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A SURVEY ON BANK EFFICIENCY RESEARCH WITH DATA ENVELOPMENT ANALYSIS AND STOCHASTIC FRONTIER ANALYSIS

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G14; G21;

Abstract

The banking industry from all over the world has been the object of DEA and SFA analysis by a significant number of researchers. Various type of DEA and SFA models have been applied in performance assessing problems and the banks production processes have further motivated the improvement of this models. This paper surveys 30+ published applications in various countries.

INTRODUCTION

One of the major objectives of the EU`s 1992 Single Market Programme (SMP) was to facilitate the free movement of goods and services across Member States and to improve economic efficiency.

An integral part of the SMP was directed at harmonizing regulations and fostering competition in the banking sector. Up until the mid-1980 there had been little progress in removing barriers to trade in financial services.

The EC's 1985 White Paper on the completion of the Single Market and its incorporation in the Single European Act of February 1986 constituted an important and renewed commitment by the European Commission towards the liberalization of the EU banking market. This culminated in the Second Banking Co-ordination Directive, adopted in 1989, together with the two parallel Directives on

Solvency Ratios and Own Funds. This formed a comprehensive framework for regulating all the banking business in the EU. By 1 January 1993 the aforementioned legislation had created the "largest and most open banking market in the world" by eliminating or lessening existing barriers and by establishing minimum regulatory requirements across EU banking systems (Casu & Molyneux).

Typically, European banking systems were characterized by relatively high levels of government controls and restrictions that inhibited competition and maintained a protected banking environment. Interest rate restrictions and capital controls were widespread, and branching restrictions existed in some countries. There were marked differences across banking systems: for instance, the United Kingdom, Germany, Denmark and the Netherlands had rather liberal and open banking markets, while regulatory restrictions limited the competitive environment in the remaining EU Member Countries (European Commission, 1997).

The banking industry is exposed to a multitude of new developments and challenges. Deregulation, liberalization, information technology and the entry of new types of competitors have contributed to internationalization of the existing capital markets and to the developments of new markets of sophisticated financial instruments. The benefits to operate on a larger scale have brought about a wave of mergers. The banking scenery changes even more radically in Europe, where the introduction of the "European passport" (the EU-wide banking permission) in 1992 and the single currency (for EMU countries) in 1999 has removed institutional obstacles for banks to operate in other EU countries (Bikker).

The EU Single Banking Market Programme represents the vanguard of the Single Market Programme for services. The principle of a single banking market allows for consumers to purchase financial services from any part of the EU. The aim of the single banking market is to foster competition and greater efficiency in banking (Matthews & Norton).

While it is clear that the Single Banking Market Programme has improved efficiency through greater consolidation and merger within continental Europe, improved competition has proved to be more elusive because of the existence of informal barriers to entry.

In this new banking landscape various studies were made on bank efficiency using Data Envelopment Analysis and Stochastic Frontier Analysis. Some studies focus on differences across countries, various size of banks, various banking category and over time (Bikker), on investigating whether the productive efficiency of European banking systems has improved since the creation of the Single Internal Market (Casu & Molyneux), on recent dynamics of bank cost efficiency by means of data envelopment analysis (DEA) (Casu and Girardone, 2010), other on efficiency explanations for cross-border bank M&As (Vander Vennet, 2012).

EFFICIENCY MEASUREMENT APPROACHES APPLIED TO BANKS

Due to rapidly increasing complexity of today`s banking environment, there is no universal agreement on the specification of bank efficiency and the challenge still remains in selecting the most suitable methodology for this task. At least two different approaches are commonly used: Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA).

Data Envelopment Analysis (DEA)

First type of DEA was proposed by Charnes, Cooper and Rhodes (1978) which had an input orientation and assumed constant returns to scale (CRS). Constant Returns-to-Scale model (CCR) was widely applied for several years. This model does not differentiate between pure "technical" inefficiencies and inefficiencies due to non-constant (increasing or decreasing) returns-to-scale effects, for example due to constraints in finance, competition etc. The input-oriented and output-oriented scores produced are the same in this case, although other results differ. The first type of DEA is not used today because is assuming that all Decision Making Unit (DMSs) operates on the optimal scale and in perfect competition. Imperfect competition, constraints on finance, etc may cause a DMU to be not operating at optimal scale.

Few years later, Banker, Charnes and Cooper (1984) proposed a variable returns to scale (VRS) model to remove this problem. Variable Returns-to-Scale model (VRS) which is commonly used today and allows the decomposition of the "global" efficiency (that is, the CCR efficiency) into a "local" pure technical efficiency (the score, in this model) and a scale efficiency factor. The input-oriented and output-oriented scores produced are not the same in this case.

Data Envelopment Analysis is the non-parametric mathematical programming approach to frontier estimation. Each bank in the sample is assigned an efficiency score between zero and one, banks with higher scores are more efficient that those with lower scores. One of the advantages of DEA is that it works well with small samples. Other advantages of this technique are that it does not require any assumptions to be made about the distribution of inefficiency and it does not require a particular functional form on the data in determining the most efficient banks. DEA has drawbacks, it assumes data to be free of measurement error and it is sensitive to outliers. Coelli et al. (2005) also point out that: (i) having few observations and many inputs and/or outputs will result in many firms appearing on the DEA frontier; (ii) treating inputs/outputs as homogenous commodities when they are heterogeneous may bias the results; (iii) not accounting for differences in the environment may give misleading results; (iv) standard DEA does not control for multi-period optimization or risk managerial decision making.

Data Envelopment Analysis (DEA) is a powerful method widely used in the evaluation of performance of Decision Making Units (DMUs). These can be business units (for example points of sales, bank branches, etc.). All DMUs under comparison are assumed to operate homogeneously: they receive the same inputs and produce the same outputs (in differing quantities, of course) and these inputs and outputs are representative of the whole population. The main advantage to this method is its ability to accommodate a multiplicity of inputs and outputs. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/exclusion of variables can affect the results (Berger, 2010).

Stochastic Frontier Analysis (SFA)

Stochastic frontier production function was independently proposed by Aigner, Lovell and Schimdt (1977) and Meeusen and van den Brock (1977). The original specification involved a production function specified for cross-sectional data which had an error term which had two components, one to account for random effects and another to account for technical inefficiency. This model can be expressed in the following form:

$$Y_i = x_i\beta + (V_i - U_i), i = 1, \dots, N \quad (1)$$

Where Y_i is the production (or the logarithm of the production) of the i-th firm;

x_i is a kx1 vector of (transformations of the) input quantities of the i-th firm;

β is a vector of unknown parameters;

V_i are random variables;

U_i are non-negative random variables which are assumed to be account for technical inefficiency in production.

The original specification has been used in a vast number of empirical applications over the past two decades. The specification has also been altered and extended in a number of ways. These extensions include the specification of more general distributional assumptions for the U_i such as the truncated normal or two-parameter gamma distributions; the consideration of panel data and time-varying technical efficiencies; the extension of the methodology to cost functions and also to the estimation of systems of equations (Coelli).

MAJOR PAPERS USING DEA AND SFA

The efficiency of banks has been widely and extensively studied in the past few decades. For banks, efficiency implies improved profitability, greater amounts of funds channeled through the system, better prices and service quality for consumers, and greater safety in terms of improved capital buffers in absorbing risk (Berger et al. 1993). In the last years, many

studies have been conducted in Europe and other parts of the world. The problem is that few researchers studied developing countries. Indian Government has implemented a series of reforms in the last fifteen years and a study was necessary to show the effect and improvement over banking efficiency. Data Envelopment Analysis was used for measuring technical efficiency of banks in Indian banking sector. The results showed that the reforms were implemented with success and the efficiency of the banks has improved and the foreign banks have better efficiency scores that private sector and public sector banks (Sanjeev, 2006).

Cost and profit efficiency in the banking systems of ten member states of the European Union over the period 1998 – 2003 were examined using the stochastic frontier approach. A low level of cost and profit efficiency was observed in the sample, foreign banks outperform state-owned and private-owned banks in terms of profit efficiency, but results are less clear in the case of cost efficiency. Several steps have been made towards financial integration and towards enhancing integration in the banking systems from the ten EU member states but many issues still remain to be tackled (Mamatzakis et. al., 2008) An investigation over the new European banking landscape over the period 1998 – 2005 to examine the differences between old and new member states revealed that there are significant differences. Indeed total operating expenses for the ten new member states have declined during the period, but they remain at a higher level compared with the old member states. The operational performance of banks is positively related to the quality of the loan portfolio, the bank`s size and the development of the banking system and it is negatively related to liquidity and the loan ratio (Staikouras et al., 2008).

The cost and profit efficiency of banks in South Africa were analyzed using a stochastic frontier model to determine both cost and profit efficiency of four large and four small, South African-based banks. The study showed that South African banks have significantly improved their cost efficiencies between 2000 and 2005. However, efficiency gains on profitability, over the same period, have not been significant. No bank was found to be superior to another in terms of achieving efficiency gains in cost reduction and profitability. A weak positive correlation was found to exist between the cost and profit efficiencies, with the most cost efficient banks also being most profit efficient. With regard to bank size, cost efficiency declined with increasing bank size (Ncube, 2009).

Matthews et al argues that allocative inefficiency is the optimal outcome of input resource allocation subject to enforced employment constraints. Using a sample consisted of 154 bank year observations for 14 banks over the period 1997-2007, the resulting analysis suggests that allowing for rational allocative inefficiency; Chinese banks are no better or worse than their western counterparts.

Most papers indicate a preference for complex techniques over simple accounting ratios. A study was made to explore the results and relationships between bank efficiency estimates using accounting ratios and Data Envelope Analysis (DEA) with bootstrap among Jamaican bank between 1998 and 2007 (Daley & Matthews, 2009). The results indicate different outcomes for the traditional accounting ratios and the sophisticated DEA methodology in the measurement of bank efficiency. GLS random effects two-variable regression tests for superiority using a risk index for insolvency suggest an advantage in favor of the DEA.

Another study that used both methods, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) was targeted on the main banks in Romania, the Czech Republic and Hungary for the period 2000-2006. The banks from these countries reach low levels of technical efficiency and cost efficiency, the main factors that influence efficiency are quality of the assets, banks size, annual inflation rate, banking reform, form of ownership and interest rate liberalization (Andries & Cocris, 2010). Bank performance can be measured by using operational research (O.R.) and artificial intelligence techniques. Data Envelopment Analysis is one of the most widely applied O.R. technique in the field. The variables used in studies differ significantly. Some researchers start with a large list of variables and then use statistical screening or dimension reduction to

obtain a reduced set of variables (Fethi & Pasiouras, 2010).

Two-stage evaluation of bank branch efficiency using data envelopment analysis is employed on one of the "Big Five" Canadian banks with assets of over $600 billion CAD and is ranked in the top 75 banks worldwide in term of assets size. Comparing with previous branch studies, this three- dimensional efficiency analysis shows a significantly more comprehensive evaluation of bank branch performance that is also likely to be better accepted by branch level management (Paradi et al, 2011).

Another sample of 22 EU countries over the period 2000 – 2008 was investigated by using Data Envelopment Analysis, in the first stage of the analysis, then two distinct accounting ratios to capture the costs of intermediation and cost effectiveness. By strengthening capital restrictions and official supervisory powers, the efficiency of banks operations can be improved. Banks from countries with less concentrated and more developed systems tend to have relatively higher levels of efficiency (Chortareas et. al., 2012).

Many studies use some kind of frontier for measure the efficiency of banking system. A new approach was used, SORM SBM DEA for analyzing the efficiency of Indonesian banking system during the period 2003 - 2007. This method was chosen because standard DEA models fail to allow for additional potential input reductions. The Indonesian system has 130 banks with a combined balance sheet of over 213 billion $. It contains, at the end of 2007, 5 state-owned banks, 35 foreign exchange private banks, 11 foreign banks, 17 joint-venture banks, 36 non-foreign exchange private banks and 26 regional government-owned banks. At the end of the 1997, there were 222 banks, but a post-financial crisis consolidation took place. The results show that the estimated efficiency scores are very sensitive to the choice of methodology used for dealing with negative numbers (Hadad et. al, 2012).

By using 42 Taiwanese banks during 1999-2007 as observations and introducing an input-oriented generalized metafrontier Malmquist productivity index while considering the latent effect of risk-taking behavior in the analytic framework, we learn that public and private bank should face separate short-term technological frontiers, while the econometric model considering risk input can portray banks operating frontiers better (Chen, 2012).

DEA approach can be used to identify managerial groups in a large Canadian bank branch network (Paradi et al, 2012. The results from this case demonstrate that the bank branches have different managerial capabilities and strategies to deal with different operating environments – not an unexpected outcome, of course. There are several benefits of applying this hybrid grouping approach: (1) it eliminates the impact of efficiency levels on the identification of a branch's true operating characteristics; (2) branches are grouped based on their operational similarity, which is useful for senior management in analyzing the possible new branch opening strategies and deciding on long term group development plans; (3) a customized peer group is recommended consisting of the top 3 most similar references for each inefficient unit that may promote successful operating practice sharing and creating continuous improvement opportunities.

Another paper analyzes true managerial efficiencies of the branches of a case bank in Taiwan (Shyu & Chang, 2012). Results suggest that environmental variables have significant effect on branch efficiency. Moreover, scale inefficiency is the major cause of operating inefficiency in the case bank, and most branches are operating at the stage of increasing return to scale. With regards the branches' business scope, those that operate loan and wealth management services have better managerial efficiency than those that focus on wealth management only.

The determinants of efficiency and productivity of the banking systems of seven central and east European countries during a five-year period, from 2004 to 2008 were examined by using two approaches: stochastic frontier analysis and data envelopment analysis. The empirical results show that the average efficiency of banks in central and east European countries grew in the period analyzed. The improvement may be due to increased competition upon EU accession and the entry of foreign banks, as well as to extensive legislative

changes that led banks to become more efficient (Andries, 2012).

Another type of DEA is used to examine staffing decisions in branches of a large Canadian bank. Using Data Envelopment Analysis (DEA) Asmild et al find considerable 'inefficiency' which raises the question whether this is best interpreted as waste or if the apparent inefficiency may serve other purposes. To investigate this, they invoke the theoretical framework of rational inefficiency. Results demonstrates relatively large over-staffing at the supervisor level which is natural given both their strong bargaining position derived from their role in the branch hierarchy and given the relative flexibility of supervisor resources.

A paper surveys Chinese bank risk managers and constructs metrics of risk management practice and risk management organization. The metrics are used as intermediate inputs in a Network DEA framework to produce a measure of income efficiency. A statistical test is carried out to assess the importance of the risk metrics in evaluating bank income efficiency (Matthews, 2013). Results show no significant direct relationship between the two constructed measures of risk management practice and risk management organization and an objective measure of performance of the bank such as ROA. However, the input of these measures within a DEA network framework produced efficiency scores that explained ROA better than efficiency scores that excluded them.

At the beginning of the 2013, a survey on bank branch efficiency and performance research using DEA was published. The banking sector from many countries has been the object of DEA analyses by various researchers. The papers surveys 80 DEA applications in 24 countries with a specifically focus on banks branches. There is significant diversity among studies in terms of the input-output selection. The business environment is dynamic and developing more reliable DEA models will be an important topic in future bank branch studies (Paradi & Zhu, 2013).

DATA AND VARIABLES

Definition of the Samples

Many studies were made for Europe: France, Germany, Italy, Spain and the United Kingdom (Casu & Molyneux) by using a sample of 750 banks from above countries (the largest 150 bank by asset size in each respective country) using Bankscope database, for eight European countries, namely Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg and United Kingdom using Bankscope database spanning the period 1994 to 2008 (Apergis & Alevizoupoulou, 2011), for banks from eight countries namely Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovak Republic and Slovenia over the period 1998-2003, data are derived from Bankscope database, which reports published financial statements from financial institutions worldwide and using a panel data set consisting of 766 bank-level observations (Mamatzakis et al, 2008), for a sample of banks from ten EU member countries, Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Portugal, Spain and United Kingdom, which includes commercial, cooperative and saving banks for a period between 1994 and 2005 and 14,447 observations (Weill, 2009), for the EU-15 and Switzerland (Bikker), the EU-15 area using Bankscope database and includes annual information for an unbalanced panel of 11 observations between 1997 and 2003 (Casu & Girardone, 2010), commercial banks operating in 22 EU countries over 2000-2008, namely: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom and a unbalanced panel of 5227 observations (Chortares et al, 2012), for countries from Asia: India, using a sample of 130 banks with combined balance sheet of over US213$ billion (Hadad et al, 2012), Pakistan, data was obtained from Fitch/Thompson Bankscope for the period 2002-2009 (Matthews, 2010), Indonesia using Bankscope database and annual reports of individual banks and central bank statistics for missing periods, with focusing on commercial banks as it comprises the largest segment of depository institutions, over the period 1992-2007 (Zhang & Matthews, 2011), China by employing annual data for 14 banks over the

period 1997-2007 (Matthews et al, 2009; Matthews, 2013), Taiwan using an unbalanced panel data on bank industries as observation that span nine years from 1999 to 2007 (Chen, 2012), first six months of 2007 and 2008 for the 123 branches of the case bank (Shyu & Chang, 2012), America: Canada (Paradi et al, 2011; Paradi et al, 2012; Asmild et al, 2013), Jamaica (Daley & Matthews, 2009). Most studies of banking efficiency have focused on the developed economies. While there have been some studies of other Far Eastern economies, the number is small in comparison.

Variables used

The theory of measuring efficiency is straightforward if you know precisely the inputs and output a firm produces. While this is quite clear in the case of a manufacturing firm it is not straightforward in the case of a bank. The literature distinguishes between two main approaches – the intermediation approach and the production approach. The intermediation approach recognizes that the main function of a bank is a financial intermediary that takes in deposits and transforms them into loans and other earning assets. According to this approach the inputs will be deposits plus borrowed funds along with the traditional factors of production (labor and fixed assets) and the outputs will be loans and other earning assets (Sealey & Lindley, 1977). Total costs according to this approach will be what are traditionally recognized as operational expenses plus total interest costs.

In contrast, the production approach recognizes that a bank is a producer of a range of financial services. These services are to deposit holders and borrowers alike and include not just intermediation services but a host of other financial services that would be charged to the non-interest earning account. Under this approach the number of deposit and loan accounts plus the number of financial transaction logged over a period of time would be taken as the appropriate definition of output and the inputs will be purely labor and fixed assets (as a measure of capital in neo-classical production theory). Total costs would only cover operational costs and interest costs are excluded (Ferrier et al., 1993). The literature on bank efficiency has tended to produce results using the intermediation approach, largely because balance sheet and income account data is more readily available that what would be required for the production approach.

Between scholars there is not an agreement for the types of inputs and outputs used. In our research we find different types: deposits are considered as inputs, and interest on deposits is a component of total costs, together with labor and capital costs (Casu & Molyneux), loans consist of commercial, consumer and mortgage loans, demand deposits include current accounts, saving is made up of saving accounts, saving deposits and time deposits, and non-interest income consists mainly of commission and revenues from financial transactions (Bikker), total loans and securities as outputs, whereas deposits along with labor and physical capital are inputs (Casu & Girardone, 2010), total consumer deposits and commercial borrowings, total employee expenses, total non-employee expenses, total loan loss provisions, equity capital for inputs and total loans, total other earning assets and net total off-balance sheet income for outputs (Hadad et al, 2012), deposits, labor and fixed assets as inputs in the production process, total loans, total securities and total non-interest operating income as outputs of the production process (Apergis & Alevizoupoulou, 2011), personnel expenses, total fixed assets, and deposits and short term funding as inputs and total loans and other earning assets as outputs (Chortares et al, 2012), inputs are labor, capital (fixed assets) and deposits and their respective prices, unit cost of labor, unit cost of fixed assets and unit cost of deposits, outputs are distinguished by the treatment of non-performing loans as a bad output and non-interest income as an additional output (Matthews, 2010), loans and investment as outputs and labor, physical capital and borrowed funds as inputs (Weill, 2009), number of employees, fixed assets and total deposits for inputs and for outputs loans, other earning assets (model 1), total interest income and other operating income (model 2), loans, other earning assets, other operating income (model 3) (Zhang & Matthews, 2011), loans, investments, non-interest revenue as outputs, labor, physical capital and borrowed funds (Chen, 2012), operating cost and deposits as inputs, total net

interest income and non-interest income (model 1), gross loans and investments (model 2), gross loans and non-performing loans, investments (model 3), net loans and investments, non-performing loans (model 4) as outputs (Daley & Matthews, 2009), the input variables include the number of operational staff; number of business personnel; branch office rent; and operating expenses. The output variables include the net fee income and net interest spread income (Shyu & Chang, 2012). Inputs are the number of employees, fixed assets and total deposits, outputs are total loans, other earning assets, and non-interest income (Matthews et al, 2009), five staff categories (inputs) and nine different types of produced outputs in the Ontario branches of a large Canadian bank (Asmild et al, 2013).

CONCLUSIONS

The efficiency of banks has been widely and extensively studied in the past few decades. For banks, efficiency implies improved profitability, greater amounts of funds channeled through the system, better prices and service quality for consumers, and greater safety in terms of improved capital buffers in absorbing risk. In the last years, many studies have been conducted in Europe and other parts of the world.

Due to rapidly increasing complexity of today`s banking environment, there is no universal agreement on the specification of bank efficiency and the challenge still remains in selecting the most suitable methodology for this task. At least two different approaches are commonly used: Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA).

In this survey article, we have reviewed the recent academic literature on various aspects of banking efficiency using Data Envelopment Analysis and Stochastic Frontier Analysis (SFA). The sustained legislative drive over the last decades towards regulation and supervision of banking systems has presented researchers with many new challenges and opportunities for investigating economic hypotheses concerning the functioning of banking and financial markets.

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