters have a clearly specified meaning. Moreover, in this study the total costs and all the continuous explanatory variables have been divided by their respective sample means before taking logarithms[44]. This normalisation of variables permits the first-order parameters of the translog function to be directly interpreted as estimates of cost elasticities evaluated at the point of approximation. Table 6.1 shows that the parameter estimates of output quantities and input price terms are positive and highly significantly different from zero across all five model specifications. This suggests that the cost function is non-decreasing in outputs (Q) and in input prices (W) which are the theoretical requirements for a valid cost function. Therefore, the domain of applicability for the estimated parameters is at least congruent with the data points. In addition, the empirical estimates of the translog cost functions

[43] If the multicollinearity problem is mainly created by a strong positive correlation between the second order terms in the translog form of the cost function, maximum likelihood estimates are still unbiased and efficient. But in such circumstances multicollinearity problems cause the estimated standard error of the coefficients to be large leading to small values for the t-ratios. This in turn biases results towards accepting the null hypothesis that coefficients are equal to zero (see Gujarati, 2003 for more details).

[44] Since the mean values of variables are considered as the Taylor series expansion point for the translog function, all variables should be divided by their mean in order to locate a correct evaluation point before estimating the translog function.

summarised in Table 6.1 are compatible with our intuition since the output and input price variables have the expected signs (both positive) and this also suggests that multicollinearity issues are not a problem with our empirical estimates of the cost functions.

Table 6.1 Maximum Likelihood Parameter Estimates for Stochastic Frontier Cost Functions

Variables	Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	β_0	-.2289*** (0.0347)	-0.1944*** (0.0177)	-0.2515*** (0.0239)	-3.6257*** (0.9652)	-0.2173*** (0.0253)
$\ln Q_1$	β_1	0.6431*** (0.0218)	0.6419*** (0.0216)	0.5484*** (0.0261)	0.3429*** (0.0582)	0.5526*** (0.0264)
$\ln Q_2$	β_2	0.3101*** (0.0253)	0.3117*** (0.0248)	0.2693*** (0.0246)	0.1600** (0.0371)	0.2941*** (0.0250)
$\ln Q_3$	β_3	0.0524*** (0.0148)	0.0536*** (0.0148)	0.0385*** (0.0140)	0.0316*** (0.0136)	0.0314** (0.0140)
$\ln(W_1/W_3)$	χ_1	0.7903*** (0.0156)	0.7919*** (0.0155)	0.7073*** (0.0207)	0.7022*** (0.0214)	0.7259*** ()0.0211
$\ln(W_2/W_3)$	χ_2	0.1074*** (0.0206)	0.1075*** (0.0203)	0.1298*** (0.0190)	0.1413*** (0.0185)	0.1246*** (0.0195)
$0.5\ \ln Q_1 \ln Q_1$	φ_{11}	0.1016*** (0.0241)	0.1037*** (0.0238)	0.1037 (0.0639)	0.1072* (0.0629)	0.1013 (0.0648)
$\ln Q_1 \ln Q_2$	φ_{12}	-0.0615** (0.0276)	-0.0640** (0.0267)	-0.1043*** (0.0371)	-0.0789** (0.0365)	-0.1288*** (0.0368)
$\ln Q_1 \ln Q_3$	φ_{13}	-0.0152 (0.0093)	-0.0156* (0.0092)	0.0067 (0.0204)	-0.0067 (0.0197)	0.0148 (0.0207)
$0.5\ln Q_2 \ln Q_2$	φ_{22}	0.0664* (0.0400)	0.0689* (0.0385)	0.1108*** (0.0381)	0.0784** (0.0379)	0.1067*** (0.0370)
$\ln Q_2 \ln Q_3$	φ_{23}	-0.0021 (0.0176)	-0.0022 (0.0174)	-0.0206 (0.0160)	-0.0145 (0.0155)	-0.0098 (0.0154)
$0.5\ln Q_3 \ln Q_3$	φ_{33}	0.0141 (0.0123)	0.0145 (0.0121)	0.0112 (0.0120)	0.0074 (0.0117)	0.0070 (0.0112)
$0.5\ln(W_1/W_3)\ln(W_1/W_3)$	η_{11}	0.0412 (0.0240)	0.0403* (0.0237)	0.0605* (0.0337)	0.0410 (0.0327)	0.0656* (0.0345)
$\ln(W_1/W_3)\ \ln(W_2/W_3)$	η_{12}	-0.0359* (0.0309)	-0.0363 (0.0305)	-0.0293 (0.0334)	0.0057 (0.0324)	-0.0253 (0.0335)
$0.5\ln(W_2/W_3)\ln(W_2/W_3)$	η_{22}	-0.0077 (0.0377)	-0.0071 (0.0374)	0.0184 (0.0338)	-0.0288 (0.0337)	0.0101 (0.0343)
$\ln Q_1 \ln(W_1/W_3)$	ι_{11}	0.0223 (0.0208)	0.0213 (0.0201)	0.0584* (0.0347)	0.0468 (0.0338)	0.0480 (0.0344)
$\ln Q_1 \ln(W_2/W_3)$	ι_{12}	-0.0034 (0.0216)	-0.0027 (0.0207)	-0.0046 (0.0304)	0.0199 (0.0294)	0.0097 (0.0313)
$\ln Q_2 \ln(W_1/W_3)$	ι_{21}	0.0118 (0.0282)	0.0120 (0.0272)	0.0431 (0.0345)	0.0113 (0.0326)	0.0238 (0.0323)
$\ln Q_2 \ln(W_2/W_3)$	ι_{22}	-0.0304 (0.0338)	-0.0281 (0.0326)	-0.0684** (0.0329)	-0.0442 (0.0315)	-0.0349 (0.0323)
$\ln Q_3 \ln(W_1/W_3)$	ι_{31}	-0.0140 (0.0135)	-0.0143 (0.0134)	-0.0282 (0.0176)	-0.0217 (0.0165)	-0.0223 (0.0167)
$\ln Q_3 \ln(W_2/W_3)$	ι_{32}	0.0095 (0.0165)	0.0100 (0.0163)	0.0221 (0.0151)	0.0221 (0.0143)	0.0155 (0.0151)

Table 6.1 Maximum Likelihood Parameter Estimates for Stochastic Frontier Cost Functions (continued)

Variables	Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
Control variables						
$\ln Z_1$	ρ_1	-	-	0.0343 (0.0213)	0.0384* (0.0208)	0.0361* (0.0211)
$\ln Z_2$	ρ_2	-	-	0.0942*** (0.0120)	0.0796*** (0.0117)	0.0876*** (0.0121)
T	ρ_3	-	-	0.0032 (0.0043)	-0.0231*** (0.0117)	-0.0024 (0.0044)
$0.5\ln Z_1 \ln Z_1$	ξ_{11}	-	-	0.0083 (0.0192)	0.0148 (0.0189)	0.0067 (0.0199)
$\ln Z_1 \ln Z_2$	ξ_{12}	-	-	0.0002 (0.0115)	-0.0030 (0.0111)	-0.0070 (0.0118)
$\ln Z_1 T$	ξ_{13}	-	-	-0.0252*** (0.0076)	-0.0136* (0.0077)	-0.0206*** (0.0078)
$0.5 Ln Z_2 \ln Z_2$	ξ_{22}	-	-	0.0141*** (0.0025)	0.0109*** (0.0026)	0.0098*** (0.0028)
$\ln Z_2 T$	ξ_{23}	-	-	0.0068** (0.0031)	0.0012 (0.0032)	0.0008 (0.0035)
$0.5\ln Z_3 T$	ξ_{33}	-	-	0.0002 (0.0024)	0.0010 (0.0027)	-0.0004 (0.0024)
$\ln Z_1 \ln Q_1$	ψ_{11}	-	-	0.0092 (0.0366)	-0.0199 (0.0375)	0.0125 (0.0373)
$\ln Z_1 \ln Q_2$	ψ_{12}	-	-	0.0309 (0.0324)	0.0351 (0.0323)	0.0352 (0.0327)
$\ln Z_1 \ln Q_3$	ψ_{13}	-	-	-0.0114 (0.0200)	0.0002 (0.0194)	-0.0226 (0.0202)
$Ln Z_2 \ln Q_1$	ψ_{21}	-	-	-0.0179 (0.0138)	-0.0096 (0.0134)	-0.0086 (0.0145)
$\ln Z_2 \ln Q_2$	ψ_{22}	-	-	-0.0020 (0.0115)	-0.0027 (0.0112)	0.0066 (0.0120)
$\ln Z_2 \ln Q_3$	ψ_{23}	-	-	0.0027 (0.0065)	0.0068 (0.0061)	0.0010 (0.0066)
$T \ln Q_1$	ψ_{31}	-	-	0.0073 (0.0084)	0.0088 (0.0081)	0.0132 (0.0088)
$T \ln Q_2$	ψ_{32}	-	-	0.0077 (0.0078)	0.0006 (0.0074)	0.0074 (0.0079)
$T \ln Q_3$	ψ_{33}	-	-	-0.0017 (0.0053)	0.0000 (0.0049)	-0.0012 (0.0053)
$\ln Z_1 \ln(W_1/W_3)$	θ_{11}	-	-	-0.0784*** (0.0293)	-0.0500* (0.0283)	-0.0616** (0.0298)
$\ln Z_1 \ln(W_2/W_3)$	θ_{12}	-	-	0.0390 (0.0301)	0.0194 (0.0293)	0.0266 (0.0305)
$\ln Z_2 \ln(W_1/W_3)$	θ_{21}	-	-	0.0106 (0.0104)	0.0098 (0.0101)	0.0099 (0.0110)
$\ln Z_2 \ln(W_2/W_3)$	θ_{22}	-	-	0.0014 (0.0092)	-0.0134 (0.0094)	-0.0066 (0.0097)
$T \ln(W_1/W_3)$	θ_{31}	-	-	0.0005 (0.0069)	0.0020 (0.0067)	0.0032 (0.0074)
$T \ln(W_2/W_3)$	θ_{32}	-	-	0.0030 (0.0063)	0.0056 (0.0063)	0.0023 (0.0066)

Table 6.1 Maximum Likelihood Parameter Estimates for Stochastic Frontier Cost Functions (continued)

Variables	Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
Environmental variables						
state-owned banks	$\delta_1^{'}$	-	-	-	-0.0209 (0.0257)	-
foreign banks	$\delta_2^{'}$	-	-	-	-0.2591*** (0.0732)	-
size	$\delta_3^{'}$	-	-	-	0.3156*** (0.0861)	-
listed banks	$\delta_4^{'}$	-	-	-	-0.0116 (0.0299)	-
deregulation	$\delta_5^{'}$	-	-	-	0.1114*** (0.0340)	-
HHI	$\delta_6^{'}$	-	-	-	-1.8682 (1.2535)	-
market share	$\delta_7^{'}$	-	-	-	-3.6257 (0.9652)	-
intercept	δ_0	-	-	-	-	2.2074*** (0.5199)
state-owned banks	δ_1	-	-	-	-	-0.2516** (0.1065)
foreign banks	δ_2	-	-	-	-	-0.1061*** (0.2899)
size	δ_3	-	-	-	-	-0.3563*** (0.1031)
listed banks	δ_4	-	-	-	-	-0.0066 (0.0857)
deregulation	δ_5	-	-	--	-	1.2117** (0.5284)
HHI	δ_6	-	-	-	-	-1.5270 (1.2195)
market share	δ_7	-	-	-	-	-7.2047*** (2.4588)

Notes: 1. ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.
2. Asymptotic standard errors in parentheses.

The coefficient estimate of the total loans (Q_1) in Model 5 suggests that, on average, a 1% increase in the amount of loans will increase costs by about 0.55%. Similarly, the cost elasticity with respect to other earning assets (Q_2) is 0.29 in Model 5, suggesting that a 1% increase in other earning assets will raise total costs by 0.29%. Also, we

observe that the magnitude of the coefficient of non-interest income (Q_3) is significantly smaller than the estimated coefficients for Q_1 and Q_2, implying that the amount of non-interest income does not have a significant impact on total costs. This may be because off-balance activities (represented by non-interest income) accounts for only a small proportion of the output portfolio in the Chinese banking sector. The estimated cost elasticity with respect to total borrowed funds (W_1) is relatively high when compared to the other two input prices (W_2 and W_3), being in the range of 0.7022 to 0.7919 across the five models. The results indicate that total costs are very sensitive to the price of borrowed funds and suggest that, on average, a 1% increase in the price of borrowed funds will raise total costs by about 0.7% to 0.8%, depending on the model. The coefficient of the price of physical capital (W_2) captures the share of costs attributed to physical capital, which ranges between 0.1% and 0.14% depending on the specification adopted [45]. Moreover, we also observe that the coefficient of non-performing loans (Z_2) has a positive sign and is significantly different from zero in Models 3, 4 and 5, This implies that larger non-performing loans are related to higher costs. However, the coefficient of equity (Z_1) and time trend (T) are not significant in all models. This result suggests that the level of equity and the rate of technological change may not directly affect banking costs. Moreover, in Model 4, which includes all environmental factors in the deterministic kernel, most parameter estimates associated with the environmental factors are not statistically significant, implying that these variables have little influence on banking costs.

6.3 Key Estimation Results

Table 6.2 summarises some key information besides the parameters estimates for our five cost frontiers. In particular, the parameters determining the shape and location of

[45] Labour price coefficient (W_3) can be recovered by using the linear homogeneity restriction, calculated by 1- χ_1 - χ_2 and is similar in magnitude to the physical capital price.

the inefficiency distribution are shown in the first three columns of the table. The inefficiency location parameter, μ, is significantly different from zero for environmental factors in error specification (M5). This may be explained by the fact that we introduce heterogeneity into the efficiency distribution for this model. However, estimates of μ in alternative models are not significantly different from zero at the 5% level. The γ parameters corresponding to the estimated proportion of bank inefficiency in the composed total error term are significantly different from zero in both the baseline model (M1) and all alternative models. This parameter shows high values (close to unity) in the models (M2, M3, M4 and M5) which account for heterogeneity, revealing that most of the variation in observed costs from the frontier are due to bank inefficiency. The difference between the γ coefficients for Models 4 and 5 is most likely explained by the way in which the environmental factors are included in these two models. In addition, the magnitude of the variance parameter σ^2 in Models 2, 3, 4 and 5 is larger when compared to the baseline specification (Model 1).

Table 6.2 Key Estimation Results

Model specification	μ	γ	σ^2	log likelihood	LR test of one-sided error
Baseline (M1)	0	0.5115***	0.0557***	88.8902	2.4076 (3.841)
Truncated (M2)	-6.9109*	0.9637***	0.7414*	91.6750	7.977 (5.991)
Controlled (M3)	-7.4554*	0.9821***	0.8376*	164.3368	26.2449(5.991)
Kernel (M4)	-0.8215	0.9888***	0.1001	185.0729	36.2558 (5.991)
Error effects (M5)	2.2074***	0.8639***	0.1237***	175.1729	47.9171(16.919)

Notes: 1. $\sigma^2 = \sigma_u^2 + \sigma_v^2$; $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$;

2. χ^2 critical values for 5% significance level are in the parentheses;

3. ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

The logarithmic values of the likelihood function, a frequently used criterion of better statistical properties of an econometric model estimated though the maximum likelihood technique, are presented in the fourth column of Table 6.2. We find that the

log-likelihood value for Models 3, 4 and 5 are higher than the baseline (M1) and truncated specifications (M2), suggesting that including a set of explanatory variables in the specification to account for heterogeneity improves the fit significantly. The last column in Table 6.2 reports the results of one sided log-likelihood ratio (LR) tests of the standard response function (OLS) versus the full frontier model. The null hypothesis in this test is $\gamma = 0$ versus the alternative of $\gamma > 0$. If the null hypothesis is accepted, this could indicate that σ_u^2 and δ_i are zero and hence that inefficiency effects in the cost function are not present, leaving a specification with parameters that can be appropriately estimated using ordinary least squares (OLS) (Coeli, 1996). If, however, the null hypothesis is rejected, this could suggest that a standard mean response function is not an adequate representation of the data. In the case of the baseline model (M1), the null hypothesis is accepted at the 5% level of significance, suggesting that the stochastic frontier approach (SFA) provides an inappropriate specification for Chinese banking data. However, in the case of alternative models, the null hypothesis is rejected in favour of the stochastic frontier cost function. Therefore, the results of the baseline model should be viewed with caution or even perhaps discarded and the results of the alternative models (M2, M3, M4 and M5) which do account for heterogeneity appear to provide a more faithful fit to the data of the Chinese banks that is available to us.

6.4 Model Specification Tests

In order to reach the best-specified cost frontier model, we have conducted generalised likelihood ratio tests. These tests provide a convenient way to check whether a reduced (restricted) model provides the same fit as a general (unrestricted) model (see Appendix 1 for further details). Table 6.3 presents the steps and results of the log-likelihood tests which we conducted. The first column of the table lists the specifications tested. The second column presents the restriction imposed under the

null hypothesis. The third column reports the value of the log likelihood function for the given specification. The fourth column shows the calculated log-likelihood ratio test statistic. The fifth column gives the critical value for the log-likelihood ratio test statistic. The last column reports the test outcome, that is whether the null hypothesis is rejected or accepted or whether the imposed restriction is valid or not.

In Table 6.3, the first step is to test the half-normal model (M1) against the truncated normal model (M2). The null hypothesis is that the model which assumes the inefficiency term follows a half-normal distribution is better than the model which assumes that the inefficiency term follows a truncated normal distribution. This is equivalent to the restriction $\delta_0 = 0$. When this restriction is imposed on the truncated normal model, the log-likelihood value reduces to 88.890 (M1) from 91.675 (M2). The generalized log likelihood ratio test statistic turns out to be 5.57, which is greater than the χ^2 critical value at the 5% level with one degree of freedom. Therefore, we reject the null hypothesis of $\delta_0 = 0$, suggesting that the truncated-normal distribution model is more compatible with the data than the half-normal distribution model.

The second step is to compare the model specifications including different combinations of control variables to reach the most appropriate specification in this step. The unrestricted model in this step includes all three control variables in the cost function (financial capital, asset quality and time trend). Based on the first step decision, this model is estimated by assuming the inefficiency term follows a truncated normal distribution.

First, we test the model specifications which drop only one control variable against the unrestricted model. At this point, there are three null hypotheses to be tested. The first is that the specification of the cost function without time parameters gives a better fit to the data than that of the cost function which includes all the control variables, that is setting all the coefficients associated with the time trend to be equal to zero. The

second null hypothesis is that the cost function specification without the non-performing loans parameters is more compatible with the data than the unrestricted model. The third null hypothesis states that the specification of the model without equity parameters is more compatible with the data than the unrestricted model. As Table 6.3 shows, the value of the generalised log likelihood ratio statistics for all three cases is larger than the critical value. Thus, all three null hypotheses are rejected at the 5% level of significance. This means that the model which includes all three control variables is again the dominant specification when compared to the models which include only two of the control variables. Second, the unrestricted model will be compared with some alternative models which include only one control variable. Again, three null hypotheses are tested. The first null hypothesis is that the model including only the equity level is more is more compatible with the data than the unrestricted model. The next null hypothesis is that the model including only non-performing loans is more is more compatible with the data than the unrestricted model. The third and final null hypothesis states that the model including only the time trend is more compatible with the data than the unrestricted model. All three null hypotheses are rejected at the 5% level of significance according to the log-likelihood ratio statistics. So the unrestricted model is a statistically more significant model than any of the restricted models. Last, we compare the unrestricted model with the model excluding all three variables, which is the truncated normal distribution model (M2). In this case, the null hypothesis states that the truncated model without any control variables is more compatible with the data than the unrestricted model, that is all the coefficients associated with the equity, non-performing loans and time trend data are equal to zero. Again, the log-likelihood ratio test rejects the null hypothesis in favour of the unrestricted model. Thus, based on the above results we find that the control variables have significant effects on total costs and should be included in the cost function. Therefore, the most appropriately specified model up to this stage of our analysis is the truncated model including all three control variables (M3).

The third step is to examine whether including the environmental variables in the model specification has significant explanatory power. The tests are made by comparing the model including the environmental variables in the deterministic kernel of the frontier (M4) and/or in the distribution of the inefficiency term (M5) with the truncated model including all control variables (M3). Model 3 excludes the environmental factors from the analysis and thus becomes a special case of Model 4 or Model 5 in which all the coefficients associated with the environmental variables are equal to zero. The null hypotheses are that the specified truncated model including the control variables but excluding the environmental variables is more compatible with the data than the models which include both the control and environmental variables. In the above cases, the log-likelihood ratio test statistics are 41.472 and 27.67, respectively, which are both larger than the relevant critical values of χ^2 at the 5% level of significance. Thus we reject both the null hypotheses and conclude that the environmental factors should not be ignored in the study of Chinese banking efficiency.

The question of whether the environmental variables should be treated as explanatory variables in cost function (M4) or as determinants of cost inefficiency (M5) is not directly answered by the generalised log likelihood ratio test. These two model specifications are not nested and hence no set of restrictions can be imposed which allow a test of one specification against the other. Therefore, it is difficult to provide an unequivocal assessment as to whether the stochastic cost function specification M4 or the stochastic cost function specification M5 is more compatible with the Chinese banking data that is available to us.

On the basis of the above empirical results, however, we do find that sample heterogeneity significantly influences stochastic cost frontier estimation. Thus, any model of Chinese banking efficiency which is used for policy purposes should explicitly account for sample heterogeneity by introducing control variables and/or environmental variables as part of its arguments. Otherwise it would be misspecified, leading to

inappropriate parameter and efficiency estimates and more importantly, potentially flawed policy decisions. However, the selection between a model considering the environmental variables as a part of the deterministic kernel of the frontier and a model considering the environmental variables as determinants of cost efficiency is a difficult issue. Here, we prefer the model that treats environmental variables as explanatory variables of cost efficiency. The reasons for this are, first, the improved significance of the critical parameters μ γ and σ^2 in Model 5 and the insignificance of coefficients for most of the environmental variables in Model 4. Second, we also believe that the estimated frontier represents the outer boundary of the cost possibility set, irrespective of environmental issues (Coelli *et al*., 1999). Moreover, in our study, we are interested not only in the efficiency level but also wish to know the sources or determinants of the cost inefficiencies. Thus, the Model 5 specification would appear to be the most useful of all the models we examine here.

Table 6.3 Hypothesis Testing of Cost Function[46]

Model Description	Restriction (H_0)	Log likelihood	LR test of one-side error	Critical value $\alpha = 5\%$	Decision H_0: restricted model is better than unrestricted model
Step 1: Half-normal vs Truncated normal					
-Truncated normal distribution (M2)	Unrestricted	91.675			
-Normal distribution (M1)	H_0: $\delta_0 = 0$	88.890	5.57	3.841 (1)	Reject H_0
Step 2: Model without control variables vs Model with control variables					
Truncated normal with all control variables	Unrestricted	164.337			
-without Time trend parameters	H_0: $\rho_3 = \xi_{31} = \xi_{32} = \xi_{33} = \theta_{31} = \theta_{32} = \psi_{31} = \psi_{32} = \psi_{33} = 0$	151.230	26.214	15.507 (8)	Reject H_0
-without NPL parameters	H_0: $\rho_2 = \xi_{21} = \xi_{22} = \xi_{23} = \theta_{21} = \theta_{22} = \psi_{21} = \psi_{22} = \psi_{23} = 0$	123.404	81.866		Reject H_0
-without Equity parameters	H_0: $\rho_1 = \xi_{11} = \xi_{12} = \xi_{13} = \theta_{21} = \theta_{22} = \psi_{21} = \psi_{22} = \psi_{23} = 0$	148.219	32.236		Reject H_0
-Without NPL and Time trend parameters	H_0: $\rho_2 = \rho_3 = \xi_{21} = \xi_{22} = \xi_{31} = \xi_{32} = \xi_{33} = \theta_{21} = \theta_{22} = \theta_{31} = \theta_{32} = \psi_{21} = \psi_{22} = \psi_{23} = \psi_{31} = \psi_{32} = \psi_{33} = 0$	103.762	121.15	27.59 (17)	Reject H_0

[46] Log-likelihood test statistic= 2(unrestricted log - likelihood function (ULLF)-restricted log-likelihood function (RLLF))

Table 6.3 Hypothesis Testing of Cost Function (continued)

Model Description	Restriction (H_0)	Log likelihood	LR test of one-side error	Critical value $\alpha = 5\%$	Decision H_0: restricted model is better than unrestricted model
-without Equity and Time trend parameters	H_0: $\rho_1 = \rho_3 = \xi_{11} = \xi_{12} = \xi_{31} = \xi_{32} = \xi_{33} = \theta_{11} = \theta_{12} = \theta_{31} = \theta_{32} = \psi_{11} = \psi_{12} = \psi_{13} = \psi_{31} = \psi_{32} = \psi_{33} = 0$	142.023	44.628		Reject H_0
-without Equity and NPL trend parameters	H_0: $\rho_1 = \rho_2 = \xi_{11} = \xi_{12} = \xi_{13} = \xi_{22} = \xi_{23} = \theta_{11} = \theta_{12} = \theta_{21} = \theta_{22} = \psi_{11} = \psi_{12} = \psi_{13} = \psi_{21} = \psi_{22} = \psi_{23} = 0$	107.994	112.686		Reject H_0
-without all control variable parameters	H_0: $\rho_1 = \rho_2 = \rho_3 = \xi_{11} = \xi_{12} = \xi_{13} = \xi_{22} = \xi_{23} = \xi_{33} = \theta_{11} = \theta_{12} = \theta_{13} = \theta_{21} = \theta_{22} = \theta_{23} = \psi_{11} = \psi_{12} = \psi_{13} = \psi_{21} = \psi_{22} = \psi_{23} = \psi_{31} = \psi_{32} = \psi_{33} = 0$	91.675	145.324	36.415 (24)	Reject H_0
Step 3: Models without environmental variables vs Models with environmental variables					
Including environmental variables in cost function	Unrestricted	185.073			
- not including environmental variables in cost function	H_0: $\delta_1' = \delta_2' = \delta_3' = \delta_4' = \delta_5' = \delta_6' = \delta_7'$	164.337	41.472	14.067 (7)	Reject H_0
Including environmental variables in error effects	Unrestricted	175.172			
- not including environmental variables in error effects	H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7$	164.337	27.67	14.067 (7)	Reject H_0

Note: Degrees of freedom in parentheses.

6.5 Efficiency Level

In this section, we will compare the cost efficiency levels derived from the five different models. Table 6.4 provides a statistical summary of the estimated efficiency scores of all banks for the various models. Thus, the mean, median and the lowest and highest levels of efficiency for the models are presented in the Table 6.4. Regarding the overall mean values of cost efficiency scores for the entire period, we find a relatively small range, from 87.26 % to 91.14%, indicating that the average bank in the sample could reduce its costs by approximately 9% to 13%, in order to match its performance with the best possible bank practice. Model 5 (heterogeneity in the inefficiency term) yields the highest mean and medium efficiency estimates, while the baseline (half-normal) model (M1) generates the lowest efficiency estimates. This result indicates that neglecting heterogeneity across banks may create a downward bias in efficiency scores. Moreover, explicitly accounting for heterogeneity in terms of ownerships, size, market structure, etc. in the distribution of the inefficiency component leads to a mean cost efficiency that is approximately 2% to 4% points higher than in the other specifications. However, the mean efficiency scores in Models 2, 3 and 4 are similar, suggesting that accounting for the heterogeneity in the efficiency frontier did not influence efficiency estimates all that much for these models. The maximum efficiency scores are quite high for Models 3, 4 and 5, suggesting that heterogeneity across banks is an important driver of cost differences. In sum, it is clear that controlling for heterogeneity is important. However, our results show that efficiency estimates may be sensitive to the way in which we account for sample heterogeneity.

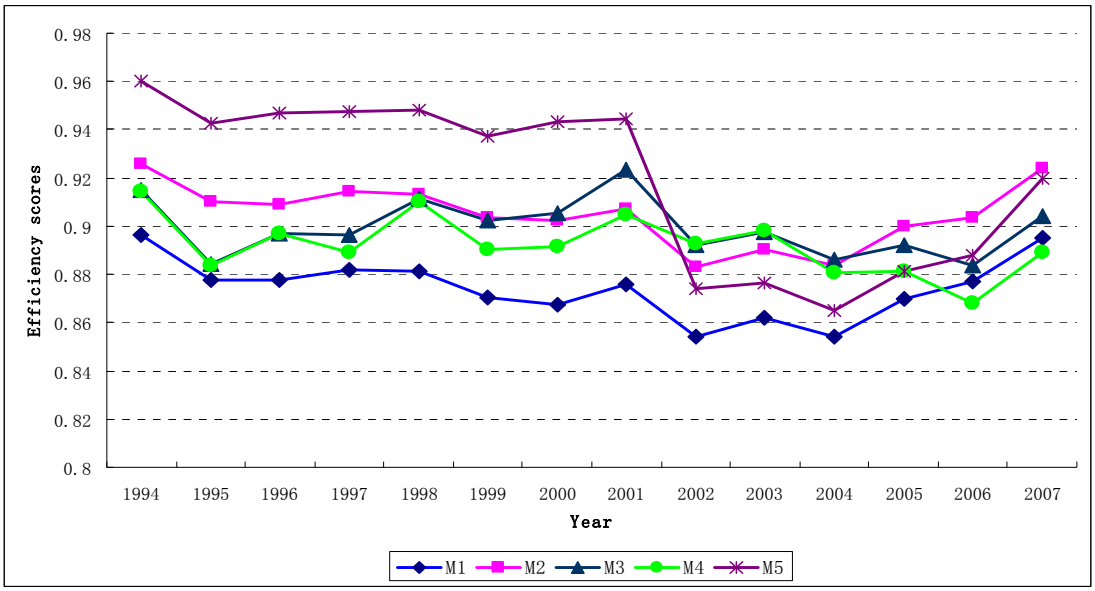
Table 6.4 Summary Statistics of the Mean Efficiency Estimates

	Model 1 Baseline	Model 2 Truncated	Model 3 Controlled	Model 4 Kernel	Model 5 Error
Mean	0.8726	0.9029	0.8983	0.8900	0.9114
Median	0.8795	0.9149	0.9166	0.9139	0.9379
Standard deviation	0.0480	0.0527	0.0668	0.0777	0.0789
Maximum	0.9581	0.9685	0.9752	0.9755	0.9808
Minimum	0.6179	0.5217	0.4802	0.4595	0.3625

Note: Efficiencies are calculated by using 14 years of data for 44 banks (397 observations) and numbers in table are based on average efficiency for each bank over sample period.

The yearly mean cost efficiency of all banks for the five different models is plotted in Figure 6.1. The trends or patterns of efficiency levels obtained from the five different specifications are broadly similar over time, especially for Models 3 and 4. In general, most banks showed high relative efficiently early on (before 2002) but rather less efficiency later on (after 2002). A significant decrease in efficiency levels appeared between 2001 and 2002 across all models. These emerging patterns may provide evidence that the 2001-2002 calendar year appeared to be associated with a structural change in the trend of cost efficiency and that this is associated with China's entry into the WTO which occurred around about this time.

Figure 6.1 Average Efficiency Scores over Time



6.6 Spearman's Correlation for Different SFA Models

Another potentially interesting comparison is whether the ranks obtained for the efficiencies scores across the different specifications show any compatibility. The ranking of banks according to the cost efficiency scores can provide important information about the impact of structural change on banking efficiency. If different models rank banks completely differently, then it is problematic whether any generalised conclusions can be drawn. The Spearman rank correlation coefficients of the efficiency estimates are summarised in Table 6.5. These coefficients capture the similarity in the efficiency rankings across the various model specifications. In

general, the rank correlations according to the efficiency scores among the first three models (M1, M2 and M3) is lower than the rank correlations between them and the last two models (that is M4 and M5). The near perfect correlation of efficiency rankings between the half-normal (M1) and truncated (M2) models suggests that these models identify the same banks as best and worst performers. This shift of the inefficiency distribution seems to influence all banks in the sample to a very similar degree. The inclusion of control variables in efficiency estimation leads to a decline in the rank correlation coefficient to around 0.8, indicating that this inclusion not only absorbs some heterogeneity but also affects competitive rankings for some banks. However, Models 3 and 4 show a very high correlation (0.94) in the estimated efficiency scores. This may suggest that introducing environmental factors into the kernel specification leads to only minor changes in the ranking order. We also find that Model 5 shows relative low correlation with other alternative models with rank order correlation coefficients ranging from 56% to 63%. These results suggest that Model 5 which includes environmental factors in the inefficiency term specification ranks bank efficiency in a markedly different way when compared to the other four models.

In sum, these results further improve our understanding of the effect of heterogeneity on efficiency estimates. It seems that accounting for heterogeneity is an important issue which if not taken into account, may lead to biased estimates of bank efficiency.

Table 6.5 Spearman Rank Correlation between Efficiency Estimates

	Model 1 Baseline	Model 2 Truncated	Model 3 Controlled	Model 4 Kernel	Model 5 Error
Half-normal (M1)	1.0000				
Truncated (M2)	0.9994	1.0000			
Controlled (M3)	0.8148	0.8150	1.0000		
Kernel (M4)	0.7623	0.7626	0.9433	1.0000	
Error (M5)	0.5778	0.5901	0.6360	0.5664	1.0000

Note: All correlations significant at 1% level

6.7 Comparison between SFA and DEA

As discussed earlier, the primary advantage of SFA is that it attempts to account for the effects of noise in the data. Here it is important to note that this methodology specifies the functional form for the cost relationship that links the decision making unit's (DMU) output and input factors and relies on distributional assumptions to separate the random errors and the efficiency terms. However, if these assumptions are misspecified, the efficiency estimates may be significantly biased. DEA methodology can avoid these types of specification error because it envelops the observed data points rather than relies on *a priori* assumptions to structure the efficiency frontier. However, DEA does not allow for random errors. If any noise exists in the data, then inefficiency may well be overestimated as a consequence. Here it is also important to note that DEA is very sensitive to outliers. Because of the deterministic nature of DEA, outliers will result in remaining DMUs having very high measured inefficiency. Since both parametric and non-parametric techniques have their own advantages and disadvantages, this studies also employs two nonparametric methods (traditional DEA and New DEA) as complementary models to the preferred SFA model utilised in previous sections.

In this study, two DEA models are used to derive cost efficiency estimates under the assumption of variable returns to scale (VRS). However, here it is important to note that factors such as imperfect competition and constraints on finance may prevent Chinese banks from operating at the optimal scale. Hence, the VRS assumption is more appropriate for our study. In addition, we estimate single year efficiency frontiers rather than one common frontier for all years[47]. The software DEA-Solver is used to solve for the DEA models (See Cooper *et al*., 2007).

Following Bauer *et al*. (1998), we are not attempting to achieve the best method for measuring efficiency in this section but we seek to provide evidence about the consistency or otherwise of the various efficiency frontier estimation methods for

[47] Both alternatives have been chosen in literature. Common frontier assumes similar technologies in all years, while single year frontiers do not need to assume the same technology for each year. Chinese authorities have embarked on a series of reforms of its banking sector over our study period, and these reforms are expected to have a significant impact on banking technology. Therefore, we prefer to apply single year frontiers to estimate banking efficiency.

Chinese banks. We test the robustness of the efficiency scores from the preferred SFA, DEA and New DEA models based on the properties of the distributions (that is, mean, maximum, skewness etc.) of the efficiency scores, the correlations of rankings of efficiency scores, identification of best and worst banks, stability over time and their relation to standard non-frontier performance measures.

6.7.1 Comparison of Efficiency Distributions

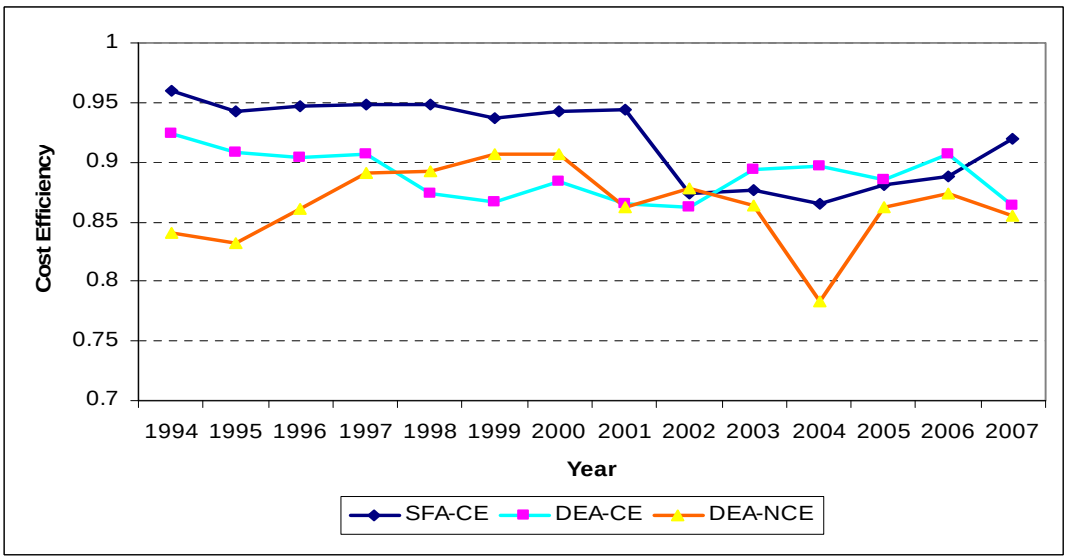
A number of standard distributional properties of the estimated efficiency measures based on the three dominant methodologies, SFA, traditional cost DEA (DEA) and new cost DEA (New DEA), are presented in Table 6.6. The SFA mean efficiency estimate is higher than that of DEA, in particular when we use the New DEA model. The mean efficiency from the SFA method is 91.14%, while from DEA and New DEA the mean efficiencies are 88.77% and 86.83%, respectively. It is not surprising that SFA efficiency scores are higher than the DEA efficiency scores because the former approach allows banks to depart from the cost frontier due to random shocks (or statistical noise) as well as inefficiency, whereas DEA measures any departure from the frontier as an inefficiency. The standard deviation of efficiency estimates for SFA (0.0789) is also less than the standard deviation from the DEA models (0.1242 and 0.1641, respectively). The inconsistency between parametric and nonparametric efficiency measures is further illustrated by the standardised skewness and excess standardized kurtosis measures for the SFA and DEA techniques. These results are consistent with the results of Bauer *et al.* (1998) and Delis *et al.* (2009). However, it is interesting to note that there is a smaller difference between distributional characteristics of efficiency scores estimated by DEA and New DEA than that between any DEA and SFA.

Table 6.6 Descriptive Statistics of Cost Efficiency Scores by Different Techniques

	SFA	DEA	New DEA
Mean	0.9114	0.8853	0.8683
Median	0.9379	0.9248	0.9335
Minimum	0.3625	0.5370	0.2969
Maximum	0.9808	1	1
Standard Deviation	0.0789	0.1239	0.1653
Skewness	-25.0601	-6.5806	-10.8926
Kurtosis	38.4520	-7.2879	-7.3449

Notes: Skewness refers to the extent to which a distribution is not symmetrical. For a normal distribution the sample skewness score is asymptotically distributed with a mean of zero and a variance of 6/n where n is the sample size. Hence, the standardized skewness score reported in the above table is (sample skewness score$\times\sqrt{n}$) /$\sqrt{6}$. Likewise the standardised kurtosis score reported in the above table is (sample kurtosis score$\times 3\times\sqrt{n}$) /$\sqrt{24}$.

Figure 6.2 Average Efficiency Over Time for Different Models



We now pay particular attention to the temporal evaluation of average efficiency under the different approaches. The year-by-year average efficiency scores over the 14-year period are displayed in Figure 6.2 which further illustrates the differences which arise between the different models. As shown, SFA generally yields higher average cost efficiency scores than either of the DEA and New DEA models. The mean efficiency estimates from SFA do not show significant variation in the sample period and do not vary too much for each sub-period when the sample is divided into two separate periods

- before and after 2002. However, the evolution of the efficiency scores for DEA and New DEA are not always monotonic and often display erratic behaviour.

In summary, we observed some differences in the distributional properties of the efficiency scores provided by the three principal models employed in our study. The differences may result from the various assumptions on which the methods are based (Weill, 2006). However, these differences are not necessarily a problem for the use of the efficiency scores. If the different frontier techniques can generate a similar rank order of efficiency, then the regulatory authorities can draw some reasonable policy conclusions from the analysis of the efficiency scores. Thus next, it is of interest to know whether these approaches generate consistent ranking of banking efficiency over the period of our study.

6.7.2 Rank Order Correlation of Efficiency Scores

Although the distributional characteristics of the efficiency scores differ between approaches, it is still possible that these methods generate similar rankings of banks in terms of their efficiency scores. Indeed, Bauer *et al.* (1998) note that the rank order structure of efficiency scores has an important role to play in regulatory policy and/or managerial decision making. Table 6.7 summarises the pairwise Spearman rank order correlation coefficients between efficiency scores obtained for each method using the full sample of banks. In general terms, we observe moderate positive rank order correlations between efficiency scores that are all significant at the 1% level. The results show that the highest rank order correlation is 0.4793 based on traditional DEA and New DEA scores, but it is lower than what one might have expected[48]. This is mainly due to the New DEA model's taking into account the heterogeneity of input prices and identifying efficient banks in different ways. When comparing parametric techniques with non-parametric techniques, the data suggest that SFA and traditional DEA are moderately consistent in their rankings, with a rank order correlation coefficient of 0.4226. However, the rank order correlation between SFA and New DEA is relatively low, at only 0.2848. Therefore, the three parametric and

[48] Many previous studies find that efficiency ranking tends to be highly correlated within the family of benchmarking techniques (e.g.Bauer *et al*., 1998; Huang and Wang, 2002).

nonparametric comprehensive evaluation models cannot be relied upon to rank banks generally in the same order and so may give problematic or even conflicting policy conclusions when evaluating important regulatory questions.

Table 6.7 Spearman's Rank Order Correlation by Various Methods

	SFA	DEA	New DEA
SFA	1	0.4226	0.2848
DEA		1	0.4793
New DEA			1

Note: All correlation coefficients are significant at the 1% level.

6.7.3 Identification of Best Practice and Worst Practice Banks

Even if the consistency in rank order correlations might be limited, different methods for assessing cost efficiencies may still be useful for regulatory purposes if they are consistent in identifying which are the best and worst practice banks (Bauer *et al*., 1998). This coherency measure is the degree to which the methods identify the same banks as being in the highest and lowest efficiency groups. We implement this idea by examining the overlap of the proportion of banks that appear in the top 25% and lowest 25% of banks by efficiency score for each of the three methods (that is SFA, DEA and NEW DEA). The results are presented in Table 6.8 and show that parametric (SFA) and the nonparametric (DEA and New DEA) models are moderately consistent in identifying the most efficient banks, with pairwise agreement statistics of 46% and 45%, respectively. These figures describe the overlap of the proportion of banks that appear in the top 25% of banks by efficiency score for SFA in comparison to the DEA and New DEA techniques. For example, of the banks identified as in the most efficient quarter by the SFA technique, 46% and 45% of these banks are also identified as being in the top 25% of efficient banks by the DEA and New DEA techniques. The traditional DEA model has somewhat more consistency with New DEA (59%) in identifying the most efficient banks. Similarly, regarding SFA and DEA, the correspondence of the worst practice 25% of banks is 0.47. This value indicates that 47% of the worst 25% of banks as identified by SFA are also in the bottom 25% as identified by DEA. The

correspondences of the worst-practice banks between the New DEA and the SFA and the DEA techniques are 0.35 and 0.33, respectively. These results suggest that the methods are somewhat less consistent in identifying the least efficient banks than they are in identifying the most efficient banks. In sum, there is moderate consistency between parametric and non-parametric methods in identifying best and worst practice banks. Within the DEA methodologies, they identify the best performers more consistently than the worst. Thus, regulatory policies targeted at either efficient or inefficient banks would hit different targets, depending upon which frontier techniques have been employed to determine the policy.

Table 6.8 Correspondence of Best-practice and Worst-practice Banks across Techniques

	Most efficient quartile			Least efficient quartile		
	SFA	DEA	New DEA	SFA	DEA	New DEA
SFA	1	0.46	0.45	1	0.47	0.35
DEA		1	0.59		1	0.33
New DEA			1			1

Notes: Each number in the **most** efficient quartile is the proportion of banks identified by one model as having efficiency scores in the most efficient 25% of banks also in the **most** efficient 25% by other model.
Each number in the **least** efficient quartile is the proportion of banks identified by one model as having efficiency scores in the most efficient 25% of banks also in the **least** efficient 25% by other model.

6.7.4 Stability of Measured Efficiency Over Time

From a regulatory perspective, it is much more useful that the efficiency measures display relative stability over time. It is usually expected that the efficiency rankings of banks do not change dramatically from one year to the next (or over moderately short periods of time). Even if some banks may improve or worsen in their overall performance in the short run, it is unlikely that a very efficient bank in one year would become very inefficient in the next year; that is, it is more likely that an efficient bank will maintain its efficiency in following year (Bauer *et al*., 1998)[49]. Thus, we compute the Spearman rank order correlation coefficient for each of the three efficiency measures between each pair of years to examine the year to year stability of the

[49] Only in exceptional cases would efficiencies be likely to fluctuate dramatically over short periods of time.

efficiency measures over time. For the full sample, 91 correlations of k-year-apart efficiencies, where k = 1, 2, … , 13, are computed in each case. Table 6.9 reports the average correlations for the different intervals of time. In general, the one and two year-apart average correlations are relatively high among the three methods, suggesting that a bank's efficiency ranking does not bounce up and down dramatically within one or two year period. After this, however, most of the correlation coefficients decline, as expected, as the number of years between the efficiency scores grows. In some cases, for example 9 to 12 years apart for SFA and DEA, a substantial proportion of insignificant correlations arise, leading to the average correlation being very close to zero. This result suggests that these two methods seem to be unstable through time. Moreover, the results show that there is little difference in the stability of the efficiency scores between the SFA and DEA methods. It is important to note that New DEA efficiencies, from 5 years-apart to 11 years-apart, still have statistically significant correlations, in the range of 23.8% to 39.5%. This indicates that for New DEA many of the best and worst practice banks tend to remain efficient or inefficient, respectively, over relatively longer periods of time. In summary, all models' efficiency measures are relatively stable over short periods of time but apart from the New DEA efficiency scores exhibit instability over longer periods time. In other words, New DEA methods generally show slightly more stability than the SFA and DEA methods in the long run.

Table 6.9 Persistence of Efficiency – the Correlations of k-year-apart Efficiencies

Years apart	*1 -*	*2 -*	*3 -*	*4 -*	*5 -*	*6 -*	*7 -*	*8 -*	*9 -*	*10 -*	*11 -*	*12 -*	*13 -*
SFA	0.662	0.618	0.518	0.463	0.393	0.370	0.311	0.211	0.055	0.094	0.116	−0.01	0.355
DEA	0.697	0.572	0.495	0.448	0.404	0.371	0.270	0.051	−0.07	−0.01	−0.03	0.003	0.297
New DEA	0.636	0.427	0.414	0.383	0.255	0.238	0.297	0.395	0.358	0.293	0.341	0.157	0.136

Notes: Following Bauer *et al*. (1998), each entry is mean of correlations of k-year apart efficiencies for single efficiency technique within 14-year time span. So for each k, figure reported is average of (14-k) correlations between efficiencies. For example, there are 8 different correlations for 6-years apart correlations that is 1994 with 2000, 1995 with2001,…, 2000-2006 and 2001-2007

6.7.5 Efficiency and Accounting-based Performance Measures

Non-frontier measures of performance are also widely used by regulators, bank managers and industry consultants. Thus, if the frontier efficiency scores are correlated with some standard financial ratio measures of performance, then policy makers could be more confident that the measured efficiencies are accurate indicators of performance and not simply artificial measures resulting from the specific assumptions on which the efficiency measures are based (Bauer *et al*., 1998). We analyse here the correlations between efficiency scores and standard performance measures in order to evaluate their consistency. The chosen conventional measures of performance are the return on average assets (ROAA), the return of average equity (ROAE), the cost to assets ratio (TC/TA, defined as total costs as a fraction of total assets) and the efficiency ratio (ER, defined as the ratio of non-interest expense to interest income plus non-interest income). The first two ratios are generally used to assess the profitability of banks and higher values are taken to imply more efficient use of bank assets or equity. The relationship between these two ratios and cost efficiency scores are expected to be positive. The cost to assets ratio measures costs in relation to the size of banks and considers it as an indicator of economic optimisation in terms of banks' costs. Last is the efficiency ratio (ER), which is what it costs the bank to generate its revenue. This ratio is often considered as a most popular non-frontier bank productivity (efficiency) measure, in part because it reflects operations both on and off the balance sheet (Forster and Shaffer, 2005). Smaller values of these two cost-related performance ratios denote better cost management and are more desirable. Thus they are expected to be negatively correlated to our cost efficiency scores.

Table 6.10 Correlations between Frontier Efficiencies and Non-frontier Performance Measures

	SFA	DEA	New DEA
ROAA	0.1407*	0.0573	0.0835
ROAE	0.1642*	0.0688	0.0718
TC/TA	-0.2300*	-0.1384*	-0.2267*
ER	-0.1868*	-0.1683*	-0.1234*

Notes: * denote an estimate significantly different from 0 at 5% level.
ROAA = return on average assets; ROAE = return on average equity; TC/TA = total costs/ total assets; ER= efficiency ratio.

Table 6.10 reports the correlations between the efficiency scores generated by the three frontier models and the four non-frontier measures of performance. The results show that both parametric and non-parametric-based efficiency scores have low correlations with the standard performance measures. The low magnitude of the correlation coefficients, ranging from -23% to 16%, may arise because the traditional financial performance ratios do not consider the effects of differences in input prices and output mix and also ignore the market value of bank equity (Berger and Humphrey, 1991). The most positive outcome, however, is that the correlations between the SFA efficiency measures and the four traditional performance measures are all statistically significant and importantly, with the expected signs. For the non-parametric measure results, however, we observe that the cost efficiency scores are only significantly correlated with the cost-related performance ratios (TC/TA and ER), and not with the profit-related performance indicators (ROAA and ROAE). This result may indicate that cost efficiency models (DEA and New DEA) cannot fully capture the characteristics of bank profit performance. Overall, however, the SFA, DEA and New DEA efficiency measures are marginally consistent with the standard non-frontier measures of performance, and especially with the cost-related performance measures. This gives some confidence that the frontier models are useful measures of actual accomplishment and not simply artificial products of the assumptions of the efficiency approaches.

6.8 Summary and Conclusion

This chapter reports and compares the empirical results from the methodologies summarised in the previous chapter. We first focus on finding a preferred SFA specification for measuring Chinese banking efficiency and then proceed to the methodological cross-checking of three frontier methods in order to assess the robustness of our results.

We followed the recent efficiency methodologies that proceed by applying various SFA model specifications to take into account the heterogeneity in the sample of Chinese banks. We find that the sample heterogeneity significantly influences some key stochastic cost frontier estimates. In order to reach the best-specified stochastic cost

frontier model, we conducted a step-wise specification testing procedure. The results suggest that the appropriate model fit should incorporate both control variables and environmental variables in order to control for systematic differences across banks. We subsequently discussed the effects of applying different SFA specifications to banks' efficiency scores and rank orders. Our results indicate that it is important to control for heterogeneity across banks. As a final result, we found a preferred SFA model specification for our sample, that is the translog cost function form includes the traditional outputs and input prices and the control variables (the level of equity, the non-performing loans and the time trend) in the cost function, and the environmental variables in the inefficiency term.

Since efficiency evaluation plays a very important role in regulatory analysis as well as management decision making, it is strongly recommended great care be exercised when choosing evaluation techniques from among the parametric and nonparametric frontier efficiency methods. We used two other nonparametric DEA and New DEA methods as complementary models to the preferred parametric SFA model to measure Chinese banking efficiency. Following Bauer *et al*. (1998), we then conduct multilevel consistency tests to compare the outcomes of different methods to determine whether serious inconsistencies arise. Consistent with the previous empirical literature, the findings, in most cases, indicate only moderate compatibility across the different methods. The differences between efficiency scores obtained from the different approaches are attributed mainly to the inherent advantages and disadvantages, detailed earlier, of each methodology. With regard to our five consistency checks, the first consistency condition check shows that the average of the SFA efficiency scores are slightly higher than those of DEA and New DEA, and some differences also emerge in other distributional properties of the efficiency scores derived from these methods. The rank order correlations of the efficiency estimates between the SFA and DEA models range from 28% to 48%. This result means that there are important differences in the order structure of efficiency scores across the different measurement approaches. The third consistency condition involves analysis of the tails of the distributions of the efficiency scores by identifying the overlap of the best and the worst quartile of banks for each method. The correspondence of the best and worst practice 25% of banks ranges from 33% to 59% across the different methods. Thus, the three methods tend to

be moderately consistent in identifying extreme performers.

In the context of the stability of the efficiency scores over time, we find that efficiency measures are relatively stable over short periods of time but exhibit instability over longer periods. This result indicates that the Chinese banking industry was subject to important technology and regulatory changes during the relatively long period of our analysis. Finally, with regard to the relation of efficiency and conventional accounting based performance measures, the frontier efficiency measures were significantly correlated with cost-related traditional performance measures, and weakly related with profit-related performance indicators, especially in the case of the DEA methodologies. The low but significant magnitude of the correlation coefficients indicates that frontier efficiency measures contain additional information compared to accounting-based performance measures.

Our results are generally compatible with previous studies. However, our results show that there is only moderate consistency between the results of the three dominant methods (SFA, DEA and New DEA). Therefore, our most important but by no means only conclusion is that policy conclusions resulting from cost efficiency estimates seem to be sensitive to the methodological selection of the frontier efficiency estimation methods used, and the use of multiple frontier approaches for robustness checking is strongly recommended.

Chapter 7 Chinese Banking Efficiency and Analysis

7.1 Introduction

In this chapter the cost efficiency of the Chinese banking sector is analysed and discussed for the period from 1994 until 2007. The empirical evidence on bank efficiency aims to highlight the features associated with the role of economic development and banking reforms that have taken place in China over the past thirty years. It is expected that the institutional and structural changes in the Chinese banking sector as a result of deregulation and liberalisation have significantly affected the efficiency and performance of Chinese banks.

The rest of this chapter is organised as follows. Section 7.2 analyses the cost efficiency levels of Chinese banks derived from the preferred stochastic frontier model developed in the preceding chapter. Beside the analysis of overall Chinese banking efficiency, particular emphasis is also placed on investigating the diversity of efficiency levels between different types of bank (that is big four state-owned banks, state-owned policy banks, joint stock commercial banks and city commercial banks) and size classes (that is very big, big, medium, small and very small). Section 7.3 reports and discusses the results of the cost efficiency measures obtained from the DEA methodologies (traditional cost efficiency and new cost efficiency measures). Section 7.4 investigates the degree of scale economies for the Chinese banking sector based on both the SFA model and the DEA models (DEA and New DEA). The scale economies measures are summarised according to bank size categories. Section 7.5 explores the impact of certain factors on banks' cost efficiencies, and this in turn provides valuable information for regulatory authorities and management to trace the sources of (in)efficiency. Finally, section 7.6 summarises the findings of this chapter.

7.2 Cost Efficiency Based on SFA

Cost efficiency estimates are derived from the preferred stochastic frontier model which includes all three control variables in the cost function (equity, non-performing loans and time trend) and allows for environmental variables (ownership structure, bank size, stock exchange listing, deregulation, market structure) to affect the distribution of the inefficiency term. Summary statistics relating to the estimated efficiency scores are reported in Table 7.1 below.

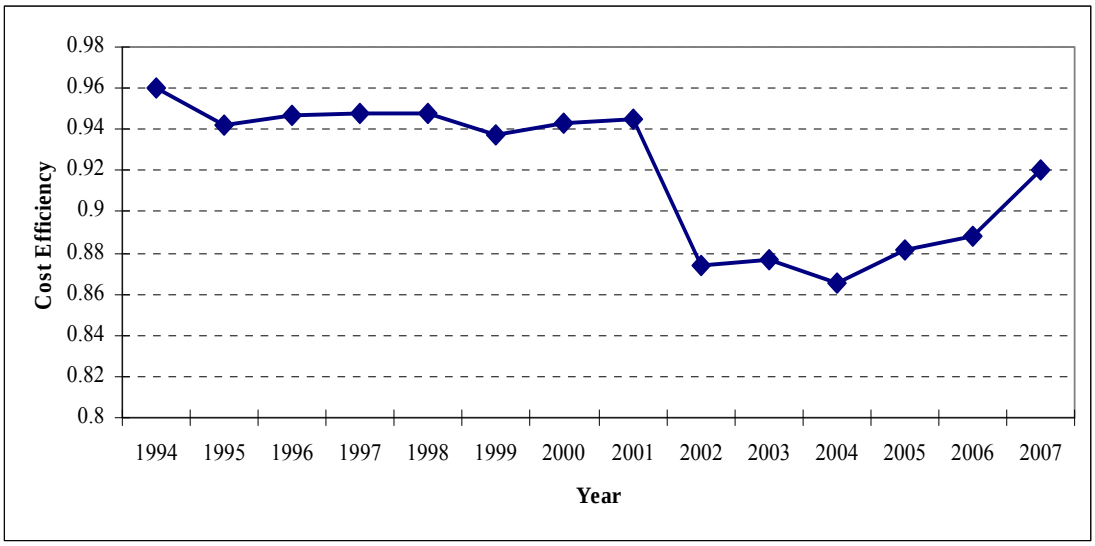
Table 7.1 Average Efficiency Scores for Chinese Banks on Basis of SFA

	Mean	*SD*	*Min*	*Max*	*Observation*
1994	0.9601	0.0070	0.9501	0.9728	11
1995	0.9425	0.0286	0.8579	0.9735	18
1996	0.9467	0.0271	0.8610	0.9729	19
1997	0.9477	0.0254	0.8881	0.9741	20
1998	0.9482	0.0317	0.8388	0.9747	20
1999	0.9374	0.0361	0.8333	0.9767	26
2000	0.9432	0.0198	0.8997	0.9741	29
2001	0.9445	0.0288	0.8519	0.9808	32
2002	0.8741	0.1128	0.3625	0.9543	34
2003	0.8765	0.1155	0.4697	0.9686	35
2004	0.8653	0.0933	0.6095	0.95867	36
2005	0.8812	0.0841	0.6158	0.9751	38
2006	0.8881	0.1005	0.5150	0.9663	39
2007	0.9200	0.0477	0.7620	0.9689	40
Overall	0.9114	0.0790	0.3625	0.9808	397

Generally, the results in Table 7.1 show relatively high average cost efficiency for Chinese banks, with efficiency scores that range between 86.5% in 2004 and 96% in 1994. This result is consistent with results reported in the previous literature; for example Berger *et al*. (2009). The average cost efficiency for the sample period is 91.14%, meaning that on average the sampled banks could potentially reduce input costs by approximately 9% by using its inputs more efficiently and without changing the level of output. We find that average cost efficiency is significantly higher (about

7%) in 2001 (before China's WTO entry) than that in 2002 (after China's WTO entry). This decline in efficiency could be a consequence of the deregulation and liberalisation reforms implemented by the Chinese government in response to China's entry into the WTO. It is also worth noting that the standard deviations of the average efficiency prior to WTO accession (1994-2001) are quite low, thereby implying that before WTO accession the cost efficiency levels of the sampled banks are very close to each other. But interestingly, the variance of the cost efficiency scores rises significantly after China's admission to the WTO (2002-2007). There are two possible explanations for this change in the dispersion of efficiency scores after China's admission into the WTO. First, the sample data before 2002 mainly include the nationwide banks which have similar characteristics in terms of inputs and outputs while the later period data also include many other types of banks, such as city commercial banks. Hence, it is this which may cause the low variation of cost efficiency across different banks in the early period but which rises in later periods. Second, the significant external environmental changes due to WTO entry may have created winners and losers amongst Chinese banks.

Figure 7.1 Average SFA Cost Efficiency Scores for Chinese Banks (1994-2007)



The temporal performance (efficiency) pattern for the Chinese banking sector is also of interest. Figure 7.1 illustrates the trend of average cost efficiency changes over the sample period. Note how the Chinese banking sector shows an overall decreasing trend in cost efficiency over the study period. The mean cost efficiency remains at a

relatively high level and varies very little during the period from 1994 until 2001. This may indicate the reforms implemented by the Chinese government may have enhanced the performance of Chinese banks over this period. Moreover, banking competition was relatively weak throughout this period. Banks enjoyed large interest margins - probably because of this. It is worth noting however, that average efficiency declined sharply after China's admission to the WTO, particularly in 2002. This may suggest that the external environmental changes introduced in 2002 may have had a negative impact on Chinese banking efficiency. Banks may have had to incur additional costs in order to prepare for the intensive competition and other environmental changes which arose from China's admission to the WTO. Moreover, the new loan classification system was formally applied to all banks from 2002. Along with this new system, banks are allowed to carry out more aggressive provisioning against non-performing loans resulting in a significant decline in the book value of bank loans. This will thus be reflected in declining efficiency because of the output reduction caused by loan write-offs without any changes in the input usage. However, we find that the negative impact on efficiency disappeared in 2005 and that the mean efficiency increased significantly between 2005 and 2007. This finding implies that banking reforms which were implemented in this period may have improved Chinese banking efficiency.

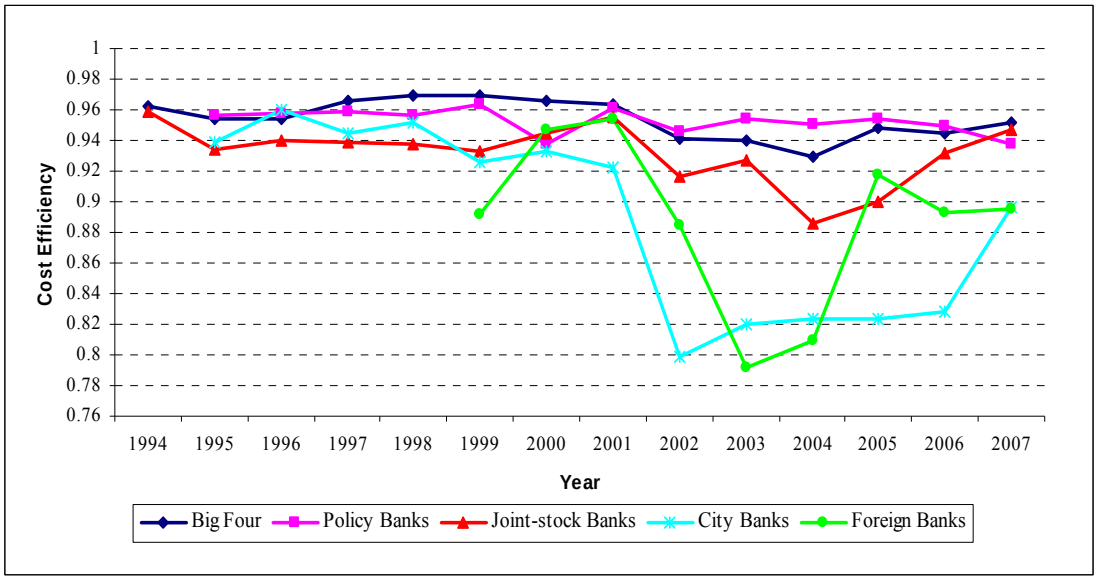
Having examined the efficiency of the aggregate Chinese banking sector over time, we now further analyse cost efficiency levels in more detail by different banking categories. Table 7.2 and Figure 7.2 display the mean value of the cost efficiency scores according to their origin and ownership, specifically the big four state-owned commercial banks (Big Four), state-owned policy banks (policy banks), nationwide joint stock commercial banks (JSCBs), city commercial banks (CCBs) and foreign banks. Although these groups of banks operate in the same market, each group faces a different set of regulations. In the light of this uneven and changing regulatory environment, we expect to find performance variation, both across groups of banks and over time. We seek to quantify and also to explain this anticipated performance variation.

Table 7.2 Average SFA Cost Efficiency Scores by Bank Types

	Big Four	*Policy banks*	*JSCBs*	*CCBs*	*Foreign banks*
1994	0.9621	-	0.959	-	-
1995	0.9536	0.9559	0.9344	0.9384	-
1996	0.9537	0.9578	0.9398	0.9598	-
1997	0.9659	0.9586	0.9387	0.9444	-
1998	0.9694	0.9561	0.9377	0.952	-
1999	0.9698	0.9634	0.9332	0.9255	0.892
2000	0.9662	0.9378	0.9443	0.9324	0.947
2001	0.964	0.9611	0.9549	0.9227	0.954
2002	0.9411	0.946	0.9163	0.7987	0.8847
2003	0.9401	0.9543	0.9275	0.8196	0.7919
2004	0.9288	0.9504	0.8856	0.8234	0.809
2005	0.948	0.9543	0.9003	0.8236	0.9181
2006	0.9449	0.9489	0.9322	0.8282	0.8929
2007	0.9522	0.938	0.9472	0.896	0.8947
Average	0.9543	0.9525	0.9322	0.8896	0.8872

Table 7.2 shows that the Big Four and the policy banks, on average, are the most efficient (95.43% and 95.25%, respectively). These are followed by the JSCBs with an average efficiency of 93.22%. The CCBs and foreign banks are the least efficient (88.96% and 88.72%, respectively). Figure 7.2 indicates that, during the period from 1994 until 2001, all bank subcategories show a relatively low variation in efficiency scores and also remain at a relatively high level of efficiency. However, they exhibit greater variability in mean efficiency over the period from 2002 until 2007. All bank groups show a significant average efficiency decline in 2002. A comparison of the five groups shows that the Big Four and the policy banks have tended to exhibit higher average cost efficiency over time than other subcategories. It is also observed that amongst the rest of the subcategories, no bank group gets a clearly dominant position over the sample period. These findings contradict a common perception in the literature and the results of some previous studies. For example, Ariff and Can (2008) found that the JSCBs are more cost efficient than the state-owned banks over the period from 1995 until 2004 and Berger *et al*. (2009) showed that foreign banks were more efficient than other bank types over the similar period. Differences in such findings may be due to different methodologies, model specifications and the sample periods being analysed.

Figure 7.2 Average SFA Cost Efficiency by Different Bank Types



Big four state-owned commercial banks

Overall, the Big Four exhibit quite good performance in cost efficiency relative to other bank types. The results can possibly be explained by the Big Four having an extensive branch network which assures a stable retail banking business. It may also reflect in part continual government subsidies on the cost side. The Big Four show an improving trend in efficiency during the period from 1997 to 1999, indicating that they took advantage of the early reforms which the Chinese government focused almost exclusively on them. For example, the Chinese government recapitalised the Big Four with RMB 270 billion in 1998. Then in 1999 the government established four asset management corporations (AMCs) to buy RMB 1.4 trillion of non-performing loans from the Big Four. From 1998, the Big Four also started to improve organisational management efficiency by reducing the number of redundant branches and employees. Up to 2002, they reduced the number of branches by nearly 30% and employees by 10%. Following China's admission to the WTO at the end of 2001, we observe however that the cost efficiency of the Big Four deteriorated. This may have occurred because of the under capitalisation of the Big Four and a large amount of non-performing loans on the Big Four's balance sheets. But beginning in 2005, the Big Four's cost efficiency began to improve again. After a few years of intense debate, the Chinese government also launched a new series of reforms for the Big Four. The government injected RMB 499.6 billion into state-owned banks at the end of 2003 and

allowed the four banks to transfer their non-performing loans to AMCs in 2004 and 2005. More recently, the government has encouraged the big state-owned banks to introduce foreign capital and to list on one or more of the Chinese stock exchanges. All these measures appear to have enhanced the banks' performance and could provide an explanation for the improvement in the cost efficiency which has occurred in the Big Four in the period beginning in 2005.

State-owned policy banks

The state-owned policy banks tend to show relatively little variation in their efficiency scores over time, and unexpectedly, exhibit high cost efficiency levels. There are several possible explanations for these results. First, the policy banks are mainly engaged in the government policy-oriented finance business and as a result, could be receiving favourable treatment from the government that improves their cost efficiency. Second, the policy banks only focus on policy lending and they may possess more experienced and specialised teams that enable them to evaluate and monitor their lending in an efficient way. Third, the policy banks, compared with commercial banks, do not necessarily have a strong network of branches and the higher staff levels associated with this and other factors result in considerable savings in their operating expenses.

Joint stock commercial banks

Our study is based on twelve joint stock commercial banks (JSCBs)[50]. Each of these banks operates on a nation wide basis. Referring to Figure 7.2, we find that JSCBs show less efficiency when compared with their counterparts – the Big Four. This result is similar to that reported by Chen (2005). However, the efficiency levels for the JSCBs and the Big Four have tended to converge over the last a few years. There are several possible explanations for these results. First, the JSCBs' branch networks are much more limited than those of the Big Four. This constrains their competitiveness and leads to relatively small market shares. Another possible explanation is that

[50] They are Bank of Communications, CITIC Bank, China Everbright Bank, China Merchants Bank, Huaxia Bank, China Mingsheng Bank, Shenzhen Development Bank, Shanghai Pudong Development Bank, Guangdong Development Bank, Industrial Bank, Evergrowing Bank, China Zheshang Bank

JSCBs do not enjoy an implicit government guarantee of their debts and they also do not receive the subsidies from government that are received by the state-owned banks. This may increase the cost of their borrowed funds and this in turn influences their cost efficiency levels. However, JSCBs have shown a considerable improvement in average cost efficiency in the last three years (2005-2007). This trend may indicate that JSCBs have gained efficiency benefits from foreign strategic investments which are expected to result in new management systems and techniques and better corporate governance.

City commercial banks

Generally, city commercial banks (CCBs) show a relatively low level of cost efficiency when compared to the efficiency scores of the other types of bank. The most likely reason for this is that city commercial banks are restricted to opening branches within their own city boundaries. This regulation may impact on their cost efficiency scores relative to nationwide banks, particularly for those located in smaller, less prosperous cities, because they are less able to achieve economies of scale and spread risk (Laurenceson and Qin, 2008). It is noteworthy that the mean efficiency levels of CCBs shows a significant difference between the period before and after 2001. This may be due in part to our sample choice. Before 2001 the sample data are only available for several big CCBs and most of these have characteristics which are similar to JSCBs. However, in the later sample period, we include more varied CCBs having different sizes and which are located widely across China. The changing nature of the CCBs over our sample period may be one of the reasons for the decline in cost efficiency in the later period.

Foreign banks

Figure 7.2 shows that foreign banks exhibit less average cost efficiency than do nationwide domestic banks. This finding may be interpreted as evidence that foreign banks are managed less efficiently, but this is not necessarily the case. It can also reflect less familiarity with the regulatory system and a greater restriction on business scope and geographic range. The foreign banks' efficiency estimates are available

only after 1999 and do not indicate a consistent trend over the study period. In the initial three years, they show an increasing trend in efficiency. In the first two years after China's admission to the WTO, we observe a significant decline in efficiency in foreign banks. However, this decline may simply reflect the costs of setting up business and branch expansion in order to facilitate competition with China's domestic banks. This is reflected in the fact that the cost efficiency of foreign banks improves significantly after 2003. The greater variability in the efficiency of foreign banks may be due to their dependence on less stable wholesale or corporate resources, interbank market borrowings and the refinancing of assets.

Size effect

In order to investigate the influence of size on efficiency, we divide banks into different categories on the basis of the size of their total assets, that is a very big bank if its total assets are greater than 1000 billion RMB (GDP deflator adjusted to the base year 1994), a big bank if 250 - 1000 billion RMB, a medium bank if 100 - 250 billion RMB, a small bank if 20 - 100 billion RMB, and a very small bank if its assets are less than 20 billion RMB. The average cost efficiency scores for the five asset size groupings of Chinese banks are shown in Table 7.3.

Table 7.3 Average Cost Efficiency by Size Groups

	Very big banks	*Big banks*	*Medium banks*	*Small banks*	*Very small banks*
1994	0.9621	0.9562	-	0.9622	0.9581
1995	0.9536	0.9526	0.9606	0.9464	0.9212
1996	0.9537	0.9649	0.9698	0.9495	0.9189
1997	0.9659	0.9644	0.9427	0.9378	0.9380
1998	0.9694	0.9625	0.9629	0.9313	0.9354
1999	0.9698	0.9683	0.9534	0.9313	0.8988
2000	0.9662	0.9522	0.9506	0.9391	0.9296
2001	0.9640	0.9664	0.9578	0.9527	0.9206
2002	0.9411	0.9392	0.9208	0.9134	0.7764
2003	0.9401	0.9320	0.9374	0.8667	0.785
2004	0.9348	0.9356	0.8753	0.8461	0.7930
2005	0.9509	0.9143	0.9054	0.8502	0.8294
2006	0.9444	0.9412	0.8598	0.8629	0.8273
2007	0.9546	0.9534	0.9320	0.8865	0.9118
All	0.9550	0.9502	0.9329	0.9126	0.8817

Both the very big and big banks exhibit similar average cost efficiencies for each individual year and the lowest efficiency scores are generally found for very small banks. The mean efficiency score for very big and big banks over the sample period is 95.5% and 95.02%, respectively. The corresponding figures for medium, small and very small banks are 93.29%, 91.26% and 88.17%, respectively. Generally speaking, the mean cost efficiency scores of banks decreased as their size decreased. This suggests that, on average, larger banks appear to be more cost efficient than smaller banks. This may be because larger banks enjoy several advantages over smaller banks resulting in cost saving and/or efficiency gains. These advantages include the ability of large banks to use more advanced technology, employ more specialised staff and implement a more extensive network of branches (Hunter and Timme, 1986). Chen *et al*. (2005) found similar results for the relationship between size and the cost efficiency of Chinese banks.

7.3 Cost Efficiency Based on DEA

Data Envelopment Analysis (DEA) is a non-parametric technique which aims to evaluate the efficiency of decision making units (DMUs). For this section we applied DEA techniques to identify the level of cost efficiency for each bank on an annual basis during the period from 1994 until 2007. As indicated earlier, the traditional cost efficiency model returns deficient efficiency scores when the unit prices of inputs are not identical across banks. Given this, we here use a new cost efficiency DEA model (New DEA model) developed by Tone (2002) as a complementary model to the traditional DEA model. Efficiency levels for Chinese banks are calculated by using the software DEA-solver. These efficiency scores represent the actual cost of a given bank compared to the optimal cost that could have been achieved. Table 7.4 provides the basic cross-sectional efficiency scores over the period from 1994 until 2007 under both the traditional and new cost efficiency measures.

In the case of the traditional DEA model, the average cost efficiency scores vary from 86.17% in 2002 to 92.42% in 1994. This result suggests that the average bank in the sample could have reduced its costs by approximately 8% to 14%, thereby achieving

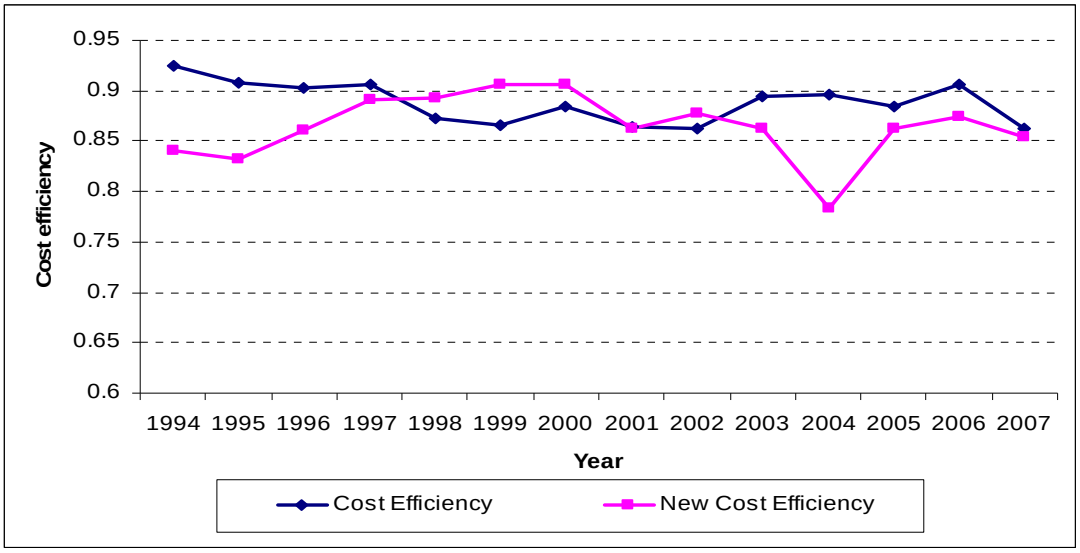
'best-practice' performance. Similarly, the minimal cost efficiency scores range from 53.7% in 2001 to 77.41% in 1994. With respect to the new cost efficiency model, the yearly average cost efficiency scores for Chinese banks over the period from 1994 until 2007 range from 78.4% in 2004 to 90.86% in 1999. The average cost efficiency over the sample period under the traditional cost and new cost models is 88.5% and 86.4%, respectively.

Table 7.4 Average Cost Efficiency Scores for Chinese Banks on Basis of DEA

	Traditional cost efficiency				New cost efficiency			
	mean	SD	max	min	mean	SD	max	min
1994	0.9242	0.0837	1	0.7741	0.8413	0.1940	1	0.5042
1995	0.9084	0.1187	1	0.6757	0.8317	0.1873	1	0.3873
1996	0.9032	0.1224	1	0.6536	0.8606	0.1499	1	0.4582
1997	0.9065	0.1042	1	0.6655	0.8904	0.1693	1	0.4704
1998	0.8731	0.1344	1	0.6284	0.8927	0.1544	1	0.5829
1999	0.8663	0.1255	1	0.6097	0.9068	0.1301	1	0.5153
2000	0.8840	0.1300	1	0.6035	0.9066	0.1536	1	0.4435
2001	0.8650	0.1445	1	0.5370	0.8622	0.1673	1	0.4492
2002	0.8617	0.1486	1	0.5464	0.8777	0.1472	1	0.3926
2003	0.8937	0.1108	1	0.6345	0.8633	0.1616	1	0.4169
2004	0.8965	0.1169	1	0.5929	0.7840	0.2033	1	0.3348
2005	0.8845	0.1093	1	0.6856	0.8629	0.1645	1	0.3094
2006	0.9064	0.1041	1	0.6257	0.8742	0.1538	1	0.3009
2007	0.8632	0.1287	1	0.6146	0.8548	0.1471	1	0.2969
Total	0.8853	0.1239	1	0.5370	0.8642	0.1653	1	0.2969

The differences in mean cost efficiency score for most years in the two models are somewhat modest - approximately 1% to 5%. The yearly average cost efficiency scores under the two different models are plotted in Figure 7.3 for comparative purposes.

Figure 7.3 Average Traditional and New Cost Efficiency Measures over Time



In Figure 7.3, with the exception of 1994, 1995 and 2004, the mean cost efficiencies for the two different DEA models varied little over the sample period. Generally, over time the cost efficiency scores show a rather flat pattern and fluctuate around 87%. Somewhat unexpectedly, the traditional and the New DEA models seem to yield slightly different temporal patterns in cost efficiency. To take one of the more obvious examples, Chinese banks showed an average cost efficiency score of 88% in 2004 according to the conventional DEA cost measure. With the New DEA model, however, the average cost efficiency score is only 78%. Thus, this indicates that some banks deemed to be (relatively) efficient using the traditional cost DEA measure may be found to have much lower cost efficiency using the New DEA model. This result is also confirmed by the low rank correlation between the efficiency scores under the two models (see previous chapter for further details). Generally, the average of the traditional cost efficiency scores shows a decreasing trend over the period from 1994 until 2002, but begins to increase after the year 2002. With respect to the new cost efficiency measures, the average efficiency gradually improves over the period from 1995 until 2000, then decreases to a low of about 78% in the year 2004 but then recovers in the later years. In sum, regardless of whether the traditional or new cost measure is used, our results reveal that Chinese banks, on average, exhibited a somewhat modest degree of inefficiency of around 12%. Moreover, the results from the two models show only modest differences in general.

We now further analyse the cost efficiency levels of Chinese banks in more detail with particular emphasis on the categories of banks described previously. The average cost efficiencies from the DEA and the New DEA models for the five different categories of banks are presented in Table 7.5 and in time profile in Figures 7.4 and 7.5. On traditional cost efficiencies, as shown in the left-hand part of Table 7.5, the policy banks and the Big Four, on average, are the most efficient (96.8% and 94.6%, respectively), followed by foreign banks (94.12%), JSCBs (88.19%) and CCBs (86.29%). With regard to the new cost efficiency scores, the right-hand part of Table 6.5 shows that the Big Four are the most efficient banks, with a mean efficiency score of 96.68%, followed by the policy banks (92.09%), foreign banks (91.93%) and JSCBs (86.17%). The CCBs return the lowest new efficiency scores with an average of 79.56%.

Table 7.5 Average DEA Cost Efficiency Scores by Different Bank Types

	Traditional cost efficiency					New cost efficiency				
	Big Four	Policy banks	JSCBs	CCBs	Foreign banks	Big Four	Policy banks	JSCBs	CCBs	Foreign banks
1994	0.9293		0.9212		-	0.876	-	0.8215	-	-
1995	0.9023	1	0.8743	1	-	0.865	0.7958	0.8254	0.8852	-
1996	0.8629	0.9714	0.8904	1	-	0.9498	0.7683	0.8598	0.7898	-
1997	0.934	0.9891	0.8811	0.8675	-	0.984	0.9693	0.8631	0.7352	-
1998	0.9154	0.9568	0.8118	1	-	0.9711	0.8609	0.8792	0.8576	-
1999	0.9434	0.9215	0.8269	0.8263	0.9651	0.9858	0.9312	0.9231	0.8199	0.8834
2000	0.9488	1	0.8856	0.7887	1	1	0.9880	0.9491	0.7989	0.8495
2001	0.9148	0.981	0.8982	0.7665	1	0.9995	0.9974	0.8865	0.757	0.8823
2002	0.9343	0.9650	0.8858	0.7631	1	0.9887	0.9989	0.9023	0.771	0.9803
2003	0.9583	0.9296	0.9059	0.8437	0.9600	0.9963	0.9581	0.8657	0.7738	1
2004	1	0.943	0.9160	0.8341	0.9250	0.9766	0.9461	0.7837	0.668	0.9071
2005	1	0.9523	0.8487	0.8664	0.8934	0.9937	0.9866	0.8509	0.8081	0.8807
2006	1	0.9743	0.9067	0.8789	0.8706	0.9923	0.8693	0.8514	0.8504	0.9228
2007	1	1	0.8937	0.7824	0.8568	0.9559	0.9016	0.8015	0.8257	0.9669
Mean	0.946	0.968	0.8819	0.8629	0.9412	0.9668	0.9209	0.8617	0.7954	0.9193

Note also that the evolution of DEA and New DEA cost efficiency scores for different bank types often display erratic trajectories. Relatively speaking, however, we find

that the Big Four and the policy banks have tended to exhibit the greatest efficiency and the CCBs have perform with least efficiency in most years. These results are consistent with our previous SFA findings. Moreover, except for the period from 1994 until 1996, the DEA cost efficiency levels of the Big Four have significantly improved over the period of our analysis. Similarly, the new cost efficiency level of the Big Four also has improved over the period of our analysis. These results suggest that the reforms focused on the Big Four have enhanced their cost efficiency over this period.

Figure 7.4 Average Traditional DEA Cost Efficiency by Bank Types

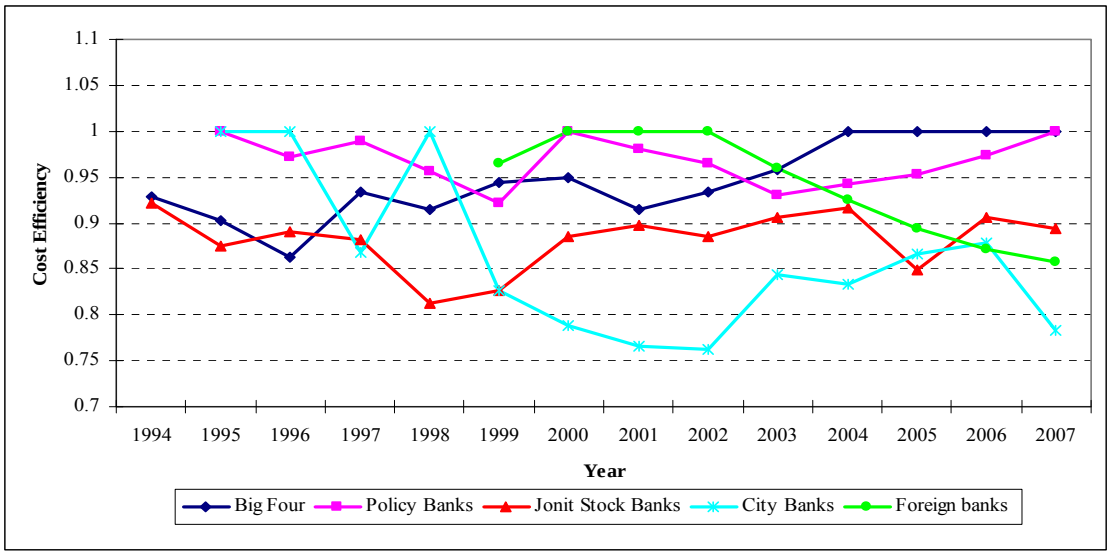


Figure 7.5 Average New DEA Cost Efficiency by Bank Types

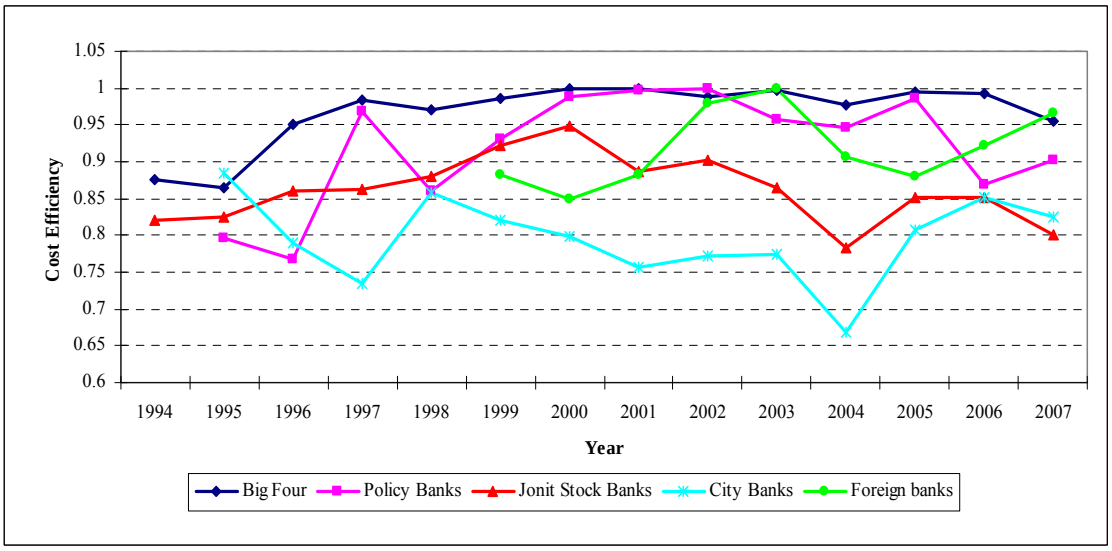


Table 7.6 reports the average cost efficiency scores from the DEA and New DEA

models across the previously defined five different size groups. Although the results do not show a consistent pattern among different size groups across each year, the less efficient banks appear to be the small and very small banks. These results also reinforce the observation previously obtained from our SFA analysis that larger banks, in general, are more efficient than smaller banks in the Chinese banking sector.

Table 7.6 Average DEA Cost Efficiency Scores by Size Classes

	Traditional cost efficiency					New cost efficiency				
	Very big banks	Big banks	Medium banks	Small banks	Very small banks	Very big banks	Big banks	Medium banks	Small banks	Very Small banks
1994	0.9293	1	-	0.9241	0.8921	0.876	1	-	0.8417	0.7547
1995	0.9023	1	1	0.8700	0.9071	0.9246	0.6934	1	0.7949	0.8613
1996	0.8629	1	1	0.8726	0.932	0.9498	0.7291	1	0.7988	0.926
1997	0.934	1	1	0.8376	0.9519	0.984	1	1	0.8087	0.8648
1998	0.9154	0.9568	0.7750	0.8415	1	0.9711	0.861	1	0.8827	0.8106
1999	0.9434	0.9216	0.8317	0.8402	0.8493	0.9858	0.9312	0.9393	0.8859	0.8516
2000	0.9489	1	0.8671	0.9012	0.8106	1	0.988	0.9208	0.9719	0.7722
2001	0.9148	0.9810	0.8901	0.8977	0.7884	0.9994	0.9974	0.8679	0.9394	0.7407
2002	0.9343	0.9029	0.9183	0.9291	0.7554	0.9887	0.9616	0.8972	0.8789	0.7907
2003	0.9583	0.9042	0.9306	0.907	0.8352	0.9963	0.9388	0.7975	0.8665	0.7943
2004	1	0.9452	0.9286	0.8170	0.8413	0.9813	0.8268	0.8032	0.5998	0.7552
2005	1	0.8554	0.9285	0.8251	0.899	0.995	0.8983	0.9536	0.712	0.8775
2006	0.9861	0.9288	0.8982	0.875	0.8909	0.9852	0.8443	0.9315	0.8295	0.9587
2007	0.9751	0.9117	0.88	0.7925	0.8479	0.9563	0.8282	0.8845	0.7982	0.9516
All	0.9432	0.9505	0.9113	0.8664	0.8713	0.9709	0.8927	0.9227	0.8283	0.8373

Note: Very big banks = total assets > 1000 billion RMB, big banks = 250-1000 billion RMB, medium banks = 100-250 billion RMB, small banks = 20-100 billion RMB, very small banks=<20 billion RMB.

7.4 Economies of Scale

Cost (or productive) efficiency arises from optimising behaviour which relates to both outputs and inputs. Regarding outputs, the banks' optimal behaviour is to choose the output levels corresponding to the minimum cost of a unit of output. This issue is closely related to economies of scale (that is, returns to scale). Moreover, industry

economies of scale also have implications for regulatory policy regarding industry consolidation and for antitrust enforcement. In this section, we first analyse economies of scale in the Chinese banking industry on the basis of the SFA methodology, and then we proceed to perform the scale economies' analysis using the traditional DEA and New DEA methodologies.

As discussed in the methodology chapter, the level of scale economies can be derived from the estimated stochastic cost frontier and indicates whether a bank that had minimised the cost of producing a particular output bundle could lower its costs yet further by producing an alternative level of output (Mester, 1996). In this section, the scale economies' measures refer to the inverse value of point estimates of the scale elasticities, which are computed using the average value of output, input price, financial capital level and non-performing loan variables along with parameter estimates from the preferred cost function specification (as in Mester, 1996 and Altunbas *et al*., 2001). A scale efficient bank will produce where there are constant returns to scale (the value of overall economies of scale is equal to one). Banks operating at decreasing or increasing returns to scale (value of overall economies is less or greater than one) imply scale inefficiency[51.]

In order to further investigate the relationship between returns to scale and bank size, banks are sub-divided into 8 classifications in terms of their total asset size. Overall economies of scale for all banks and for the different classifications of banks over the years from 1994 until 2007 are shown in Table 7.7.

[51] Scale elasticity and scale efficiency are two distinct concepts because they measure different things. Scale elasticity is measured in terms of the proportionate change in cost associated with a small proportionate change in all outputs. Scale efficiency, on the other hand, measures the average production cost at the observed operation scale compared to what is attainable at the optimal scale size. Thus, it should be emphasised, here, that a scale elasticity measure near one on does not necessarily imply small scale inefficiency; nor does a large difference imply substantial scale inefficiency (Evanoff and Israilevich, 1995).

Table 7.7 Overall Economies of Scale for Chinese Banks on Basis of SFA

Bank Size (RMB billion)	*Sample Means*	*0-10*	*10-25*	*25-50*	*50-100*	*100-250*	*250-500*	*500-1000*	*1000+*
1994	1.2614*	-	1.6823*	1.4023*	-	-	1.1000*	-	0.8611*
1995	1.2981*	1.7267*	1.6362*	1.5108*	1.3502*	1.0467	0.9573	-	0.8590*
1996	1.2686*	2.2592*	1.4556*	1.4606*	1.2931*	0.9058*	1.0233	0.9161*	0.8353*
1997	1.2418*	1.8307*	1.4995*	1.4001*	1.2715*	1.2690*	0.9345*	0.9112*	0.8181*
1998	1.2332*	1.8665*	1.5948*	1.3282*	1.2767*	1.1881*	0.9139*	0.8965*	0.8010*
1999	1.3165*	2.4012*	1.6599*	1.3493*	1.3161*	1.1671*	0.9537	0.8828*	0.8020*
2000	1.3393*	2.2421*	1.6228*	1.4016*	1.2644*	1.1554*	-	0.8889*	0.8002*
2001	1.2978*	2.1709*	1.5965*	1.3348*	1.1825*	1.1281*	-	0.8764*	0.7957*
2002	1.2540*	2.3798*	1.5061*	1.4477*	0.8828*	1.1204*	1.0375	0.8692*	0.7881*
2003	1.2124*	2.1779*	1.3972*	1.3324*	1.0415*	1.0835*	1.0111	0.8797*	0.7760*
2004	1.2128*	2.1250*	1.4097*	1.2944*	-	1.0518	0.9759	0.8575*	0.7755*
2005	1.1447*	1.8127*	1.3630	1.2793*	1.0955*	1.0141	0.9594	0.8711*	0.7625*
2006	1.1224*	1.7167*	1.3191*	1.2062*	1.1807*	1.0155	0.9561	0.8138*	0.7715*
2007	1.0787*	1.5712*	1.2535*	1.1776*	1.1104*	0.9721	0.9286*	0.8727*	0.7438*
ALL	-	2.0216*	1.4997*	1.3518*	1.1888*	1.0859*	0.9792	0.8780*	0.7993*

Notes: The scale economies measure is $1/\sum_{i=1}^{n} \partial \ln TC / \partial \ln Q_i$ and the estimates are evaluated at the mean of the data rather than mean estimate of scale economies calculated at each observation.
Number of observations: 397 total sample; 55 in the subsample <RMB 10 billion; 63 in subsample RMB 10-25 billion; 53 in subsample RMB 25-50 billion; 39 in subsample RMB 50-100 billion; 59 in subsample RMB 100-250 billion; 37 in subsample RMB 250-500 billion; 29 in subsample RMB 500-100 billion; 62 in subsample > RMB 1000 billion.
* Scale economise estimates are statistically different from one at 5% level for a 2-tailed test.

Generally, overall scale economies estimates for all banks over the years from 1994 until 2007 are significantly greater than one, suggesting that economies of scale are present in the Chinese banking system considered as a whole. However, it should be noted that the scale economies estimates over time exhibit a downward trend (declining economies of scale), especially for the later years of the sample. This tendency may indicate that most Chinese banks tend to achieve optimal operating efficiency (constant returns of scale) by gradually changing their scale of production. Based on the scale economies estimates for each of the eight size classifications, we find that high and significant scale economies exist in small banks (banks with asset size RMB 0-100 billion), implying that small banks can potentially save operating costs through extending their production scale. For the large size category (banks with assets over RMB 500 billion), the values of scale economies are significantly less than one. This

result suggests that big banks experience diseconomies of scale and could reduce their average cost and gain efficiency by decreasing their scale of operations. Interestingly, there is no consistent evidence of statistically significant scale economies or diseconomies in banks with RMB 100 - 500 billion total assets. The value of scale economies for banks with assets of RMB 250-500 billion is very close to one and scale advantages do not appear to arise for banks beyond this size. This result indicates that the optimal bank size is in the range of RMB 250-500 billion, because banks in this classification exhibit constant returns to scale. Overall, as asset size increases, returns to scale pass from increasing, to constant, and to decreasing. The average cost curve shows a U-shape, with medium-sized banks being more scale efficient than either very large or very small banks. This finding is in accordance with previous studies of the Japanese banking system and European banking system (see Altunbas *et al*., 2000 and Altunbas *et al*., 2001).

The characterisation of Chinese banks in relation to returns to scale under the DEA and New DEA models are shown in Table 7.8. The figures are expressed as the number and percentage of banks exhibiting different returns to scale within the same size classification. Looking at the full sample, the majority of Chinese banks are scale inefficient over the period from 1994 until 2007 (that is experiencing DRS and IRS). Specifically, 52.9% and 65.5% of all banks, for the DEA and New DEA models respectively, exhibit DRS. This result indicates that an investment in input factors for these banks will generally lead to a less than proportionate increase in outputs and so a further consolidation of large banks on scale economy grounds should be viewed with some skepticism. A relatively small proportion of banks operate under IRS, at 27.7% and 16.4% for the DEA and New DEA models respectively. Moreover, only 19.4% and 15.6% of all banks are scale efficient in the industry, based on the DEA and New DEA models respectively, suggesting that it is not easy to attain constant returns to scale in the Chinese banking industry.

Table 7.8 Returns to Scale of Chinese Banks on the Basis of DEA

Bank Size (RMB billion)	Traditional Cost Efficiency			New Cost Efficiency			Total banks
	DRS	CRS	IRS	DRS	CRS	IRS	
0-10	3(5.4%)	10(18.2%)	42(76.4%)	9(16.4%)	12(21.8%)	34(61.8%)	55
10-25	27(42.9%)	10(15.8%)	26(41.3%)	33(52.4%)	13(20.6%)	17(27%)	63
25-50	21(39.6%)	11(20.8%)	21(39.6%)	33(62.3%)	6(11.3%)	14(26.4%)	53
50-100	17(43.6%)	12(30.8%)	10(25.6%)	19(48.7%)	14(35.9%)	6(15.4%)	39
100-250	38(64.4%)	13(22%)	8(13.6%)	52(88.1%)	7(11.9%)	0 (0%)	59
250-500	29(78.4%)	8(21.6%)	0(0%)	32(86.4%)	5(13.5%)	0(0%)	37
500-1000	17(58.6%)	9(31%)	3(10.4%)	24(82.8%)	1(3.4%)	4(13.8%)	29
1000+	58(93.5%)	4(6.5%)	0(0%)	58(93.5%)	4(6.5%)	0(0%)	62
All	210(52.9%)	77(19.4%)	110(27.7%)	260(65.5%)	62(15.6%)	75(16.4%)	397

Notes: DRS = decreasing returns to scale, CRS = constant returns to scale, and IRS = increasing returns to scale; Percentage of banks operating under DRS, CRS or IRS in the parentheses.

The relationship between returns to scale and bank size is also of interest. In general, the four largest asset size groups are dominated by instances of decreasing returns to scale. A large proportion of banks in the three smallest asset size groups operate under IRS and the percentage of banks with IRS increases monotonically with the size of the banks. It is also worth noting that a significant number of banks (over 30%) are operating under CRS in the asset size RMB 50 - 100 billion group. This pattern is generally consistent with our previous SFA findings that as asset size increases, returns to scale of banks pass from increasing, to constant, and to decreasing.

7.5 Determinants of Cost Efficiency

In the previous sections, we presented and analysed the cost efficiency of the Chinese banking sector obtained from the preferred SFA, traditional DEA and New DEA models. In this section, we examine the effects of other factors on cost efficiency levels in order to provide some explanations for variations in efficiency scores and also to offer

insights for the improvement of bank management and regulatory policies. In accordance with the theoretical and empirical literature, we hypothesize that the determinants of bank efficiency stem from the nature of bank ownership, size, market discipline, deregulation and market structure and that these factors are at least partially exogenous. Moreover, we also investigate whether the impact of these environmental variables are the same for each of the SFA, DEA and New DEA models. If the three models provide the same information content, then the policy implications and other decisions which are based on this information will be more reliable and valuable.

Our preferred SFA model is the one-step estimation procedure, proposed by Battese and Coelli (1995), which assumes that cost (in)efficiency can be expressed as a function of a number of environmental (at least, partially exogenous) variables. Results for the SFA cost efficiency model are summarised in Table 7.9 and explicitly identify the relationships between the environmental variables and cost efficiency[52]. Table 7.9 also summarises results from applying a Tobit regression to the banks' DEA and New DEA efficiency scores (dependant variable) and the eight environmental variables previously referred to (independent variables). As mentioned earlier, due to the limited nature of the efficiency scores, which range in value between 0 and 1, it is necessary that we employ the Tobit regression model.

[52] Because the original results from the preferred SFA model provide the relationship between the environmental variables and an *inefficiency* score we must reverse all signs of the estimated parameters associated with the environmental variables to identify effects of these variables on bank *efficiency*.

Table 7.9 Determinants of Cost Efficiency

Determinants of efficiency		SFA	DEA	New DEA
Ownership indicators	State-owned banks	0.2516** (0.1065)	0.0458*** (0.0167)	0.0566*** (0.0215)
	Foreign banks	0.1061*** (0.2899)	0.1297*** (0.0289)	0.1748*** (0.0373)
Size indicator	Log (total assets)	0.3563*** (0.1031)	0.0149*** (0.0058)	0.0203*** (0.0075)
Market discipline indicator	Listed banks	0.0066 (0.0857)	-0.0095 (0.0188)	0.0267 (0.0242)
Deregulation indicator	WTO accession	-1.2117** (0.5284)	0.0246 (0.0188)	-0.0422* (0.0242)
Market structure indicators	HHI	1.5270 (1.2195)	0.3335 (0.325)	-0.3037 (0.419)
	Market share	7.2047*** (2.4588)	0.0725 (0.143)	0.1604 (0.1844)
	Intercept	-2.2074*** (0.5199)	0.6182*** (0.09)	0.6531*** (0.116)
	Log-likelihood	175.1729	298.625	197.716

Notes: 1. SFA changes the sign to interpret as efficiency
2. ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.
3. Asymptotic standard errors in parentheses

7.5.1 Effect of Ownership on Efficiency

First, it is important to investigate the observed variation in cost efficiency as determined by banks' ownership structure. The role of ownership in determining cost efficiency is provided by group dummies. Thus we divide Chinese banks into three categories, namely state-owned banks, domestic private banks and foreign banks. The domestic private banks are omitted in the regression to avoid problems with collinearity our regression equations. Thus, other ownership banks' efficiencies are measured relative to the domestic private banks' efficiency. We observe that the coefficients of the state-owned and foreign banks are statistically significant in both the SFA and DEA models. These results indicate that ownership is indeed a significant determinant of bank cost efficiency.

In our analysis, we find that the sign of the coefficient on state-owned banks is positive and statistically significant in all three regressions summarised in Table 7.9. This

result suggests that state-owned banks are more efficient than domestic private banks, the omitted category of bank. This is consistent with previous studies dealing with the Chinese banking sector (Berger *et al*., 2009), the Indian banking sector (Bhattachary *et al*, 1997; Shanmugam and Das, 2004) and the Turkish banking sector (Isik and Hassan, 2003). It might be that the commonly expressed idea that state-owned banks have less incentives to minimise costs and suffer more serious agency problems than private banks is debatable for the Chinese banking sector or that there are some additional factors involved. Chinese state-owned banks benefited more than any other category of bank from generous government subsidies and the banking reforms which were mainly focused on them. These factors might therefore be responsible for the apparent greater efficiency of the state owned Chinese banks over the private banks. Moreover, state-owned banks are often perceived as protected by implicit government guarantees, due not only to their size and systemic impact, but also because of their role as vehicles for political lending. Hence, state-owned banks have low default and bankruptcy risk and would be likely to attract funds by paying lower rates of interest on borrowing than private banks. This in turn can save the state owned banks considerable sums of money and improve their cost efficiency as a consequence. Another possible explanation is 'skimping' behaviour under which banks might economise loan underwriting and monitoring costs to achieve higher cost efficiency in the short run - behaviour which is likely to lead to poor loan revenues in the longer term (Berger and DeYong, 1997)[53]. Moreover, the loan approvals and extensions of state-owned banks are generally less prudential because of government intervention. This loose lending policy boosts loan production and other bank outputs per unit of input in the state-owned banks (Isik and Hassan, 2003). This may also be one of the reasons for the perceived higher cost efficiency of the state owned banks.

As expected, looking across the three regressions, the foreign bank variable displays a positive and statistically significant coefficient. It suggests that foreign banks exhibit higher cost efficiency than domestic private banks under both the SFA and DEA efficiency measures. This result may indicate that foreign banks in the Chinese market

[53] Further examination may confirm this explanation. State-owned banks, particularly the Big Four, have much higher rates of non-performing loans than other banks.

have succeeded in using their superior technology and managerial expertise and experience, and this in turn has offset potential cross-border disadvantages, e.g. lack of knowledge about the local market, barriers of culture and regulations, etc. Our findings are in line with other studies on emerging markets (Havrylchyk, 2006; Shanmugam and Das, 2004; Isik and Hassan, 2002).

One can also see from Table 7.9 that the coefficient associated with the ownership dummy for state-owned banks in the SFA model is generally much larger than the coefficient associated with the ownership dummy for foreign banks. This indicates that under the SFA model state-owned banks are more cost efficient than foreign banks. The reasons for this could be that foreign banks incurred large costs in attempting to provide a superior quality of service with the expectation of higher revenues and they also hired highly skilled workers which led to higher salary expenditures. But our efficiency measure does not take these factors into account, and thus foreign banks may be wrongly considered as being less cost efficient. In contrast, this relationship between the coefficients of the two ownership dummy variables reverses for the DEA and New DEA models. Thus, under the two DEA specifications foreign banks outperformance both types of domestic banks (state-owned and domestic private banks) in terms of cost efficiency. The results do support the *global advantage* hypothesis, proposed by Berger *et al*. (2000), which states that foreign banks may possess comparative advantages when compared to their domestically owned counterparts and as a result, they are able to operate more efficiently than domestically owned banks. However, there can be no firm conclusions about this matter given the SFA results reported earlier for the two ownership dummy variables.

7.5.2 Effect of Bank Size on Efficiency

From the prior banking literature, we expect bank size to be highly correlated with bank performance. We thus use the log of a bank's total assets as a proxy for its size. We then use this size proxy in our SFA, DEA and New DEA regression equations. Table 7.9 shows that the coefficient associated with the size variable is positive and significantly different from zero for all three regressions. These results indicate that

bank size is an important factor that drives the variation in efficiency scores across banks and the larger banks tend to be relatively more efficient than the smaller banks. Our finding is consistent with many previous efficiency studies in both developed and developing countries, e.g., Berger *et al*., 1993 b; Miller and Noulas, 1996; Hasan and Marton, 2003; Ali and Hang, 2006; Laurenceson and Qin, 2008.

There may be a number of reasons for the positive relationship between bank size and efficiency. First, larger banks may have experienced economies of scale and scope from growth and joint production and these lead to higher efficiency. Second, larger banks may have a more professional or specialised management team which has greater ability to control costs and increase revenues. Third, larger banks can be assumed to possess more flexibility in financial markets and be better able to diversify credit risk in an uncertain environment (Cole and Gunther, 1995). Fourth, large and small banks might concentrate on different markets, which could affect their performance (Isik and Hassan, 2002). Large banks are typically operating in the large metropolitan areas or nationwide and may face more competitive pressures than small banks which often operate within a relatively small area. This could be valid in the Chinese banking sector since small banks operating in China are typically city commercial banks which cannot extend their business beyond their own immediate area due to government restrictions. Hence, these geographical restrictions may make it difficult for small banks to control costs and be efficient. Finally, if bank size is positively related to market power, larger banks may pay less for their inputs than their smaller counterparts.

7.5.3 Effect of Market Discipline on Efficiency

As we discussed in our review of the literature, market discipline may impose strong incentives on banks to conduct their business in a safe and sound way. If this is so then market discipline will be an effective mechanism for improving bank efficiency by pressuring relatively inefficient banks to become more efficient. The listed bank dummy, as a proxy for market discipline, is incorporated into our regression analysis in order to capture the impact of market discipline on banks' cost efficiency scores. Moreover, this variable may also relate to banks' corporate governance. Once a bank

goes public, it becomes subject to legal, regulatory and disclosure requirements which usually lead to better corporate governance. In our study, the market discipline hypothesis implies that bank stockowners have a disciplinary effect on bank management. It might be expected that banks whose shares are publicly traded would exhibit higher cost efficiency, that is the listed bank variable will be positively related to the banks' cost efficiency measures.

From Table 7.9, we find that in all three regressions the coefficient associated with the listed bank dummy variable is positive but not statistically significant from zero at the usual levels of significance. This result indicates that intense public scrutiny exerts only weak market discipline over bank management and listed banks are not necessarily more efficient than those not listed on the stock exchange. Thus, our findings do not support the market discipline hypothesis and are in line with a study done for the Polish banking sector by Havrylchyk (2006). The reason for this could be that stock markets respond more strongly to profit measures than to cost efficiency measures (Chu and Lim, 1998). Moreover, even if some Chinese banks are publicly listed, the government still maintains more than 50% ownership. This in turn may undermine the effectiveness of market discipline (stockholders' monitoring).

7.5.4 Effect of Deregulation on Efficiency

The principal aim of deregulation is to improve resource allocation and the efficiency of the banking sector by creating a competitive environment (Berger and Humphrey, 1997). Begining in 1994 the Chinese government began a continuous programme of deregulation of the banking industry as well as introducing a number of major banking reforms. However, China's entry into the WTO at the end of 2001 was an important milestone in the banking deregulation process and marked the beginning of a new era. The main consequences of China's entry into the WTO are that the Chinese government now allows the entry of foreign-controlled banks into the local market (both corporate and retail) and promotes foreign strategic investments in domestic banks (up to a 25% ownership stake). In this study, we attempt to examine the impact of WTO accession on Chinese banking in terms of cost efficiency. It is hypothesised that after China was

admitted to the WTO in 2001 banking competitiveness improved, which in turn disciplined banks in their resource management and forced them to be more efficient. Thus, a dummy variable is included in our regression equations in order to capture the impact of the deregulation measures adopted in China after its admission to the WTO[54].

Table 7.9 shows that the coefficient associated with the deregulation dummy variable is negative in both the SFA and New DEA regressions and statistically significant at the 5% and 10% levels, respectively. However, although the reported coefficient of the deregulation dummy is positive in the DEA regression, it is not statistically significantly different from zero at conventional levels. On the whole these results indicate that China's entry into the WTO has not fulfilled its expectation in terms of cost efficiency gains. This result, however, is not unique to China. In some other countries, deregulation also appears to have lead to a deterioration or at least, no significant improvement in measures of efficiency; for example, Grifell-Tatjé and Lovell (1996) for Spain, Humprey and Pulley (1997) for the U.S. and Denizer et al. (2000) for Turkey. There are a number of factors which probably explain these results. First, the discouraging impact of deregulation may be due to a lag effect. Competition in the Chinese banking sector may not have significantly increased during the transition period (2002-2006) because some regulatory obstacles were still in place for foreign banks. For example, the CBRC imposed new rules that foreign banks must be locally incorporated as legal entities before they can conduct local currency business for Chinese citizens. Otherwise, foreign banks will not be allowed to issue bank cards and their "threshold" for RMB fixed deposits will be 1 million. As a consequence, domestic banks may have had less of a motivation to improve their performance immediately. In addition, after China's WTO entry, Chinese domestic banks expected that they would face increasing competition from their foreign rivals. Hence, domestic banks may have devoted considerable resources towards preparing for the environmental changes associated with WTO membership and this could have resulted in a fall in their cost efficiency. Although China's WTO accession did not show a positive impact on banking cost efficiency in the short run, there is evidence that it has

54 This dummy variable separates the sample into the pre-deregulation (1994-2001) and post-deregulation (2002-2007) periods.

improved Chinese banking efficiency in the longer term. In order to reduce possible negative impacts after WTO entry, the Chinese government also launched a variety of reform measures on its banking sector which mainly took effect after 2003. Our earlier analysis also shows that banking cost efficiency improved in the later years of the sample period - see Figures 7.1 and 7.3. These figures support our optimistic view of the impact of China's entry into the WTO in the long run.

7.5.5 Effect of Market Structure on Efficiency

Extensive theory and empirical research reveal that market structure conditions can affect bank performance and efficiency. Thus, this study also examines the relationship between cost efficiency and market structure by incorporating a market concentration measure (the Herfindahl-Hirschman index) and market share (in terms of the proportion of total assets) as determinants of efficiency in our regression equations. Higher concentration may be associated with higher costs (lower cost efficiency). Banks in a less competitive market (high levels of market concentration) could charge prices in excess of competitive levels and eventually earn supernormal profits. Under this relatively relaxed environment, bank mangers might not work as hard to control bank costs and this could result in lower cost efficiency (quiet life hypothesis). However, higher market concentration may also be associated with lower costs (higher cost efficiency). As suggested by the structure-conduct-performance (SCP) paradigm, banks in markets with higher concentration can benefit from market power, such as paying lower deposit rates and this directly or indirectly, could lead to higher cost efficiency. Our results show that the coefficient associated with the Herfindahl-Hirschman index (HHI) variable is positive in the SFA and the DEA regressions and negative in the New DEA regression. However, none of coefficients are statistically significantly different from zero at reasonable levels, indicating that market concentration is not a significant factor in determining cost efficiency for the Chinese banking sector. Therefore, our results seem to support neither of the above hypotheses – the quiet life hypothesis nor the SCP hypothesis (on the cost side).

Regarding the relationship between market share and cost efficiency, the coefficient

associated with the market share variable (proportion of total assets) is positive in all three models, but it is only statistically significant in the SFA regression[55]. The results, based on SFA efficiency measures, indicate that banks with a dominant share of banking assets could be associated with lower average total costs and thereby have higher cost efficiency. This evidence seems to support the relative-market power hypothesis under which banks with large market shares and well-differentiated products exert more market power and eventually achieve more profits or better performance (Shepherd, 1982). However, this result may suffer from an identification problem because the causality might run both ways. The bigger market share may be the result of either superior management and/or greater efficiency in the production process. Such a reverse causation occurs under the efficient-structure hypothesis of Demsetz (1973). However, we cannot find any significant relationship between market share and cost efficiency in the two DEA regressions, both of which indicate that market share is not particularly important in determining efficiency differences amongst banks.

Overall, our results show that the relationship between market structure and cost efficiency does not seem to be strong for the Chinese banking sector. The most likely explanation for this finding is that the prices banks charge for their services and other activities are mainly controlled by the state. Banks have only limited capacity to exercise market power by paying lower deposit rates and/or charging higher loan rates. Thus, they do not have much opportunity to enjoy the benefits which flow from a concentrated market structure (Fu and Heffernan, 2009).

7.6 Summary and Conclusion

This chapter investigates the cost efficiency levels of Chinese banks during the reform period from 1994 until 2007. The efficiency scores are obtained from the SFA, DEA and New DEA models. Our results show that when the SFA model is applied to our

[55] Market share as proxied by the proportion of total deposits and total loans has also been used in empirical work in the literature, e.g. Berger and Mester, 1997; Fu and Heffernan 2009. However, when we used this proxy in our regression equations we obtained results that are not materially different from those using the alternative market share proxy (proportion of total assets) on which the empirical analysis summarised in the text is based.

data, the mean cost efficiency scores range from 86.5% in 2004 up to 96% in 1994. We find that the average cost efficiency sharply declined after China's admission to the WTO. This result indicates that the external environmental changes due to WTO entry have significantly affected banks' cost efficiency levels. In contrast, the other banking reforms implemented between 1995 and 2004 appear to have enhanced the cost efficiency of Chinese banks. When categorising sample banks into the Big Four, state-owned policy banks, nationwide joint stock commercial banks, city commercial banks and foreign banks, the Big Four and policy banks show a relatively higher mean level of efficiency and amongst the rest of the subcategories, no one bank group gains a clearly dominant position over the sample period. Moreover, large banks, on average, seem to be relatively more cost efficient than small banks. This result indicates that large banks may enjoy some advantages when compared with the smaller banks.

Based on the results of the DEA and New DEA models, the overall cost efficiency of Chinese banks averaged 89% and 86.5% respectively over the period from 1994 until 2007. Although the DEA and New DEA efficiency measures are similar over the sample period, they seem to be some different temporal patterns in their respective cost efficiency estimates. Specifically, the evolution of DEA and new DEA cost efficiency scores for different bank types often display erratic trajectories. Generally, the Big Four, policy banks and foreign banks seems to be relatively more cost efficient than the JSCBs and CCBs. Moreover, the cost efficiency of the Big Four has significantly improved over the sample period. This result suggests that the Big Four could be benefiting from government subsidies and bank reforms which have focused mainly on these Big Four banks. Our findings based on the DEA models, also indicate that small and very small banks seem to be less efficient than the lager banks.

This chapter also explores whether economies of scale exist for the Chinese banking sector using both the SFA and DEA models. The results show that scale inefficiency is present in the Chinese banking sector. Generally, small banks face economies of scale and large banks, diseconomies of scale. The medium-sized banks seem to be most scale efficient.

Finally, this chapter investigates whether ownership structure, size, market discipline, deregulation and market structure significantly affect the cost efficiency levels of Chinese banks. In order to provide robust information, this analysis is conducted using SFA, DEA and New DEA cost efficiency measures. Our results show that both state-owned and foreign banks are more efficient than domestic private banks. Moreover, based on the results of two the DEA regressions, foreign banks exhibit more cost efficiency than their domestic counterparts (state-owned and domestic private banks). Thus our results show that differences in ownership structure significantly affect Chinese banks' performance in terms of cost efficiency. With respect to bank size, we find that larger banks tend to be relatively more efficient than smaller banks. This indicates that larger banks may have some advantages, such as economies of scale and scope and more specialised management teams, and these appear to have a favourable impact on their cost efficiency. Our results also show that a bank's listing on the stock exchange does not have a significant impact on its cost efficiency, implying that listed and non-listed banks might be equally efficient. We also conclude that market discipline may not be an important factor in determining the variation in efficiency scores across banks. Regarding deregulation, we find no evidence to support the view that deregulation (China's WTO entry) improved bank efficiency significantly. Based on the SFA and the New DEA regression results, the post-deregulation period (2002-2007) shows banks to be less efficient than in the pre-deregulation period (1994-2001); however, this relationship is not significant in the traditional DEA regression model. These results may have arisen because competition in the Chinese banking sector did not become more intense immediately after China's WTO entry and also, banks were forced to spend additional resources in order to deal with the environmental changes associated with WTO entry. Finally, our results reveal that the relationship between market structure (market concentration and market share) and cost efficiency seems not to be very strong, except for the case of the SFA regression in which market share is significantly positively related to cost efficiency. There is no evidence to support the quiet life hypothesis. Overall, the SFA, DEA and New DEA efficiency measures provide similar information about the determinants of Chinese bank cost efficiency. The results for the determinate of cost efficiency do not seem to be very sensitive to methodological choices for the application of the frontier efficiency techniques.

Chapter 8 Conclusion and Limitations

8.1 Introduction and Summary of Findings

The Chinese banking sector has experienced significant changes over the last thirty years. Under the reform process implemented by the Chinese government, liberalisation, deregulation and financial innovation have been major forces impacting on the performance of the Chinese banking sector. In such a context, regulators and bank management are now more concerned with analysing banking costs and the efficiency levels of the banking sector. Therefore, this study seeks to investigate the cost efficiency levels of the Chinese banking sector during the reform period from 1994 until 2007.

Since the late 1970's the Chinese government has implemented a series of banking reforms in order to build a safe and sound banking system. Prior to 1979, the Chinese banking sector was a Soviet-style mono-banking system, entirely dominated by the People's Bank of China (PBC). However, during the period from 1979 until 1992 the Chinese government implemented the first round of its banking reforms. The mono-banking system was broken up and a two-tier banking system consisting of a central bank (the PBC) and various kinds of other banking institutions was formally established. Moreover, starting in 1993 the government initiated a second round of banking reforms which aimed to reduce excessive government intervention in banks' operations and also, to maintain the financial stability of the banking sector. Before 1993, major Chinese (state-owned) banks were under the direct control of the government, and were granted very little in the way of decision-marking powers, especially in relation to credit and lending decisions. Because of excessive government intervention in banks' operations (in particular in relation to lending policies) state-owned banks accumulated enormous volumes of non-performing loans and bad debts. In order to mitigate this problem, the reforms implemented by the government employed measures designed to transform the policy-driven banking

system which had been in existence since the formation of the Peoples' Republic of China into a market-oriented banking system. The measures mainly included establishing policy banks to separate policy lending from commercial lending and commercialising the state-owned banks by giving them more autonomy in their decision making. However, after the Asian financial crisis of 1997, the Chinese government recognised the importance of confidence and stability in the operations of the Chinese financial sector. Thus, since this time the reforms implemented by the government have been mainly concerned with reducing the financial difficulties inherited by the state-owned banks through the provision of substantial injections of equity capital and the removal of nonperforming loans from the affected banks' balance sheets.

After being admitted to the World Trade Organisation (WTO) in December 2001, China launched a third round of banking reforms designed to modernise its banking sector and to fulfil its WTO commitments. The major reforms during this phase of the reforms process include the establishment of a new regulatory organisation, the rehabilitation of the state-owned commercial banks, the elimination of restrictions on the entry and operations of foreign banks, the introduction of foreign strategic investors and the public listing of bank securities on the stock exchange. Currently, the Chinese banking system consists of a variety of institutions such as state-owned commercial banks, policy banks, joint-stock commercial banks, rural credit cooperatives, etc. However, the state-owned commercial banks dominate the Chinese banking system. For example, in 2007 the big four state-owned commercial banks held over 50% of total banking assets.

Bearing the aforementioned developments in mind, a primary aim of this study is to provide an empirical analysis of the cost efficiency of the Chinese banking system over the period from 1994 until 2007. To this end and following the empirical literature on banking efficiency, we employ both stochastic frontier analysis (SFA) and data envelopment analysis (DEA) techniques to estimate the cost efficiency of Chinese banks. Moreover, we also investigate the main determinants of Chinese banking efficiency under both the SFA and DEA frameworks. For the present study the sample is an unbalanced panel which covers 41 Chinese banks and totals 397 observations.

The main inferences that can be drawn from the results of our empirical study can be summarised as follows. In order to reach the best-specified stochastic cost frontier model for measuring Chinese banking efficiency, we compare five different stochastic frontier model specifications. We conducted a step-wise specification testing procedure. The results show that the specification which incorporates both control and environmental variables (thereby accounting for heterogeneity across banks) provides a better fit to the data of Chinese banks than any of the other alternative specifications. We also discuss the effect of accounting for bank heterogeneity on key parameter estimates, on efficiency levels and on efficiency ranks. Our empirical results show that accounting for heterogeneity across banks is crucial. If heterogeneity is not taken into account, the estimates obtained for banking cost efficiency may be biased. The preferred model specification for our sample is the one stage SFA model that includes the traditional input prices, the outputs and the control variables (that is, the level of equity, the amount of non-performing loans and the time trend) in the cost frontier and the environmental variables (that is, the ownership structure, size, deregulation, market structure and market discipline) in the inefficiency term.

This study also employs two cost DEA models (traditional DEA and New DEA) as a complement to the preferred cost SFA model for methodological cross-checking purposes. As far as we are aware this is the only empirical study that compares different efficiency frontier techniques using a common set of Chinese banking data. We check five consistency conditions through which to assess the compatibility of the SFA, the DEA and the New DEA models. The results show that there is only moderate consistency between the results of these three dominant models. This is perhaps because the DEA models do not disentangle the statistical noise term from the inefficiency term. This in turn means that the DEA models may underestimate the cost efficiency scores. Against this, the SFA method is implemented using a specific functional form to estimate the efficiency frontier, and it is entirely possible that the functional form which is used may be mis-specified. More specifically, the first consistency condition check shows that some differences emerge in the distributional characteristics of the estimated efficiency measures based on the three different frontier models. The rank correlations of cost efficiency are around 0.45 between the SFA and DEA models; similar for the DEA and New DEA models. But the correlations

between the SFA and New DEA models tend to be lower (only 0.28). This evidence suggests that these three models may rank the sample banks in different orders thereby leading to different assessments of relative banking efficiency (consistency condition 2). With respect to consistency condition 3, the results suggest that the SFA, DEA and New DEA models tend to have moderate consistency in identifying the best and the worst quartile banks. Moreover, under consistency condition 4 the efficiency scores obtained from all models exhibit relatively stability over short periods of time but show considerable instability over longer periods (more than five years). This result indicates that the Chinese banking sector may be subject to important technological and regulatory changes over relatively long periods. In the context of the relation between the frontier efficiency measures and conventional performance measures, the parametric efficiency (that is, SFA) measures are significantly correlated with conventional performance measures. Against this, the non-parametric efficiency (that is, DEA) measures are only significantly correlated with the conventional cost-related performance measures but not with the conventional profit-related performance indicators (consistency condition 5).

This study finds that Chinese banks, on average, exhibit a somewhat modest degree of cost inefficiency. In the case of the SFA model, the average cost efficiency of Chinese banks over the period from 1994 until 2007 is around 91% (that is, an inefficiency level of 9%). Based on the results of the DEA and New DEA models, the average cost efficiency for Chinese banks over the sample period is about 89% and 87%, respectively. We also find that Chinese banking efficiency has deteriorated after China's admission to the WTO (at the end of 2001). This result suggests that the significant external environmental changes which arose from China's admission to the WTO may have had a negative impact on Chinese banking efficiency. However, we note that the negative impact arising from WTO entry seems to disappear in the later stages of our sample period (2004-2007); that is, the average of the cost efficiency scores shows an increasing trend during this later stage of our sample period. This efficiency improvement could be due to the banking reforms implemented by the Chinese government in response to China's WTO entry (e.g. capital injection, non-performing loan write-offs, introduction of foreign strategic investors, etc.). However, the SFA, DEA and New DEA efficiency estimates do not always show similar temporal patterns

over the sample period. For example, the average of cost efficiency scores obtained under the SFA and DEA models show an increasing trend over the period from 1995 until 1998. Against this, under the New DEA model, average cost efficiency shows a decreasing trend over the same period.

When our sample banks are categorised by bank type (that is, big four state-owned banks, state-owned policy banks, joint stock commercial banks and city commercial banks) and size class (that is, very big, big, medium, small and very small) we find that the Big Four and the policy banks have tended to exhibit greater efficiency than other bank types. This result may suggest that the Big Four and policy banks have benefited more significantly from the reform process than other banks - something which might be expected given that government policy had a particular focus on these two categories of banks. Similarly, the results show that banks from the very big and big bank categories, in general, are more efficient than banks from the other size categories. This suggests that big banks have advantages over small banks, such as an extensive network of branches, more specialised management teams, more advanced technology, etc. – all of which have the potential to enhance their relative efficiency.

Based on the SFA model's results, we find that economies of scale are prevalent across the Chinese banking sector. This finding is mainly a result of widespread scale economies arising in small banks (banks with assets size between 0 to 250 billion RMB). This suggests that small-sized Chinese banks can obtain cost savings by increasing the scale of their operations. In contrast, medium-sized and large-size banks (banks with assets size over 250 billion RMB) exhibit constant or diseconomies of scale. Overall, the results obtained from the DEA models show that the majority of Chinese banks exhibit diseconomies of scale. In contrast, the results obtained from the SFA model shows that in general, Chinese banks tend to exhibit increasing returns to scale. However, the results for different size categories of banks are similar to those found for the SFA model. The smallest banks exhibit economies of scale and the largest banks exhibit diseconomies of scale. Overall, both the SFA and DEA models generally show that scale inefficiency is present in the Chinese banking sector (that is, most banks exhibit either decreasing or increasing returns to scale). In particular, as asset size

increases, Chinese banks tend to pass from increasing, to constant, and then to decreasing returns to scale.

The empirical analysis carried out in this thesis also investigates the main determinants of Chinese banking efficiency because this could provide important insights for the potential improvement of bank management and regulatory policies. In particular, we examine the impact of environmental factors (that is, ownership structure, size, deregulation, market structure and market discipline) on the cost efficiency levels of banks. Our results show that both state-owned banks and foreign banks are more efficient than domestic private banks for all three regression models (based on the efficiency scores obtained from the SFA, DEA and New DEA models). In addition, the results of our DEA regressions confirm the global advantage hypothesis which states that foreign banks may possess comparative advantages over their domestically owned counterparts and as a result, they are able to operate more efficiently than domestic banks. Another important result is that larger banks tend to be relatively more efficient than smaller banks for all three regressions. Moreover, we find no evidence to support the view that deregulation (China's WTO accession) has had a positive impact on Chinese banking efficiency. In particular, the post-WTO accession period (2002-2007) shows banks to be less efficient than in the pre-WTO accession period (1994-2001) for both the SFA and the New DEA models. Furthermore, except for the case of the SFA regressions in which market share is significantly positively related to cost efficiency, the market structure factors do not have a significant impact on Chinese banking efficiency. Similarly, our results do not support the hypothesis that listing on the stock market exerts much in the way of market discipline over Chinese banks or indeed, that it improves banking efficiency. Overall, however, the SFA, DEA and New DEA cost efficiency estimates provide robust information regarding the main determinants of Chinese banking efficiency.

8.2 Policy Implications

The empirical findings from this study shed light on the potential direction of future banking reforms in China and also, on the issue of how banks might go about increasing

the efficiency of their operations. The policy implications from this study are summarised as follows.

First, our empirical findings indicate that small-sized banks (asset size less than 50 billion RMB) exhibit economies of scale. Thus, from a scale efficiency perspective, small-sized banks, which our empirical analysis indicates are generally operating under increasing returns to scale, could improve their scale efficiency by growing in size. Moreover, our analysis also demonstrates that larger banks are more cost efficient than smaller banks. This finding suggests that in general, Chinese banks could improve their cost efficiency by increasing their size; perhaps by using mergers and acquisitions. In addition, the government should consider removing regulations that confine city commercial banks to operating within their own city boundaries. This geographical constraint is likely to be damaging to city commercial banks' efficiency because it prevents them from effectively spreading risk and achieving economies of scale.

Secondly, private ownership by itself may not be sufficient to insure that Chinese banks operate efficiently due to the fact that our empirical procedures find statistically significant evidence that state-owned banks are more cost efficient than domestic private-owned banks. Moreover, we find that foreign banks are significantly more efficient than (private) domestic banks and so the competitive pressures induced by the relaxation of foreign bank entry into the Chinese banking sector ought to make an important contribution towards improving overall banking efficiency. It is also the case that foreign banks may have advantages over domestic banks such as superior risk management skills, advanced technology, international operating experience, etc. Competitive pressures mean that these advantages ought to be transferred to their domestic counterparts and thereby result in an improvement in overall Chinese banking efficiency. Thus, the opening up of the Chinese banking sector to the entry of foreign banks is important in the ongoing process of efficiency improvement and innovation in the banking system.

Thirdly, the findings from this study suggest that the deregulation programme consequent upon China's admission to the WTO did not provide the anticipated banking

efficiency gains. The Chinese banking sector shows only marginally lower cost efficiency in the post-WTO accession period (that is, after 2001). However, industry conditions prior to deregulation are crucial for the success of the deregulation measures implemented by the government. Chinese banks faced a number of challenges, such as large amounts of non-performing loans, insufficient capital, extensive government intervention and poor corporate governance standards before China's entry into the WTO. Thus, deregulation without accompanying reforms which address these underlying problems of the Chinese banking sector, will be insufficient to boost productivity and efficiency in the Chinese banking system. In particular, the Chinese government should continually introduce reform measures to reduce political intervention and improve risk management, transparency and corporate governance in Chinese banks.

Finally, we do not find a significant relationship between a bank's stock exchange listing status and the level of its operating efficiency. Hence, there is no evidence that merely listing on the stock market enhances bank governance procedures or their operating efficiency Moreover, Chinese banking regulators should continue to liberalise interest rates in order to enhance the role of market forces in resource allocation and so that credit can be allocated more efficiently. Furthermore, stock market reform may also be necessary so that banking fundamentals are more adequately reflected in stock market valuations. One might then expect that the Chinese stock market will then exert more effective discipline over bank management and this in turn will improve overall banking efficiency.

8.3 Limitations of the Study and Future Research

Our study has some limitations and these suggest potential directions for future work. The first shortcoming of the present study is that we only investigate the cost efficiency of Chinese banks. Cost efficiency gives a measure of how close a bank's costs are to those of the best banking practice after controlling for comparative output levels. As indicated by Berger and Mester (1997), a bank that is relatively cost efficient at its current output levels may not be cost efficient at optimal output levels, since this

typically involves a different scale and mix of outputs. However, profit efficiency which is based on the economic goal of profit maximisation, could capture inefficiencies on the output side as well as those on the input side. Thus, further research into investigating the profit efficiency of Chinese banks would be a valuable addition to the literature.

Although this study employs both the stochastic frontier analysis (SFA) and data envelopment analysis (DEA) methodologies in the field of efficiency analysis, not all the different efficiency frontier techniques which are available are used in this study. For example, we do not apply the distribution free approach, the thick frontier approach or the free disposal hull approach to our sample data. Thus, an interesting direction for further research would be to employ all these frontier techniques to estimate the relative efficiency of Chinese banks. This would also enhance the methodological cross-checking procedures which have been so valuable to researchers and policy makers for assessing the robustness of empirically estimated efficiency levels in this area of the literature.

In addition, this study is also subject to limitations related to the number of observations included in the data sample, because of the relatively small number and short history of Chinese banks. Some advanced models, such as the Fourier-flexible functional form, are not appropriate for estimating the efficiency levels of Chinese banks because of the limited size of our sample. Fortunately, a more exhaustive data set for Chinese banks is gradually becoming available. Therefore, future research can use this emerging and larger sample to provide a more comprehensive study of Chinese banking efficiency. As was discussed in Chapter 4, the Chinese deregulation programme is a continuous process and some of the reforms have only been gradually implemented since 2004. Thus, the Chinese banking sector may not have had sufficient time to effectively implement the cost savings and revenue enhancing possibilities permitted by these reforms at the time we undertook our empirical analysis of banking efficiency. Evidence of this is provided by the fact that Chinese banking efficiency levels display a significant increase in the latter years of our study period. Thus, future research that extends the study period beyond 2007 will also provide a better understanding of the impact of the deregulation policies that have recently been implemented by the Chinese

government.

Finally, this study models heterogeneity in the stochastic frontier model framework by incorporating bank specific heterogeneity variables either in the cost function itself or as explanatory variables in a simultaneous regression model where cost inefficiency is the dependant variable. It is entirely possible, however, that the heterogeneity variables employed in our regression procedures are not complete and that our empirical analysis is therefore afflicted by an omitted variables problem. This, in turn, may create potential biases in the estimates of our inefficiency scores. A potential way to address this problem is to use "true effects model" proposed by Greene (2005). Greene's model integrates an additional stochastic term in the traditional SFA model in order to distinguish all time invariant unobserved heterogeneities from the inefficiency term.

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Appendix 1

Log-likelihood Ratio test

The likelihood ratio (LR) test is a very powerful and widely used method for choosing models or verifying/validating assumptions. The LR test examines whether a reduced model (with restrictions on the number of parameters) provides as good a fit to the data as a completely specified model (without any restrictions on the parameters). If the reduced model is valid, then it should not lead to a large reduction in the value of the likelihood function (Green, 2008). Thus, the LR test is based on the ratio of the maximum value of the likelihood function under the restricted model to the corresponding maximum value of the likelihood function under the unrestricted model. The likelihood ratio is defied by $\lambda = L_R / L_U$, where L_R is the maximum of the likelihood function when the restrictions are imposed; L_U is the maximum of the likelihood function when the restrictions are not imposed. Because a restricted specification is never superior to an unrestricted specification the log-likelihood ratio will always be non-negative; that is, the likelihood ratio, λ, always lies between 0 and 1. The likelihood ratio test is normally based on minus two times log-likelihood ratio and is give by:

$$\text{LR} = -2 \ln \lambda = -2(\ln L_R - \ln L_U)$$

If the sample size is sufficiently large, the log-likelihood test statistic is asymptotically distributed as a Chi-square (χ^2) variate with the degrees of freedom equal to the number of restrictions imposed by the null hypothesis. Thus, we can find out whether the difference between the restricted and unrestricted log-likelihood functions is statistically significant at any given level of significance. If the log-likelihood test statistic exceeds the appropriate critical value from the Chi-Square (χ^2) tables, then the null hypothesis is rejected; that is, the imposed restrictions are invalid. The null hypothesis is accepted if

the log-likelihood test statistic is less than the Chi-square critical value, meaning that the imposed restrictions are valid.

Appendix 2

Appendix 2a: SFA Cost Efficiency Scores for Chinese Banks 1994-2007 -Individual Bank Estimates

Bank name	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Bank Average
Industrial & Commercial Bank of China	0.9728	0.9568	0.9729	0.9663	0.9711	0.9712	0.9741	0.9696	0.9524	0.9456	0.9471	0.9259	0.9473	0.9577	0.9593
China Construction Bank Corporation	0.9501	0.9436	0.9429	0.9645	0.9665	0.9704	0.9515	0.9611	0.9217	0.9441	0.9373	0.9505	0.9547	0.9547	0.9510
Agricultural Bank of China	0.9575	0.9538	0.9291	0.9584	0.9653	0.9637	0.9680	0.9557	0.9366	0.9322	0.9535	0.9662	0.9616	0.9402	0.9530
Bank of China	0.9679	0.9602	0.9700	0.9741	0.9747	0.9738	0.9710	0.9696	0.9537	0.9388	0.8776	0.9494	0.9159	0.9562	0.9538
China Development Bank		0.9606	0.9698	0.9643	0.9519	0.9663	0.9362	0.9631	0.9543	0.9593	0.9587	0.9624	0.9663	0.9689	0.9602
Agricultural Development Bank of China		0.9556	0.9673	0.9630	0.9611	0.9620	0.9467	0.9669	0.9398	0.9537	0.9577	0.9607	0.9358	0.9338	0.9542
Export-Import Bank of China		0.9516	0.9366	0.9484	0.9553	0.9618	0.9305	0.9532	0.9440	0.9499	0.9348	0.9398	0.9446	0.9113	0.9432
Bank of Communications	0.9562	0.9497	0.9625	0.9660	0.9745	0.9767	0.9738	0.9692	0.9525	0.8438	0.8938	0.8813	0.9205	0.9500	0.9407
China Merchants Bank		0.9540	0.9651	0.9626	0.9618	0.9491	0.9323	0.9808	0.9062	0.9461	0.9479	0.7811	0.9419	0.9498	0.9368
China Minsheng Banking Corporation			0.8611	0.9045	0.8388	0.8949	0.9418	0.9495	0.9340	0.9418	0.9456	0.9219	0.9313	0.9591	0.9187
China CITIC Bank	0.9663	0.9735	0.9492	0.9427	0.9639	0.9624	0.9680	0.9622	0.9394	0.9380	0.9415	0.9434	0.9519	0.9586	0.9544
Shanghai Pudong Development Bank	0.9528	0.9344	0.9671	0.9584	0.9713	0.9479	0.9423	0.9512	0.9171	0.9253	0.9206	0.8548	0.9266	0.9384	0.9363
Industrial Bank	0.9578	0.8579	0.9098	0.8923	0.9240	0.9059	0.9309	0.9436	0.9169	0.9319	0.9480	0.9493	0.9457	0.9629	0.9269
Hua Xia Bank		0.9616	0.9502	0.9301	0.9327	0.9487	0.9328	0.9355	0.9050	0.9243	0.6392	0.9405	0.9328	0.9499	0.9141
Guangdong Development Bank	0.9582	0.9518	0.9541	0.9463	0.9523	0.9588	0.9551	0.9618	0.9430	0.9550	0.9412	0.9484	0.9481	0.9620	0.9526
China Everbright Bank	0.9660	0.9262	0.9579	0.9649	0.9628	0.9434	0.9541	0.9640	0.9439	0.9478	0.9423	0.9618	0.9567	0.9659	0.9541
Evergrowing Bank		0.9511	0.9277	0.9698	0.9257	0.8770	0.9281	0.9296	0.8135	0.8795	0.8081	0.8650	0.9119	0.8921	0.8984
Shenzhen Development Bank	0.9558	0.8839	0.9337	0.8881	0.9064	0.9006	0.9289	0.9567	0.9078	0.9686	0.8627	0.8836	0.9353	0.9657	0.9198
China Zheshang Bank											0.8373	0.8729	0.8842	0.9122	0.8766

Appendix 2a SFA Cost Efficiency Scores for Chinese Banks 1994-2007 -Individual Bank Estimates (continued)

Bank name	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Bank Average
Bank of Beijing						0.9350	0.9541	0.9739	0.9412	0.9155	0.9081	0.9006	0.9306	0.9668	0.9362
Tianjin City Commercial Bank						0.9252	0.9377	0.9441	0.8905	0.8731	0.8820	0.8626	0.5150	0.8729	0.8559
Bank of Shanghai		0.9385	0.9598	0.9491	0.9590	0.9613	0.9558	0.9448	0.8780	0.9290	0.8929	0.8974	0.9089	0.9363	0.9316
Bank of Jiangshu												0.6750	0.5794	0.8797	0.7114
Bank of Nanjing				0.9398	0.9450	0.9365	0.9609	0.9395	0.9297	0.9340	0.9361	0.8914	0.9297	0.8897	0.9302
Bank of Ningbo							0.9272	0.9257	0.8241	0.8255	0.8546	0.8561	0.8724	0.8163	0.8627
Bank of Dalian								0.8519	0.8294	0.8327	0.8283	0.8298	0.9044	0.9036	0.8543
Jinan City Commercial Bank								0.9250	0.8419	0.8941	0.8902	0.8536	0.7989	0.7902	0.8563
Hangzhou City Commercial Bank								0.9443	0.8935	0.9363	0.9056	0.9340	0.9379	0.9336	0.9264
Huishang Bank													0.8515	0.8955	0.8735
Dongguan City Commercial Bank						0.8803	0.9375	0.8647	0.6942	0.6814	0.6699	0.7037	0.8832	0.9335	0.8054
Xi'an City Commercial Bank							0.9003	0.9144	0.7886	0.8611	0.8018	0.9094	0.9271	0.9082	0.8764
Nanchong-city Bank									0.3625	0.4697	0.6095	0.6158	0.6834	0.8944	0.6059
Fuzhou City Commercial Bank										0.8233	0.7979	0.7975	0.9012	0.9214	0.8483
Xiameng International Bank						0.9150	0.9187	0.9461	0.7751	0.7572	0.7890	0.8848	0.9116	0.9264	0.8693
Wenzhou Bank							0.8997	0.8983	0.7342	0.7413	0.7623	0.7426	0.7154	0.8676	0.7952
First Sino Bank						0.8333	0.9322	0.9563	0.8878	0.8812	0.8846	0.8719	0.8318	0.9317	0.8901
Qingdao International bank						0.9507	0.9617	0.9517	0.8268	0.5359	0.7099	0.8984	0.8990		0.8418
BNP PARIBAS (China)									0.9394	0.9588	0.8324	0.9269	0.9327	0.9533	0.9239
Bank of East Asia (China)												0.9751	0.9082	0.7620	0.8818
HSBC(China)														0.9387	0.9387
Standard Chartered Bank (China)														0.8880	0.8880
Year Average	0.9601	0.9425	0.9467	0.9477	0.9482	0.9374	0.9432	0.9445	0.8741	0.8765	0.8653	0.8812	0.8881	0.9200	

Appendix 2b Traditional DEA Cost Efficiency Scores for Chinese Banks 1994-2007 -Individual Bank Estimates

Bank name	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Bank Average
Industrial & Commercial Bank of China	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
China Construction Bank Corporation	0.8580	0.7660	0.7981	0.8808	0.7985	0.7946	0.7954	0.8981	0.8973	1.0000	1.0000	1.0000	1.0000	1.0000	0.8919
Agricultural Bank of China	0.8594	0.8433	0.6536	0.8551	0.8632	0.9789	1.0000	0.7612	0.8398	0.8332	1.0000	1.0000	1.0000	1.0000	0.8920
Bank of China	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
China Development Bank		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Agricultural Development Bank of China		1.0000	1.0000	1.0000	0.8705	0.7647	1.0000	0.9431	0.8949	0.7889	0.8290	0.8568	0.9229	1.0000	0.9131
Export-Import Bank of China		1.0000	0.9141	0.9675	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9909
Bank of Communications	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8275	1.0000	0.7856	0.9168	0.8508	0.9558
China Merchants Bank		0.8219	0.7867	0.8435	0.6961	0.7989	0.8473	0.9248	0.9381	1.0000	1.0000	0.6997	1.0000	1.0000	0.8736
China Minsheng Banking Corporation			1.0000	1.0000	0.8522	0.8180	1.0000	1.0000	1.0000	1.0000	1.0000	0.8311	0.8413	0.7719	0.9262
China CITIC Bank	1.0000	1.0000	0.6888	1.0000	0.8539	0.9009	0.9603	0.9044	0.7396	0.7158	0.9224	0.7822	0.8007	0.8056	0.8625
Shanghai Pudong Development Bank	0.8729	0.6757	1.0000	1.0000	1.0000	0.8878	0.9063	0.7986	0.8891	0.9312	0.8943	0.9328	0.8248	0.7544	0.8834
Industrial Bank	0.8434	0.6862	1.0000	0.7956	0.8502	0.6097	0.8551	0.8376	0.9082	0.9590	1.0000	1.0000	1.0000	1.0000	0.8818
Hua Xia Bank		1.0000	0.8139	0.8112	0.6284	0.8007	0.7918	0.8802	0.8572	0.8360	0.8181	0.8134	1.0000	1.0000	0.8501
Guangdong Development Bank	0.7741	0.7884	0.7641	0.6655	0.6481	0.7932	0.7338	0.7840	0.8269	0.9993	1.0000	0.8527	1.0000	0.9251	0.8254
China Everbright Bank	0.9982	0.9342	0.9905	0.8798	0.7629	0.8336	0.8878	0.9390	0.8367	0.9704	0.9713	1.0000	0.9694	0.9481	0.9230
Evergrowing Bank		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9655	0.7894	0.7339	0.7568	0.7694	0.7941	0.9084
Shenzhen Development Bank	0.9601	0.8367	0.7508	0.6964	0.6382	0.6535	0.7598	0.8116	0.7832	0.9364	0.7314	0.7299	0.7585	0.9065	0.7824
China Zheshang Bank											0.9203	1.0000	1.0000	0.9679	0.9721

Appendix 2b Traditional DEA Cost Efficiency Scores for Chinese Banks 1994-2007 -Individual Bank Estimates (continued)

Bank name	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Bank Average
Bank of Beijing						1.0000	1.0000	1.0000	1.0000	0.8527	0.9509	0.9843	0.9416	1.0000	0.9699
Tianjin City Commercial Bank						0.7922	0.8026	0.8640	0.8216	1.0000	0.9445	0.9165	0.9252	1.0000	0.8963
Bank of Shanghai		1.0000	1.0000	0.8792	1.0000	1.0000	1.0000	0.8733	1.0000	1.0000	1.0000	1.0000	1.0000	0.7773	0.9638
Bank of Jiangshu												0.7184	0.7908	0.7165	0.7419
Bank of Nanjing				0.8558	1.0000	0.8112	0.8994	0.9956	1.0000	1.0000	1.0000	1.0000	1.0000	0.7459	0.9371
Bank of Ningbo							0.6462	0.6339	0.7234	0.8075	0.7730	0.9086	0.8393	0.8852	0.7771
Bank of Dalian								0.5370	0.5929	0.7085	0.6693	0.6856	0.8341	0.6478	0.6679
Jinan City Commercial Bank								0.7011	0.7511	0.8442	0.8696	0.8563	0.8323	0.7761	0.8044
Hangzhou City Commercial Bank								0.9868	1.0000	1.0000	0.9223	0.9572	0.9142	0.7361	0.9310
Huishang Bank													0.6257	0.6146	0.6202
Dongguan City Commercial Bank						0.6224	0.7069	0.5600	0.5612	0.6345	0.5929	0.6894	0.8598	0.7175	0.6605
Xi'an City Commercial Bank							0.6035	0.6331	0.7353	0.8243	0.7388	0.8101	0.8339	0.8187	0.7497
Nanchong-city Bank									0.5464	0.8911	0.8927	1.0000	1.0000	0.7399	0.8450
Fuzhou City Commercial Bank										0.7731	0.7804	0.8359	0.9387	0.8176	0.8291
Xiameng International Bank						0.7322	0.8318	0.8203	0.6363	0.8168	0.8419	0.8409	0.9747	0.8738	0.8187
Wenzhou Bank							0.6079	0.5928	0.5524	0.6593	0.7018	0.7934	0.7520	0.6516	0.6639
First Sino Bank						1.0000	1.0000	1.0000	1.0000	0.8801	0.7751	0.7649	0.6545	1.0000	0.8972
Qingdao International bank						0.9302	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		0.9913
BNP PARIBAS (China)									1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Bank of East Asia (China)												0.8089	0.8281	0.7092	0.7821
HSBC(China)														0.9492	0.9492
Standard Chartered Bank (China)														0.6257	0.6257
Year Average	0.9242	0.9085	0.9032	0.9065	0.8731	0.8663	0.8840	0.8650	0.8617	0.8937	0.8965	0.8845	0.9064	0.8632	

Appendix 2c New DEA Cost Efficiency Scores for Chinese Banks 1994-2007 -Individual Bank Estimates

Bank name	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	**Bank Average**
Industrial & Commercial Bank of China	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
China Construction Bank Corporation	1.0000	0.8067	1.0000	1.0000	0.9355	0.9433	1.0000	1.0000	0.9548	1.0000	0.9067	0.9750	0.9693	0.9365	0.9591
Agricultural Bank of China	0.5042	0.6533	0.7993	0.9361	0.9490	1.0000	1.0000	0.9979	1.0000	0.9852	1.0000	1.0000	1.0000	1.0000	0.9161
Bank of China	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8872	0.9919
China Development Bank		1.0000	1.0000	1.0000	1.0000	0.9726	0.9641	0.9923	0.9968	1.0000	1.0000	1.0000	1.0000	1.0000	0.9943
Agricultural Development Bank of China		0.3873	0.4582	1.0000	0.5829	0.8210	1.0000	1.0000	1.0000	0.8744	0.8384	0.9601	0.6080	0.7048	0.7873
Export-Import Bank of China		1.0000	0.8467	0.9081	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9811
Bank of Communications	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9027	0.9421	0.9140	0.9828
China Merchants Bank		1.0000	1.0000	1.0000	1.0000	1.0000	0.9809	0.7035	1.0000	1.0000	0.9734	0.9866	1.0000	1.0000	0.9726
China Minsheng Banking Corporation			1.0000	1.0000	1.0000	1.0000	1.0000	0.9258	1.0000	0.8663	0.6913	0.9118	0.8725	0.8004	0.9223
China CITIC Bank	1.0000	0.8089	0.6108	1.0000	1.0000	1.0000	1.0000	1.0000	0.9166	0.9538	0.7639	0.8699	0.8247	0.9314	0.9057
Shanghai Pudong Development Bank	0.9226	0.7924	0.8261	0.9014	1.0000	1.0000	1.0000	0.8259	1.0000	0.9727	0.7757	0.9315	0.9253	0.9446	0.9156
Industrial Bank	0.6552	0.5887	0.8399	0.5872	0.6072	0.8632	1.0000	1.0000	0.9263	0.8830	0.6624	0.8765	0.8557	0.7106	0.7897
Hua Xia Bank		1.0000	1.0000	0.9416	0.7560	0.5910	0.8750	0.8889	0.7557	0.9335	1.0000	0.8484	0.8995	0.8132	0.8695
Guangdong Development Bank	0.5814	0.6173	0.6841	0.6096	0.7032	0.7573	0.6944	0.7606	0.7682	0.7218	0.8527	0.7674	0.8071	0.6429	0.7120
China Everbright Bank	0.9049	0.6657	0.7848	1.0000	0.9832	1.0000	0.9287	0.9710	0.8947	0.8431	0.7448	0.9282	0.8063	0.9057	0.8829
Evergrowing Bank		1.0000	0.8574	0.5944	0.6213	1.0000	1.0000	0.7821	0.7763	0.7552	0.4242	0.5382	0.8246	0.6995	0.7595
Shenzhen Development Bank	0.6864	0.7817	0.8551	0.8601	1.0000	0.9423	0.9605	0.8934	0.8881	0.5934	0.5154	0.8144	0.7757	0.6838	0.8036
China Zheshang Bank											1.0000	0.8357	0.6840	0.5714	0.7728

Appendix 2c New DEA Cost Efficiency Scores for Chinese Banks 1994-2007 - Individual Bank Estimates (continued)

Bank name	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	**Bank Average**
Bank of Beijing						0.7908	1.0000	1.0000	0.7362	0.6716	0.5922	1.0000	1.0000	1.0000	0.8656
Tianjin City Commercial Bank						0.8877	1.0000	0.7433	0.6641	0.7439	0.3348	0.5301	0.9928	0.7226	0.7355
Bank of Shanghai		0.8852	0.7898	0.4704	0.7152	0.8983	0.9397	1.0000	1.0000	0.9814	1.0000	1.0000	0.9759	0.9048	0.8893
Bank of Jiangshu												0.8514	0.9062	0.8340	0.8639
Bank of Nanjing				1.0000	1.0000	0.9877	1.0000	1.0000	1.0000	1.0000	0.8792	1.0000	1.0000	0.7335	0.9637
Bank of Ningbo							0.7039	0.6697	0.7679	0.6563	0.6592	0.8726	0.8548	1.0000	0.7730
Bank of Dalian								0.4649	0.3926	0.4169	0.3508	0.4393	0.4951	0.9231	0.4975
Jinan City Commercial Bank								0.7640	0.7672	0.5622	0.7333	0.8907	0.8509	0.8067	0.7679
Hangzhou City Commercial Bank								1.0000	0.8518	0.8422	0.6369	0.8250	0.7864	0.7690	0.8159
Huishang Bank													0.9432	0.8352	0.8892
Dongguan City Commercial Bank						0.8395	0.8214	0.8146	0.8894	0.9564	0.7381	0.9299	1.0000	0.8379	0.8697
Xi'an City Commercial Bank							0.5030	0.4492	0.5050	0.4980	0.3989	0.3094	0.3009	0.2969	0.4077
Nanchong-city Bank									0.8258	0.8658	0.6968	1.0000	1.0000	0.9717	0.8934
Fuzhou City Commercial Bank										0.9041	0.7569	0.8719	1.0000	0.9604	0.8986
Xiameng International Bank						0.5153	0.4435	0.5503	0.8032	0.9690	1.0000	0.8812	0.6925	0.7804	0.7373
Wenzhou Bank							0.7786	0.6286	0.8196	0.7660	0.5750	0.7194	0.8076	0.8347	0.7412
First Sino Bank						1.0000	1.0000	1.0000	1.0000	1.0000	0.8525	1.0000	0.9554	1.0000	0.9787
Qingdao International bank						0.7669	0.6991	0.7647	1.0000	1.0000	1.0000	1.0000	1.0000		0.9038
BNP PARIBAS (China)									0.9410	1.0000	0.8689	0.6987	0.9889	1.0000	0.9163
Bank of East Asia (China)												0.8243	0.7469	0.9315	0.8342
HSBC(China)														1.0000	1.0000
Standard Chartered Bank (China)														0.9032	0.9032
Year Average	0.8413	0.8326	0.8606	0.8904	0.8927	0.9068	0.9066	0.8622	0.8777	0.8633	0.7840	0.8629	0.8742	0.8548	