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Essays on Banking Efficiency

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Essays on Banking Efficiency

Thesis submitted to the Graduate Program in Business Management at University of Brasília in partial fulfillment of the requirements for the degree of Ph.D in Business Management.

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To my parents: Maria da Conceição Sousa de Abreu and José Marcelo Rocha de Abreu

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"There is nothing so useless as doing efficiently that which should not be done at all."

Peter Drucker

Abstract

This thesis consists of three articles covering topics in banking efficiency. The first article analyses and presents the current mainstream research on banking efficiency by assessing recent articles from major finance journals. It examines 87 papers that were published between January 2011 and July 2017. It classifies these manuscripts based on study type, approach, objective, and method. It applies clusters and citation networks to identify the evolution of the studies, including research gaps and paradigms. It also analyses the origin of the studies through geographical coordinates to visualize the global connections among the articles. The study contributes to a future research agenda, an studies' integration at international level, and a dissemination of relevant findings on the topic. Moreover, using Lotka's Law, it find that the field of banking efficiency had low productivity, without a significant number of prolific specialized authors or institutions..

The second article attempts to verify which qualitative banking attributes can determine the level of American state-chartered Financial Institutions (FIs) and evaluate its underlying variables. The methodology followed three procedures of analysis. First, we measured banking efficiency using a two-stage SBM network data envelopment analysis (NDEA). Subsequently, we used machine learning methods to predict efficient FIs from qualitative attributes. Finally, we tested the variables related to the attributes, using a fractionated logistic regression controlled by economic-financial variables. As main results, we found that attributes linked to political-administrative localization criteria were the more important attribute in predicting if the FI was in the efficient group; we confirmed the recent findings of the literature that state that less governmental influence (freedom) is related to more efficient institutions. Besides that, we found that a population with a higher financial education have FIs with higher levels of efficiency.

The third article focuses on a proposal and application of a prudential approach to the evaluation and measurement of bank efficiency. After theoretically justifying the approach, we applied it via a two-stage DEA network for Brazilian commercial banks. For comparability purposes, we also measure efficiency through the application of the traditional banking intermediation approach. The results showed significant differences in the results found by the two models. Finally, we used the results to test the diversity-efficiency hypothesize, and to evaluate the productivity performance of the sector in the period of the beginning of the 2015 Brazilian fiscal crisis.

Keywords: Banking Efficiency, Brazilian Banks, DEA Network, Data Envelopment Analysis, Prudential Approach

Resumo

Esta tese consiste em três artigos que abordam tópicos sobre eficiência bancária. O primeiro artigo analisa e apresenta pesquisas atuais sobre eficiência bancária, avaliando artigos recentes de revistas conceituadas de finanças. Para isso examina 87 artigos que foram publicados entre janeiro de 2011 e julho de 2017. Os manuscritos forão classificados com base no tipo de estudo, abordagem, objetivo e método. Aplicou-se *clusters* e redes de citações para se identificar a evolução dos estudos, incluindo lacunas de pesquisa e paradigmas. Analisou também a origem dos estudos por meio de coordenadas geográficas para visualizar as conexões globais entre os artigos. O estudo contribui para uma futura agenda de pesquisa, a integração de estudos em nível internacional e a divulgação de achados relevantes sobre o tema. Além disso, usando a Lei de Lotka, traz evidências que o campo da eficiência bancária ainda possui baixa produtividade, sem um número significativo de autores ou instituições prolíficos especializados.

O segundo artigo busca verificar quais atributos bancários qualitativos podem determinar o nível das Instituições Financeiras (FIs) e quais são suas variáveis subjacentes. A metodologia seguiu três procedimentos de análise. Primeiro, mediu-se a eficiência bancária usando uma *Network* Análise Envoltória de Dados SBM de dois estágios (NDEA). Posteriormente, usou-se métodos de aprendizado de máquina para prever FIs eficientes a partir de atributos qualitativos. Por fim, testou-se variáveis relacionadas aos atributos, utilizando-se uma regressão logística fracionada controlada por variáveis econômico-financeiras. Como principais resultados, evidenciou-se que os atributos vinculados a critérios político-administrativos de localização foram os atributos mais importantes para a predição da eficiência da FI; foi confirmadas as recentes descobertas da literatura que afirmam que menos influência governamental (liberdade) está relacionada a instituições mais eficientes. Além disso, constatou-se que uma população com maior nível de educação financeira possui IFs com maior nível de eficiência.

O terceiro artigo enfoca a proposta e aplicação de uma abordagem prudencial para a avaliação e mensuração da eficiência bancária. Depois de justificar teoricamente a abordagem, a proposta é aplicada via uma *network* DEA de dois estágios para bancos comerciais brasileiros. Para fins de comparabilidade, também foi medida a eficiência via aplicação da abordagem tradicional de intermediação bancária. Os resultados mostraram diferenças significativas nos resultados encontrados pelos dois modelos. Por fim, utilizamos os resultados para testar a hipótese de diversidade-eficiência e avaliar o desempenho da produtividade do setor no período do início da crise fiscal brasileira de 2015.

Palavras-chave: Eficiência Bancária, Bancos Brasileiros, Network DEA, Análise Envoltória de Dados, Abordagem Prudencial.

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Chapter 1

Introduction

In the last three decades, Financial Institution (FI) efficiency has been a major object of specialized literature. Currently, this interest has been driven by different factors, as the major financial crises, the increased level of risk, and major structural changes in the sector. Technological advances, new regulatory processes, and changes in market structures have substantially altered the factors and methods of evaluating the performance of FIs.

Due to that increasing complexity of the environment, there is no general agreement on the specification of FI efficiency, and the challenge is to select the best methodology for this purpose. In view of this challenge, the second chapter of this thesis examines the current state-of-the-art on banking efficiency research. As it is shown at the results, the application of the DEA method in the banking sector has proliferated over the last years and there is no study that applies machine learning methods for evaluating the banking efficiency determinants. This research gap is addressed in the third chapter of this thesis where the methodology applied involves the evaluation of qualitative attributes of bank efficiency performing different machine learning methods. The literature review also shows that the bank efficiency measurement depends mainly on the analyst's point of view about the FI objectives. Further, there is no approach that specifically turns to the point of view of the banking supervisor. That is, a approach that assess economic efficiency by maintaining adequate levels of risk. In the literature in this area it is possible to see a preference for production and intermediation approaches, and the studies usually do not incorporate the risk dimension in their inputs and outputs. The fourth chapter intends to respond to some of the limitations found in the literature on the subject of banking efficiency, applying a prudential approach and comparing to the intermediation approach usually performed in this study area.

Thus, the objective of the three integrated articles of this thesis is to contribute with some methodological innovations and new evidences about banking efficiency. The first article focuses on the literature and gaps that may represent research opportunities, using an innovative selection process which does not filter studies by convenience; rather, it uses the selection criteria of an independent institution (ABS, 2015) to define the relevant journals to browse for papers. The second essay attempts to verify which qualitative banking attributes can determine the level of American state-chartered Financial Institutions (FIs) and evaluate its underlying variables.

This thesis is organized as follows. Chapter 2 is a bibliometric study and review of the literature on banking efficiency named "What Is Going On with Studies on Banking Efficiency?". Chapter 3 verifies which qualitative banking attributes can determine the level of American state-chartered Financial Institutions (FIs) and evaluate its underlying variables. Its name is "Determinants of Efficiency in State-Chartered Financial Institutions: Why Financial Education and Freedom Matter". Finally, Chapter 4 presents a proposal and application of a prudential approach to the evaluation and measurement of bank efficiency. Its name is "Is The Choice Between Stability and Efficiency a Catch 22? A Prudential Approach for Evaluation of Banking Efficiency".

Chapter 2

What Is Going On with Studies on Banking Efficiency?

2.1 Introduction

Bank efficiency has been a major object of analytical and empirical literature in the last 30 years. Nowadays, this interest has been driven not only by the major financial crises of recent decades but also by major structural changes in the sector. Technological advances, new regulatory processes, and changes in market structures have substantially altered the factors and methods of evaluating the performance of financial institutions (FIs).

The efficiency of FIs depends on factors that (directly or indirectly) affect the absorption of costs and the delivery of services to clients. In this way, more than just explicit costs affect FIs' performance. On one hand, the range of issues that influence banks' ability to obtain information about the market and about the borrowers themselves can also affect FIs' productivity and efficiency. On the other hand, banks have improved the ability to conduct transactions in a secure and timely manner. Therefore, a variety of factors are essential for measuring and explaining efficiency, including the nature of accounting practices, the rules of governance, the existence of databases, and the level of market concentration.

The significant changes in the most diverse sectors have caused specialized research interests to change substantially. For example, nowadays the main research areas on the efficiency of financial institutions, as categorized by Berger et al. (1995) or Berger and Humphrey (1997) in the end of the 1990s, do not have the same status. Our study demonstrates that the efficiency of private and government financial institutions has not been a main area of research in the main journals anymore. In contrast, the implications that bank mergers have on efficiency remains an area of great interest, and the determinants of financial-institution efficiency has become such a complex category that it should be divided into several major sub-areas of interest.

Concurrently, the number of publications and sources of information about the topic has also grown exponentially. This fact makes extremely difficult for researchers, policymakers and other professionals follow the advances and challenges of the sector. Thus, knowing where are the major research centers, their specific interests, and their main researchers have a fundamental role for obtaining, propagating and generating knowledge on banking efficiency.

Additionally, due to the high degree of interconnection of the financial system with the whole economy, studies in bank efficiency provide important information not only for experts and academics in the area but also for those seeking to understand how changes in that industry can affect different areas of study and markets.

Therefore, proposals for advancing the research in banking efficiency presuppose that information has been obtained on its current state, as well as on how its development occurs and on

which factors affect this development. Bibliometric and scientometric studies become increasingly relevant as it enables the analyses of the integration of research at an international level, the dissemination of results relevant to the sector, and the identification of the main centers of knowledge generation in the area. Thus, adapting the method employed by Jabbour (2013) and (Silva et al., 2017), this study's objectives are as follows:

- Identify in the main finance journals the articles that are related to banking efficiency, aiming to build a sample of relevant works. Our research is singular because it uses a selection method that only admits articles that are characterized as "excellent" instead of using all articles from certain databases (Silva et al., 2017) or using selection by citation (Cintra et al., 2017).
- Classify the papers' characteristics, scope, and objectives and then perform a cluster analysis for comparability purposes.
- Formulate the studies' citation network; analyse the authors' productivity; and identify the most influential regions, journals, authors, and articles.
- Identify the main paths of the current mainstream research.
- Provide a framework to address the relevant gaps in the current discussion.

The paper is structured as follows. After this introduction, the second section presents the study's research method and describes the two first steps followed in the research; in the first step, we select papers using objective procedure and criteria; in the second step, we structure the classification system. The next section focuses on the third step, which builds a framework of the current discussion. The fourth section brings the fourth step, discussing the study's main results and the profile of the recent scientific production on banking efficiency. Finally, the fifth section outlines the fifth step, where the main conclusions of the research and listing the challenges and opportunities for future studies are presented.

2.2 Research Method

We use a methodology based on the procedure used in Jabbour (2013) and Silva et al. (2017). Nevertheless, our selection process is innovative because we do not filter studies by convenience; rather, we use the selection criteria of an independent institution (ABS, 2015) to define the relevant journals to browse for papers. The steps of the method are as follows:

- First step: We conduct a survey of the relevant articles from the best journals, as identified in the *Academic Journal Guide of Association of Business Schools* (ABS, 2015), and tabulate the pertinent data;
- Second step: We develop a classification system using a logically structured code to identify factors such as research networks, main authors, major journals, and areas of study related to banking efficiency;
- Third step: We apply the classification system to provide a framework for the current discussion on banking efficiency, including its level of productivity and its main research networks;
- Fourth step: We provide a profile of the scientific production on the theme based on the papers gathered from influential journals;

- Fifth step: We conclude our study by stating the main opportunities and challenges for future studies.

Our main objective is to assess the current state of the art in banking efficiency studies. Therefore, our methodology involves only evaluating the articles from the top finance journals. To select the papers, as already discussed, we use the *Academic Journal Guide of Association of Business Schools* ABS (2015) as an initial criterion for classifying the scientific journals.

The ABS (2015) categorization criterion is interesting because it follows an objective systematic approach that uses statistical citation information to assess the judgments of authors, editors, and specialists regarding hundreds of publications. ABS (2015) classifies journals in several areas of focus, including finance. For each thematic area, ABS (2015) scores journals from 1 to 4; where higher scores are better, and a level of distinction is identified as 4*. These categories are described in Tab. 2.1.

Table 2.1: Description – ABS Ratings.

Rating	ABS Description of Quality Rating
4*	Journals of Distinction. Within the business and management field including economics, there are a small number of grade 4 journals that are recognised world-wide as exemplars of excellence. Their high status is acknowledged by their inclusion in a number of well-regarded international journal quality lists. In addition, journals from core social sciences disciplines that do not appear in those listings may also be rated 4* on the grounds that they are clearly of the finest quality and of undisputed relevance to business and management.
4	All journals rated 4, whether included in the Journal of Distinction category or not, publish the most original and best-executed research. As top journals in their field, these journals typically have high submission and low acceptance rates. Papers are heavily refereed. Top journals generally have the highest citation impact factors within their field.
3	3 rated journals publish original and well-executed research papers and are highly regarded. These journals typically have good submission rates and are very selective in what they publish. Papers are heavily refereed. Highly regarded journals generally have good to excellent journal metrics relative to others in their field, although at present not all journals in this category carry a citation impact factor.
2	Journals in this category publish original research of an acceptable standard. A well-regarded journal in Its field, papers are fully refereed according to accepted standards and conventions. Citation impact factors are somewhat more modest in certain cases. Many excellent practitioner-oriented articles are published in 2-rated journals.
1	These journals, in general, publish research of a recognised, but more modest standard in their field. Papers are in many instances refereed relatively lightly according to accepted conventions. Few journals in this category carry a citation impact factor.

Source: Adapted from ABS (2015, p. 7).

The classification by period, theme, and quality allows us to use only articles published in journals that are classified as high level and that have had a recent impact on the scientific community. We evaluate only articles from journals classified as 4*, 4, or 3 in the ABS (2015) score, focusing on banking efficiency and targeted to the specialized finance community. Using the ABS classification from 2015, 37 journals met this criterion.

In addition to evaluating the journals' quality and the studies' impact on the scientific community, we use bibliometrics to determine which banking- efficiency topics the finance community has studied recently. We also restrict our search to articles published from the beginning of 2011 until the first seven months of 2017. The delimitation of our review period (2011-2017) is justified by two main reasons. First, we seek to evaluate how the recent research in the area is structured and thus compare the results with surveys from previous periods. The second reason is to reach

the period after the financial crisis of 2008-2011 which has as its final mark the issuance of the Budget Control Act of 2011 (Hu and Zarazaga, 2016). Our procedure for selecting and analysing the articles is indicated in Tab. 2.2.

Table 2.2: Procedures performed in bibliometrics.

Step	Description
1.	Definition of the *Academic Journal Guide* as a reference for the segregation of the main journals;
2.	Selection of 37 journals that met defined quality criteria (score >2);
3.	Direct access to the databases of the respective publishers and electronic platforms of the selected journals;
4.	Search for articles from the following search filters:
a)	Keywords: "banking efficiency" or "efficiency in banking" or "technical efficiency" and "bank".
b)	Period: 2011 to 06/2017.
c)	Search places: summaries, keywords, and titles.
d)	Language: English.
5.	Correction of false positives. Reading of abstracts for elimination of undue filter selection, that is, articles that despite meeting the search criteria did not have as purpose the study of banking efficiency;
6.	Data tabulation, descriptive analysis, Lotka Productivity test, and network analysis.

After collecting the data from the publishers' databases and electronic platforms, we read the abstract, introduction, and methodology sections of each paper in the pool of studies, which totals 87 papers. We also examined the articles' references. We then recorded this information on worksheets using logical categories and analysed the data using descriptive statistics.

We tabulated the number of papers published in each year, the number of authors per paper, and the countries of origin of the authors. We then identified and catalogued the geographic coordinates of the authors' institutions. This procedure made it possible to build maps of the research networks and to visually demonstrate the origins of the studies.

To formulate the categories, we used a process similar to the one that Silva et al. (2017) and Jabbour (2013) used. However, we adapted the categories to our unique selection process and restricted them to the studies objectives. For the methodological framework, we used the following classification (depicted in Tab. 2.3): (1) study type, (2) objective, (3) method of measurement, (4) method of association, and (5) main subject.

Table 2.3: Classification and coding used to analyze the articles.

Rating	Meaning	Encryption
1	Study Type.	A – Theoretical and Empirical. B – Theoretical.
2	Objective.	A – Measurement. B – Association. C – Both. D – Not Applicable.
3	Methods Used - Measurement.	A – SFA. B – DEA. C – Others. D – Not Applicable.
4	Methods Used - Association.	A – Statistical/Parametrical. B – Statistical/Non or Semi Parametrical. C – Mathematical Modelling. D – Not Applicable.
5	Main Object of Study.	A – Competitiveness, Concentration, and Efficiency. B – Diversification, Risk, and Efficiency. C – Efficiency and Governance. D – Islamic, Conventional Banks, and Efficiency. E – Efficiency in Small Institutions. F – Mergers and Acquisitions, TBTF, and Efficiency. G – Proposed Alternative Models, Simulation to Evaluate Efficiency. H – Supervision and Regulation of Banks and Efficiency. I – Others.

For the study type, we used two categories: "theoretical" and "empirical-theoretical". Note that we did not include the usual classification of "empirical" because, after analysing the data, we did not find any purely empirical studies in our sample.

Regarding the objective, scientific studies often aim to describe, explain, predict, or evaluate an established phenomenon. We found two major objectives for the bank-efficiency studies: "association" and "measurement". The first objective is related to studies that are focused primarily on prediction or explanation of banking efficiency. This class is similar to the category that Berger et al. (1995) presented as "determinants of financial institution efficiency". The second category (measurement) refers to studies that are dedicated especially to determining a method or model for defining levels of efficiency in FIs.

Note that we chose not to distinguish among description, prediction, and explanation because of the old controversies regarding the distinctions between these concepts. Hanna (1969) presents a good discussion on the subject. Furthermore, description objective was not verified in our sample as the main goal of the studies, usually having a secondary role in the papers. This fact demonstrates the advance of the area since in previous studies the mere description of the average of the scores and its dispersion consisted of a specific field of analysis, as noticed in Berger and Humphrey (1997).

Therefore, in our analysis, the objective had four categories: "measurement", "association", "both", and "not applicable". Taking into account the previous discussion, studies categorized as "measurement" are mainly aimed at evaluating how banking efficiency should be measured. These studies classified as "association" are those that focus on understanding the components of banking technology and identifying what determines whether a bank operates efficiently. "Both" was the classification for those studies that lacked a clear and specific focus, mixing association and measurement.

We verified two main methods of measurement: stochastic frontier analysis (SFA) and data

envelopment analysis (DEA). These two methods are quite traditional and have been used by the specialized literature in the last decades (Berger and Humphrey, 1997), but their variations have received substantial advances. We also used four methods of association: "statistical/parametric", "statistical/non- or semi-parametric", "mathematical modelling", and "not applicable". Finally, the fifth dimension (main subject) encompasses eight comprehensive subjects, which we defined based on the main theme addressed in each study.

Finally, it is important to highlight that our classification system (Tab. 2.3) does not comprise all the methods and research techniques used in banking and finance studies. Therefore, the methodological framework used in this analysis should be understood in the context of this paper's scope and its methodological restrictions.

2.3 Framework of the Current Discussion on Banking Efficiency

There are several ways of understanding and addressing the problem of how to evaluate FIs' efficiency (Matousek et al., 2015; Paradi et al., 2011). One of the most basic way is the separation of structural from non-structural approaches (Hughes and Mester, 2008). Another very common classification divides studies based on their use of parametric or non-parametric methods (Berger and Humphrey, 1997; Casu et al., 2004). These segmentations are interesting when researchers desire to theoretically understand the process of evaluating banking efficiency.

An underlying theoretical structure, together with an optimization concept, allows for a theoretical model to be compared with empirical results, thus establishing a metric for efficiency. In contrast, the non-structural approach, which is not used in this theoretical framework, mainly is used to compare FIs' efficiencies to enable evaluation (Hughes and Mester, 2008). In other words, the non-structural approach considers institutions based on a set of performance indicators. The main difference between the two approaches is in the necessity of a theoretical model in the structural approach, which presupposes that models exist and that the concept has been optimized.

We highlight that some authors understand the concept of efficiency only as linked to methods that involve a measurement of a frontier. For example, Berger and Humphrey (1997) analyze only efficient frontier studies, which are subdivided by the authors into five "approaches": DEA, FDH, SFA, DFA, TFA. However, we do not use this classification because we consider it very restricted.

It is important to separate studies that only evaluate the performance of some metrics from the studies that analyse a set of indicators that have the ability to indirectly evaluate efficiency or productivity. Our research is focused on studies that evaluate the efficiency or productivity of FIs; we have not considered any study that evaluates only performance variables, such as profitability or return.

In spite of the restriction of our study to the Finance field, the complexity of the factors involved in banking-efficiency analysis has fostered a multiplicity of approaches for their measurement, comparison, and understanding. These approaches, in turn, use a variety of techniques, tools, and theoretical or empirical studies. On the one hand, this leads to progress in knowledge, but, on the other hand, it complicates the monitoring of all existing advances and challenges in the area.

For these reasons, the dual segmentation of areas in banking efficiency is not enough to understand how the theory of finance is now being evaluated. Therefore, more specific examination is needed regarding the methodological approaches, research objectives, and techniques used in recent scientifically relevant studies.

Similarly, banking theory has gained new contours, which have in turn modified the studies on banking efficiency. The literature has shifted away from traditional microeconomic theory moving towards a modern theory of banking intermediation, combined with the microeconomics of

banking production (Hughes and Mester, 2012; Bhattacharya and Thakor, 1993). The bibliographic survey allowed us to verify the major questions and objectives of current studies, described in the classification of Tab. 2.3.

One of the major current research areas has the aim of verifying the impact that competitiveness in the banking industry has on FIs' efficiency. This area is quite traditional and has already been discussed for more than two decades (Berger and Humphrey, 1997). Within the studies with this goal, we can also find the impact of concentration at the level of efficiency and productivity as an objective of interest.

Studies in this area have analysed, for example, the impact that cross-border banks have on cost efficiency and competition (Lozano-Vivas and Weill, 2012); the effect that financial liberalization has on banks' total-factor productivity (Tanna et al., 2017); the relationships among competition, bank risk, and measures of efficiency (Leroy and Lucotte, 2016); and the relative cost-effectiveness of banks in areas that enjoy greater economic freedom (Chortareas et al., 2016).

Especially since the economic crisis of 2008–2010, other areas that have been of great importance in studies on banking efficiency are the evaluation of diversification's impact and the absorption of efficiency risks in the banking sector. There is great interest in understanding the relationship between efficiency and group convergence during stable periods (Mamatzakis et al., 2015; Tan and Floros, 2013) or economic crises (Besstremyannaya, 2017; du Toit and Cuba, 2018).

One traditional area in the theory of bank intermediation has gained more relevance; focusing on the dynamics between key regulatory and supervisory policies and on various aspects of banking efficiency. The importance of regulatory issues has been addressed in the governance area (Hughes and Mester, 2008). However, regulatory questions have gained specific contours, and prudential policies and regulatory reforms adopted after the economic crises at the beginning of the century have encouraged further studies in this area; examples include the observations of the new changes, principles, and rules of the Basel Committee (Ayadi et al., 2016).

Usually, these studies seek to identify the relationships that regulatory and supervisory frameworks have with banks' productivity (Delis et al., 2011; Lozano-Vivas and Pasiouras, 2013; Triki et al., 2017). However, the studies also assess the effects of specific regulatory reforms, as Casu et al. (2016) analysed, or even the indirect aspects that depend on banking regulations, such as economic creditor rights and information sharing (Kalyvas and Mamatzakis, 2017).

In addition, several important studies have been concerned with the ways in which mechanisms or governance structures impact banks' efficiency. These studies look for evidence regarding corporate governance's impact on banks' performance (Mamatzakis et al., 2015) or focus on how the level of banking efficiency can impact equity capital markets' disciplinary power (Qian and Yeung, 2014).

Studies in the regulatory and governance areas are closely related to those that seek to evaluate the relations between efficiency and competitiveness in the banking sector. Our paper proposes a classification that seeks to determine the main objectives of the selected studies. In this context, we aim at to further segregate the streams of research to provide a better understanding of studies' advances and the questions they raise.

The analysis of efficiency is directed at several types of FIs. A comparison that is usually made is between Islamic and conventional banks (Abdul-Majid et al., 2017; Wanke et al., 2016a,c). The Islamic banks are those that operate within the rules of Shariah, also known as the "Islamic Rules in Transactions". Many analyses focus on this type of institution when investigating the factors that affect efficiency (Wanke et al., 2016c); other analyses compare the performance of traditional FIs with those of institutes (Wanke et al., 2016a).

Small FIs are also normally segregated into specific analyses. This group of studies usually seeks to evaluate how certain factors impact small institutions. The assumption is that efficiency depends on the size of the FIs; therefore, small FIs would need specific analysis.

In these studies several fields that normally are considered in terms of large banks are targeted only at small FIs. For example, some of these studies evaluate the effectiveness of certain governance mechanisms on the efficiency of small FIs (Hartarska and Mersland, 2012; Servin et al., 2012); others papers determine whether regulatory pressure impacts small FIs' performance (Glass et al., 2014).

One area of banking research is aimed at verifying the merger and acquisition (M&A) processes and the "too big to fail" theory on the efficiency of the financial sector as a whole and of FIs in particular. For some time, scholars have formed a general consensus that the integration of FIs is beneficial up to a certain (relatively small) size, and there is evidence that mergers yield economies of scope and gains in managerial efficiency (Amel et al., 2004). Although, some studies also found that the M&A effect is tenuous and that the distinction between target and acquiring banks must be analysed to obtain more reliable results (Du and Sim, 2015).

The M&A area continues to produce many studies in major financial journals. Current studies seek to assess whether M&As are better when the banks are efficient (Halkos and Tzeremes, 2013) and whether efficiency improvements drive bank megamergers (Devos et al., 2016).

The testing of theoretical hypotheses does not completely dominate banking- efficiency studies. There are also studies with the objective of creating new models or even indicators (using the non-structural approach) to evaluate or measure FIs' performance as in Ouenniche and Carrales Escobedo (2018).

These studies include simulation techniques that are meant to evaluate the accuracy of the estimated inefficiency scores (Goddard et al., 2014), the application of innovative approaches with modifications (Fujii et al., 2014; Tabak et al., 2013), and even model comparisons (Wanke et al., 2016c).

Some of the selected articles did not fit into any of the categories for the objectives. We categorized these articles as "others" because we understand that such new objectives are not yet clear lines of research in the banking literature.

We provide examples of the articles in the sample, but for a deeper analysis of the subjects discussed, we recommend reading the articles directly (see Tab. 2.4).

Table 2.4: Method used for association and mains object of study.

Method used	Object of study																		
	4A		4B		4C		4F		4G		4G		4D		4E		4H		Total
Statistical/Parametrical.	16	18%	10	11%	4	5%	6	7%	1	1%	9	10%	1	1%	2	2%	0	0%	49
Statistical/Semi or Non Parametrical.	4	5%	0	0%	1	1%	2	2%	1	1%	4	5%	0	0%	1	1%	1	1%	14
Mathematical Modelling.	0	0%	0	0%	0	0%	1	1%	1	1%	0	0%	0	0%	0	0%	0	0%	2
Not Applicable.	3	3%	6	7%	1	1%	3	3%	4	5%	3	3%	0	0%	2	2%	0	0%	22
Total.	23	26%	16	18%	6	7%	12	14%	7	8%	16	18%	1	1%	5	6%	1	1%	87

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

2.4 Main Results

2.4.1 Productivity, Citations Networks, Localization, and Clusters

After data tabulation, we classified the articles into large groups based on research area. Fig. 2.1 shows the main research on banking efficiency and the bibliometric dimensions that we evaluated.

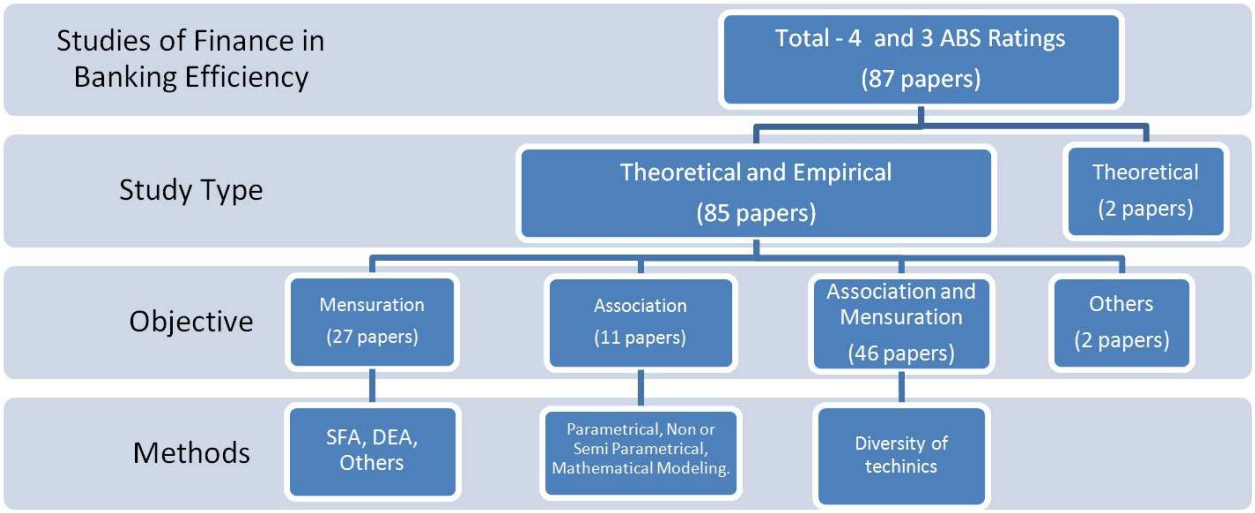

Figure 2.1: Papers distribution.

Fig. 2.1 facilitates the understanding of the articles' distribution among this study's main classification categories. Firstly, we selected the initial sample of articles, following the steps indicated in Tab. 2.2. The second line of this table indicates the distribution of the articles based on type of study; the preponderance of them are empirical studies. After this, the distribution of the works' main objectives is indicated. Finally, this tables shows the link between studies' purposes and the techniques they employed.

Tab. 2.5 shows the distribution of the 87 articles that we identified from high-quality journals referenced in ABS (2015) from January 2011 through July 2017, based on the contents of their titles, abstracts, and keywords. It is noteworthy that, of the 37 high-quality journals, only 15 had at least one publication on banking efficiency in the period evaluated. This result shows that most of the analysed financial journals have not been interested or have been difficulties to receive studies in this area. In addition, most of the published articles came from the *Journal of Banking & Finance*, which makes sense due to this journal's focus on banking issues.

Tab. 2.5 also depict the evolution of the number of publications per year. Only one journal had consistent publication in every year: the *Journal of Banking & Finance*. In the other journals' publications were scattered, which demonstrates that they have not targeted the area of banking efficiency and have only a circumstantial interest in the subject matter.

Table 2.5: Papers quantity per periodical and year of publication.

Journal	Year							
	2011	2012	2013	2014	2015	2016	2017/1	Total
Journal of Banking & Finance.	5	4	9	3	2	3	2	28
Journal of International Financial Markets, Institutions & Money.	1	0	4	5	0	4	1	15
Journal of Financial Stability.	0	3	0	1	1	2	1	8
Journal of Money, Credit and Banking.	2	1	0	1	1	1	0	6
Journal of Financial Services Research.	2	1	1	0	0	0	0	4
European Financial Management.	0	2	0	0	0	0	0	2
Review of Quantitative Finance and Accounting.	1	0	1	1	0	0	0	3
Financial Management.	0	0	1	0	0	1	0	2
Financial Markets, Institutions and Instruments.	2	0	0	0	1	0	0	3
Journal of Empirical Finance.	1	0	0	0	0	1	1	3
The European Journal of Finance.	3	0	2	0	1	1	1	8
International Review of Financial Analysis.	0	1	0	0	0	1	0	2
Journal of Corporate Finance.	0	0	0	1	0	0	0	1
Quantitative Finance.	0	1	0	0	0	0	0	1
The Journal of Financial Research.	0	0	0	0	0	1	0	1
Total.	17	13	18	12	6	15	6	87

To detect and interpret patterns and ties among the researchers, geographic regions, and institutions that are producing state-of-the-art studies on banking efficiency, we conducted a set of network analyses. We set up a network-adjacency matrix to indicate which pairs of items in the network were linked by citations. More pairs of linked items indicate greater strength of their relations.

The distance between circles expresses the number of ties as closely as possible (see, for example, Fig. 2.3). In other words, closely connected papers are closer together than are unrelated papers.

We use this association-strength method to normalize the strength of the links between the items and to generate a network layout. This is also known as a probabilistic affinity index, a proximity index, or a pseudo-cosine. van Eck and Waltman (2009) expressed this method's advantages; its equation is presented as Eq. 2.1, where c_{ij} is the observed number of co-occurrences and $s_i s_j$ is the expected number of co-occurrences for papers i and j.

$$S_A(c_{ij}, s_i, s_j) = \frac{c_{ij}}{s_i s_j}, \tag{2.1}$$

We use a unified approach to drawing and clustering bibliometric networks, as proposed by Waltman et al. (2010). This approach has the advantage of starting from similar ideas and assumptions, unlike the many works that combine techniques with different principles (Waltman et al., 2010).

However, we drew our political maps using geographical coordinates that represent the institution location for each work's first author (for an example, see Fig. 2.2). The links between the studies are displayed, and the strength of the links are expressed by the sizes of the circles.

Fig. 2.2 shows how journals are distributed across the world and describes their relationships via the citation network. The two journals with the most publications, *Journal of Banking & Finance* and *Journal of International Financial Markets, Institutions & Money*, publish articles

from institutions in many countries.

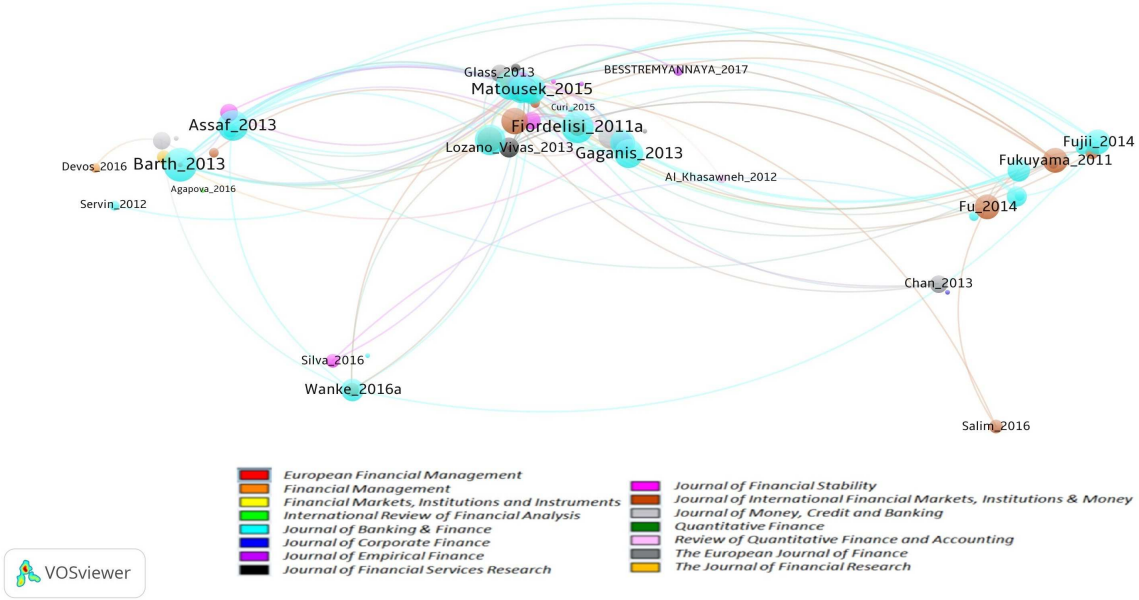

Figure 2.2: Network journals - distribution around the world.

The visualization of the position and location on the drawing, as carried out using Waltman et al.'s (2010) approach, makes it possible to verify that finance studies tend to be strongly influenced by the periodicals in which they are published. One point that deserves to be highlighted regarding network design is that the *Journal of International Markets, Institutions & Money* functions as an interconnection between the three large groups indicated in the network in Fig. 2.3.

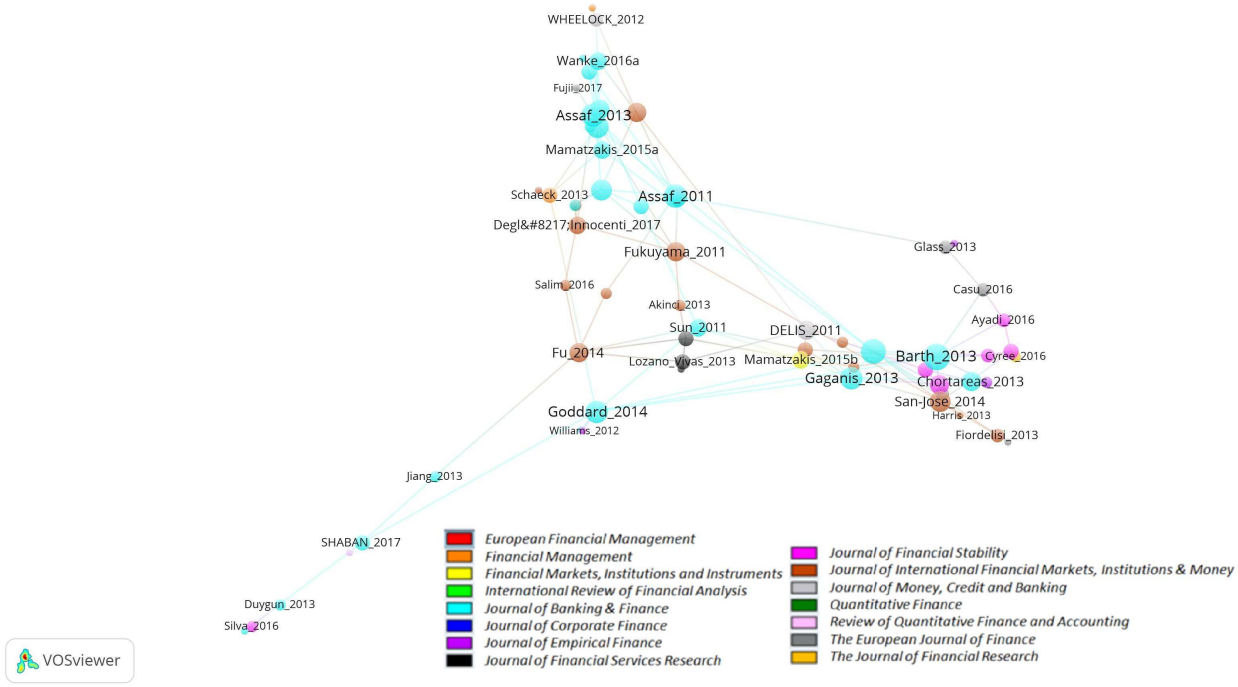

Figure 2.3: Network journals - strength relation and clusters.

We can verify that the relationships between the studies are related to their journals. Papers tend to be based more strongly on past studies that were published in the same journals that they are eventually published in. On the other hand, Fig. 2.4 is a visualization of the network in which each specific agent is a vertex of the network. This result shows that the *Journal of Banking & Finance* has great centrality and that it connects the main studies on banking efficiency.

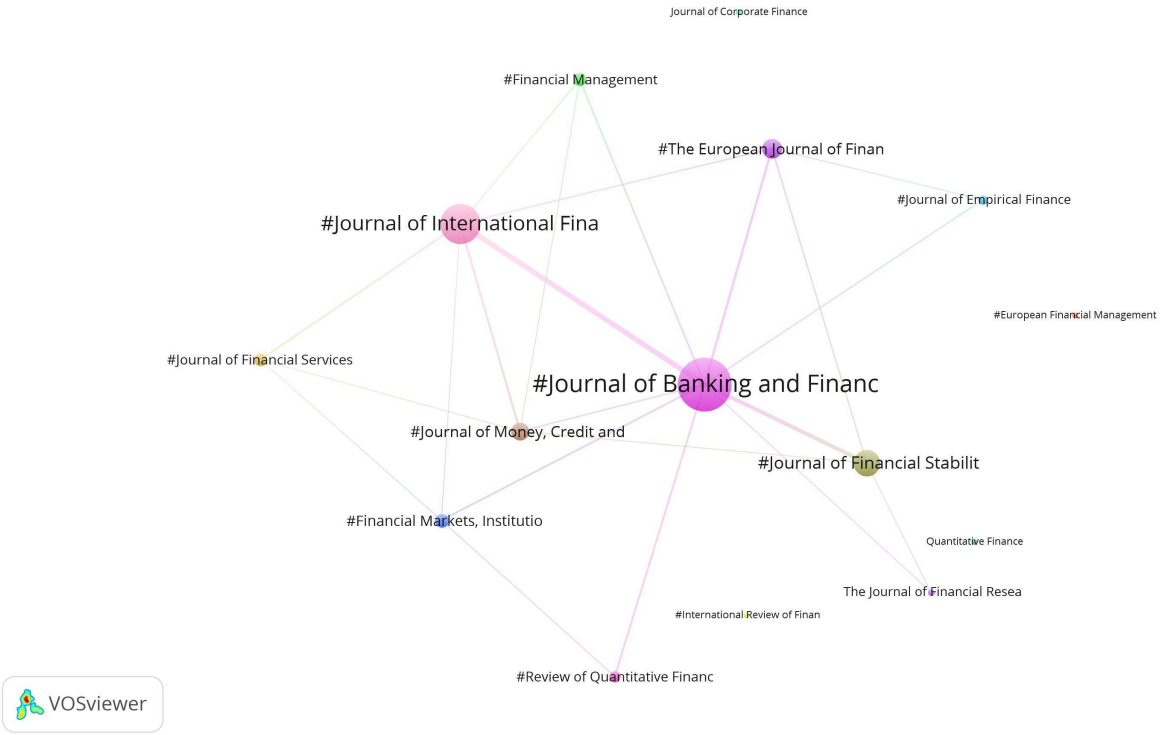

Figure 2.4: Network - centrality of main journals.

The network shows that journals are connected, and information reaches the majority of journals. However, we should note that the network's structure is similar to that of a star-network. In other words, the *Journal of Banking & Finance* (central vertex) is connected to most all other journals, including an indirect link to the *Journal of International Markets, Institutions & Money*, but the other journals have weak connections among themselves.

Tab. 2.6 shows the number of articles according to their number of authors and journals of publication. We verified that the most common number of authors was three, followed immediately by two. It is important to note that articles with only one author are rare, which indicates that most works in the sample are constructed from collaboration or from the preparation of papers during academic courses.

Table 2.6: Number of papers by quantity of authors journals.

Journal	Number of Authors					
	1	**2**	**3**	**4**	**5**	**Total**
Journal of Banking & Finance.	0	6	17	4	1	28
Journal of International Financial Markets, Institutions & Money.	0	7	5	3	0	15
Journal of Financial Stability.	1	2	3	2	0	8
Journal of Money, Credit and Banking.	1	3	2	0	0	6
Journal of Financial Services Research.	0	1	3	0	0	4
European Financial Management.	0	2	0	0	0	2
Review of Quantitative Finance and Accounting.	1	0	1	0	1	3
Financial Management.	0	1	1	0	0	2
Financial Markets, Institutions and Instruments.	0	2	1	0	0	3
Journal of Empirical Finance.	1	1	1	0	0	3
The European Journal of Finance.	0	2	3	3	0	8
International Review of Financial Analysis.	0	1	1	0	0	2
Journal of Corporate Finance.	0	1	0	0	0	1
Quantitative Finance.	1	0	0	0	0	1
The Journal of Financial Research.	1	0	0	0	0	1
Total.	6	29	38	12	2	87

In addition, Tab. 2.7 shows the authors' level of production in the area of banking efficiency and in the selected journals. The author who stood out most from the group, with ten publications in the sample, was Roman Matousek, who is a professor at Kent Business School in the United Kingdom. The second-most prominent author was Claudia Girardone, a professor at the University of Essex, also in the United Kingdom. Tab. 2.11 shows the research objectives of the four most productive authors.

Table 2.7: Number of published articles and number of authors.

Number of Published Articles	Number of Authors
1	117
2	25
3	6
4	6
5	2
6	0
7	1
8	0
9	0
10	1
Total	158

Seeking a further indication of the low productivity of individual authors in banking efficiency, we carried out a test using the equation for the Lotka constant (Lotka, 1926), where a_n is the number of authors who have published n articles, a_1 is the number of authors who have published just one article, and c is the Lotka constant. For finance articles, this constant is estimated to be approximately 2 (Chung and Cox, 1990), as shown in Tab. 2.8. This test confirms the low productivity of this research area relative to that of finance research as a whole (Chung and Cox, 1990).

$$log\left(\frac{a_n}{a_1}\right) = -c.log(n) + \varepsilon, \tag{2.2}$$

Table 2.8: Test of Lotka constant (Productivity).

Coefficient	Coefficients	Standard Error	Stat t	$P-value$
Intercept (forced 0).	0	-	-	-
Variable X, log(n).	4.846	1.013	4.781	0.0014

Note: Observations with values equal to zero would generate the calculations of undefined values (log 0). In order not to lose the observations, we have replaced those by values proximally zero.

We emphasize that the concept of productivity used should not be interpreted in order to indicate the authors' general productivity. That is, the concept of productivity that we use expresses a quantity of articles produced in this specific subject matter, i.e. banking efficiency in the finance area. Thus, for example, many authors can be quite productive, but in consequence of the fact that they are working in different fields they end up not having all their studies evaluated in our research focused on efficiency of FIs.

Thus, the productivity concept of Lotka's Law is adequate mainly to indicate a low scientific autonomy of the area. In other words, the significant distance between the most productive authors and the others would be an evidence that the area is not yet a specific field of knowledge, and is still a field within other areas, such as Banking, Finance or Operational Research.

Regarding the countries of the authors' affiliations, the nation that contributed the most to the sample was the United Kingdom (29 papers), which had more than twice as many articles as the second-place United States (11 papers). This is particularly surprising given the U.S. tradition in the study of finance and the relatively large sizes of the U.S. economy and population compared to those of the United Kingdom.

Fig. 2.5 confirms the strong concentration of the research from the European continent. The density of relationships and quantity of articles are indicated by the red colour.

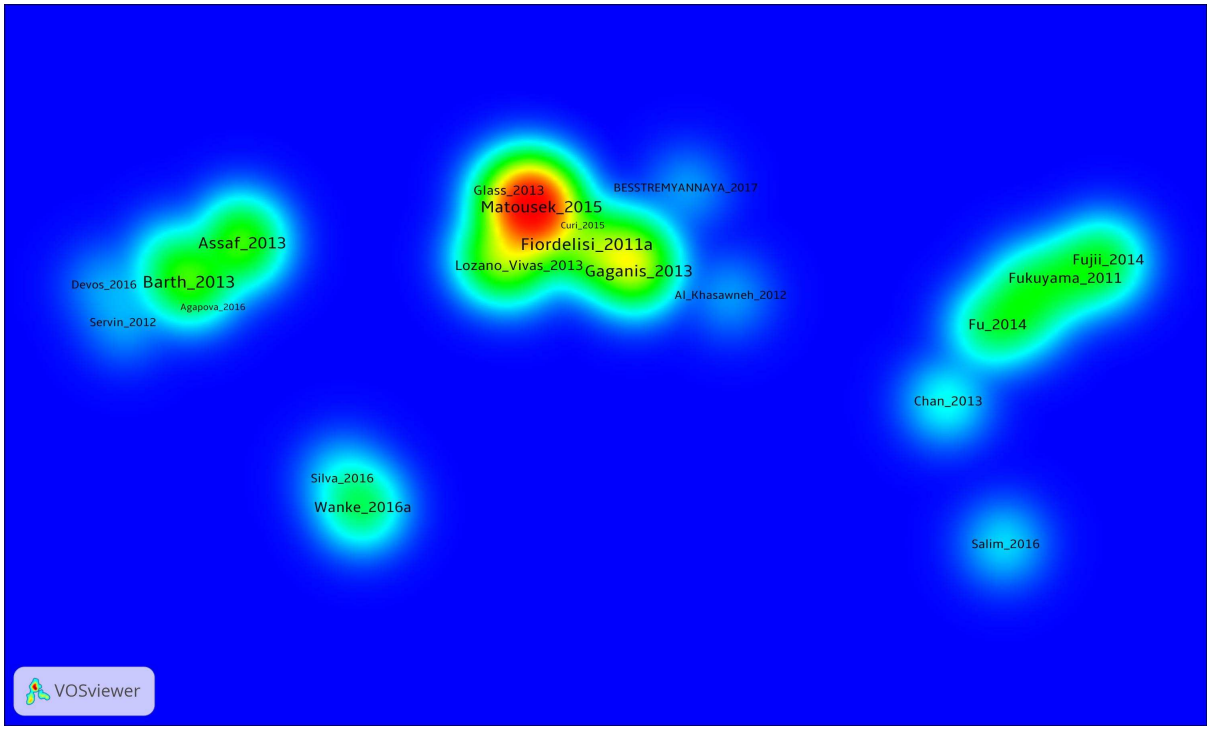

Figure 2.5: Density and locality of research on banking and efficiency.

We can visualize the papers structure and countries relationships according to the pattern of their citation (Fig. 2.6). For instance, the nations whose works either cite or are cited by almost all of the other countries are classified as core countries; they are in the centre of the circle. The world network has a great level of centrality, and the disposition of connections shows how information spreads easily and how the centre works to transmit information between the countries. In this case, we presuppose that authors exchange information in both directions when linked by a citation.

The direct and indirect links between the origins of the studies by country are better analysed in the circular network depicted in Fig. 2.6. The centrality of the United Kingdom is indicated in this figure, which also makes it possible to verify which countries have papers with direct and indirect links to other countries.

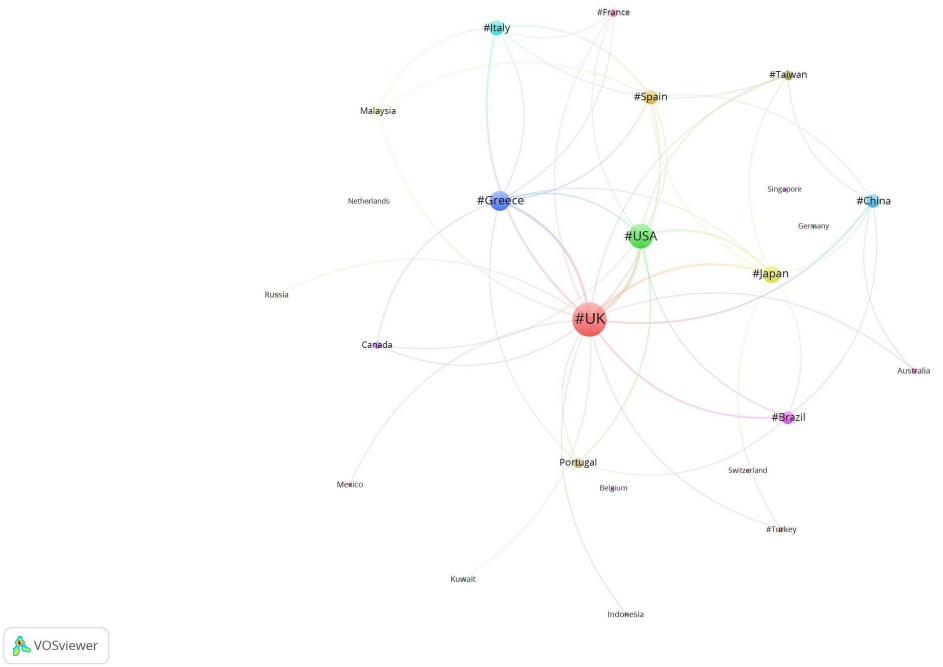

Figure 2.6: Countries centrality of research on banking efficiency.

Tab. 2.9 shows the objectives that had the highest number of articles in the study's period. The links between diversification, risk, and banking efficiency (4B) were highlighted in 16 published articles (the largest number); the next most popular objectives were those that linked supervisory and regulatory factors (4H) and those that combined competitiveness and concentration (4A).

As we discussed, scholars in the diversification and risk area seek to create empirical models and studies to evaluate various financial risks so as to meet needs caused by business failures and economic crises. This area has had singular relevance in studies of banking efficiency, mainly those with structural approaches; it includes the risk variable in the measurement of FIs' efficiency, which the traditional studies that form the foundation of microeconomic theory did not do.

The banking literature in supervision and regulation considers the effects that banks' regulatory environment, including capital requirements and regulatory or supervisory policies, have on banking efficiency (Barth et al., 2013; Ayadi et al., 2016; Pessarossi and Weill, 2015). Another area of study is the evaluation of the differences between regulated and unregulated FIs, which is hypothesised to generate comparative inefficiencies within the financial market (Barros and Wanke, 2014). These issues appear to have been driven by recent financial crises and by the consequent imposition of additional prudential regulations such as the Basel Accords.

The competitiveness and concentration objective involves measuring the impact that competitiveness of different markets has on FIs' efficiencies. It is common to involve evaluations of possible associations between advances in economic freedom and indicators of market performance and efficiency. Although this area is quite traditional (Berger and Humphrey, 1997), new issues have been found, including the complementary roles that financial freedom and free political systems play in increasing banking efficiency (Chortareas et al., 2013).

Another commonly researched objective involves M&As, which accounted for 13.7 % of the total studies. Research in this area seeks to understand the causes and effects of M&A processes, especially those that create gains in economic efficiency or in returns. Topics in this area range from the relation between banking efficiency and merger processes and the resulting efficiency when two efficient banks combine via M&A (Pasiouras et al., 2011; Halkos and Tzeremes, 2013), as shown in Tab. 2.9.

Table 2.9: Papers by year of publication according to main object of study.

Year	4A		4B		4C		4F		4G		4G		4D		4E		4H		Total
2011	4	17%	5	31%	0	0%	4	33%	1	14%	2	13%	0	0%	1	20%	0	0%	17
2012	6	26%	1	6%	0	0%	1	8%	2	29%	1	6%	0	0%	2	40%	0	0%	13
2013	3	13%	3	19%	3	50%	2	17%	2	29%	4	25%	0	0%	1	20%	0	0%	18
2014	1	4%	2	13%	1	17%	3	25%	1	14%	3	19%	0	0%	1	20%	0	0%	12
2015	1	4%	2	13%	1	17%	0	0%	0	0%	2	13%	0	0%	0	0%	0	0%	6
2016	5	22%	2	13%	1	17%	1	8%	1	14%	3	19%	1	100%	0	0%	1	100%	15
1/2017	3	13%	1	6%	0	0%	1	8%	0	0%	1	6%	0	0%	0	0%	0	0%	6
Total.	23	100%	16	100%	6	100%	12	100%	7	100%	16	100%	1	100%	5	100%	1	100%	87

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

Tab. 2.10 shows some journals' specializations in terms of objectives and thematic areas. The *Journal of Banking & Finance* has concentrated more than 60% of its articles on the 4B and 4G approaches, indicating that this journal has a lot of interest in articles that provide innovative measurement models or evaluations of banking efficiency. For example, Caselli et al. (2016) found that banks' share-price losses following sovereign downgrades increased as their efficiency increased and as banks' systematic risk increased.

In contrast, as an example of a study with a newly proposed model (4G), Holod and Lewis (2011) showed that the effect that the amount of deposits has on banking efficiency depends on different stages of the bank- production process. The authors proposed an alternative DEA model in which deposits were an intermediate product. They argued that one weakness of current banking-efficiency models is a lack of consensus of the role that deposits play in the bank-production process.

In the *Journal of International Financial Markets, Institutions & Money*, 70% of the articles focused on the 4B and 4H areas. As expected due to its scope, most of the papers in the Journal of Financial Stability concentrated on banking efficiency in the supervisory and regulatory approaches, as these issues are directly linked to the need for financial- market stability. One case study with regulation as its main objective is Barth et al. (2013), which states that stronger official supervisory power is positively associated with greater banking efficiency only in countries that have independent supervisory authorities. The results are shown in Tab. 2.10.

Table 2.10: Main object of study by journal.

Journal	Object of Study																					
	4A		4B		4C		4F		4G		4G		4D		4E		4H		Total			
European Financial Management.	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	1.15%	0	0.00%	2			
Financial Management.	1	1.15%	0	0.00%	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2			
Fin. Mark. Inst. and Instruments.	0	0.00%	1	1.15%	1	1.15%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3			
J. of Banking & Finance.	7	8.05%	6	6.90%	2	2.30%	2	2.30%	6	6.90%	2	2.30%	1	1.15%	2	2.30%	0	0.00%	28			
J. of Corporate Finance.	0	0.00%	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1			
J. of Empirical Finance.	1	1.15%	1	1.15%	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3			
J. of Financial Services Research.	0	0.00%	1	1.15%	0	0.00%	2	2.30%	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	4			
J. of Financial Stability.	3	3.45%	2	2.30%	0	0.00%	0	0.00%	0	0.00%	3	3.45%	0	0.00%	0	0.00%	0	0.00%	8			
J. of Int. Fin. Mark. Inst. & Money.	2	2.30%	4	4.60%	1	1.15%	1	1.15%	1	1.15%	4	4.60%	0	0.00%	1	1.15%	1	1.15%	15			
J. of Money, Credit and Banking.	1	1.15%	0	0.00%	0	0.00%	1	1.15%	0	0.00%	4	4.60%	0	0.00%	0	0.00%	0	0.00%	6			
Rev. of Quant. Finance and Accounting.	1	1.15%	0	0.00%	0	0.00%	2	2.30%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	3			
Int. Review of Financial Analysis	2	2.30%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	2			
The J. of Financial Research.	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	1			
Quantitative Finance.	0	0.00%	1	1.15%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1			
The European J. of Finance.	4	4.60%	0	0.00%	1	1.15%	1	1.15%	0	0.00%	1	1.15%	0	0.00%	1	1.15%	0	0.00%	8			
Total.	23	26%	16	18%	6	7%	12	14%	7	8%	16	18%	1	1%	5	6%	1	1%	87			

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

Referring to the thematic approach adopted by the selected studies' authors, Tab. 2.11 presents some insights regarding the works of the most prominent authors. The most productive author, Roman Matousek, published studies using three approaches, but the other authors focused on specific approaches; for instance, Franco Fiordelisi published three articles on the relationships that efficiency has with competitiveness and banking concentration.

Table 2.11: Authors and main object of study - at least five publications.

Author	4A	4B	4C	4F	4G	4H	4D	4E	Others	Total
Roman Matousek.	2	2	0	1	2	1	0	1	1	10
Claudia Girardone.	1	0	0	2	0	1	0	0	0	7
Georgios E. Chortareas.	0	0	0	1	0	3	0	0	0	5
Emmanuel Mamatzakis.	0	2	0	0	1	1	0	0	0	5

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

It should be noted that the authors Georgios E. Chortareas, Alexia Ventouri, and Claudia Girardone shared the same research focus because these authors worked together on their articles. However, the most productive authors focused on the area that links efficiency to competitiveness and banking concentration.

From Tab. 2.12, it is possible to verify that the thematic approaches are widely distributed among the studies of banking efficiency. The search for measurements of efficiency or associations between various factors and efficiency is thus not linked to a particular thematic approach.

Table 2.12: Main object of study and objective.

Objective	Object of Study																
	4A		4B		4C		4F		4G		4G		4D		4E		4H	Total
Measurement.	4	5%	6	7%	1	1%	2	2%	5	6%	1	1%	0	0%	2	2%	0	0%	21
Association.	5	6%	1	1%	1	1%	2	2%	0	0%	2	2%	0	0%	0	0%	0	0%	11
Measurement and Association.	14	16%	9	10%	4	5%	6	7%	2	2%	11	13%	1	1%	3	3%	1	1%	51
Not Applicable.	0	0%	0	0%	0	0%	2	2%	0	0%	2	2%	0	0%	0	0%	0	0%	4
Total.	23	26%	16	18%	6	7%	12	14%	7	8%	16	18%	1	1%	5	6%	1	1%	87

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

Still, in relation to the studies' objectives, the analysis of networks in Fig. 2.7 allows the visualization of how the approach that joins measurements and associations is the most prominent (this includes relationships based on citations). The approach that measures efficiency is the second-most common. However, there are few links among the articles that focus only on associations.

We verify that, currently, the main focuses of banking-efficiency studies are the measurement of efficiency and the association of other variables with efficiency. However, Fig. 2.7 indicates that studies with the main objective of measuring efficiency have stood out in several regions, including in Europe, which has the main concentration of papers.

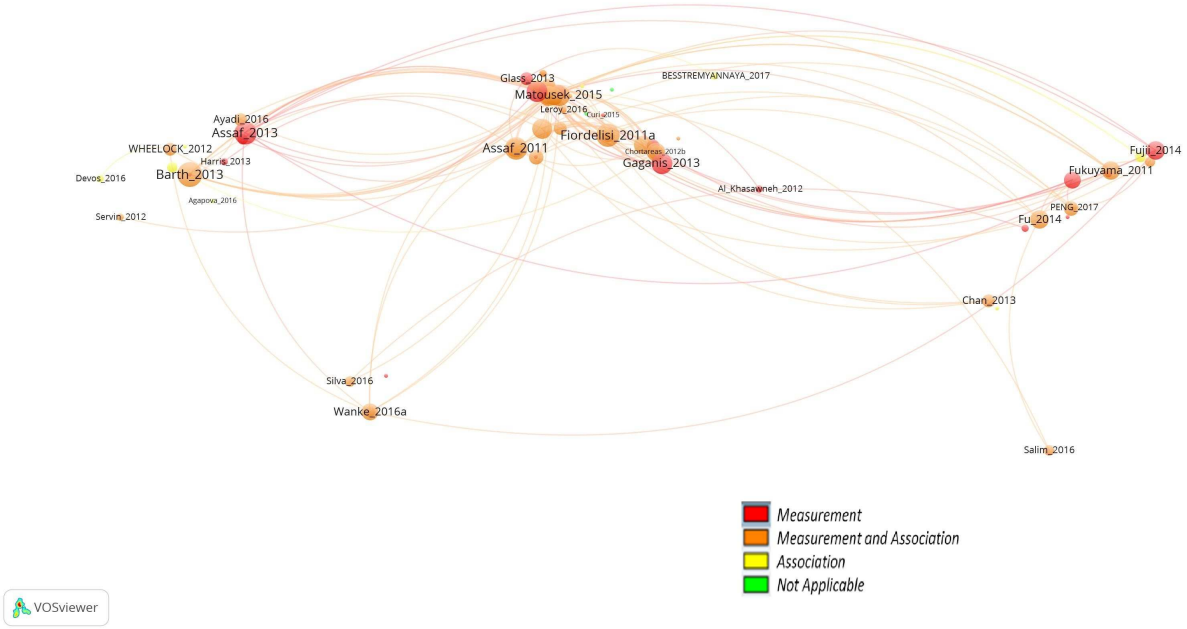

Figure 2.7: Network objective of study - distribution around the world.

However, there does not seem to be any relationship between the clusters, according to the network of citations and the previous classifications related to the purpose of the studies. The visual network in Fig. 2.8 indicates that the articles with the objective of measurement are grouped in clusters, which suggests an interconnection between the studies. This result was expected, as the majority have two the main objectives (efficiency measurement and the association of variables).

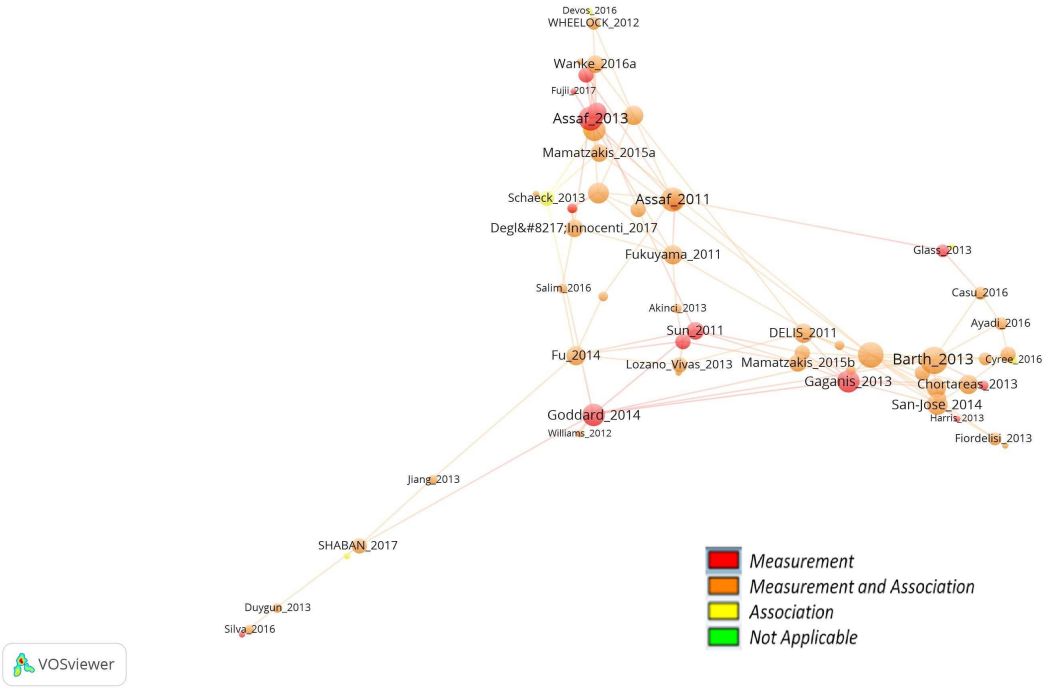

Figure 2.8: Network objective of study - strength relation and clusters.

Regarding the empirical technique used in the studies, we have verified the predominance of SFA and DEA in the measurement of efficiency for the various thematic approaches. Both methods are used to measure banking efficiency. Although studies' methods are advancing, the improvements lie within application and refinement; they are not altering the fundamentals of the methods. The main changes are been used by banking studies to solve constraints in the assumptions of the models (convexity, heterocedasticity, etc.) and the increase of possibilities in their structures (network models, slack based measures, etc.). For example, network DEA models have been a workaround to the old discussion about the nature of bank deposits since they allow intermediate variables as in Wanke et al. (2017).

These tools both focus on association and measurement, and they tend to be used together, which allows researchers to evaluate the results obtained from the two methods. Here again, we can check the biases of the structural and non-structural approaches. Efficiency frontiers are usually addressed using an established theoretical framework and a linear optimization approach such as DEA. The results are given in Tab. 2.13.

Table 2.13: Method used for measurement and main object of study.

Method Used	Object of Study																		
	4A		4B		4C		4F		4G		4G		4D		4E		4H		Total
DEA.	12	14%	3	3%	2	2%	5	6%	2	2%	4	5%	1	1%	1	1%	0	0%	30
SFA.	6	7%	10	11%	3	3%	3	3%	3	3%	8	9%	0	0%	3	3%	0	0%	36
Others.	1	1%	2	2%	0	0%	1	1%	2	2%	0	0%	0	0%	1	1%	1	1%	8
Not Applicable.	4	5%	1	1%	1	1%	3	3%	0	0%	4	5%	0	0%	0	0%	0	0%	13
Total.	23	26%	16	18%	6	7%	12	14%	7	8%	16	18%	1	1%	5	6%	1	1%	87

Note: Islamic and Conventional Banks (4D), Banking Supervision and Regulation (4H), Mergers and Acquisitions and TBTF (4F), Competitiveness, Concentration and Efficiency (4A), Efficiency in Small Institutions (4E), Governance (4C), Diversification and Risk (4B), and Mod Alter Proposal, Simulation (4G).

We emphasize that works with different measurement techniques are related through their citation networks. In Fig. 2.9, many lines change colours, indicating that the related articles use different measurement techniques.

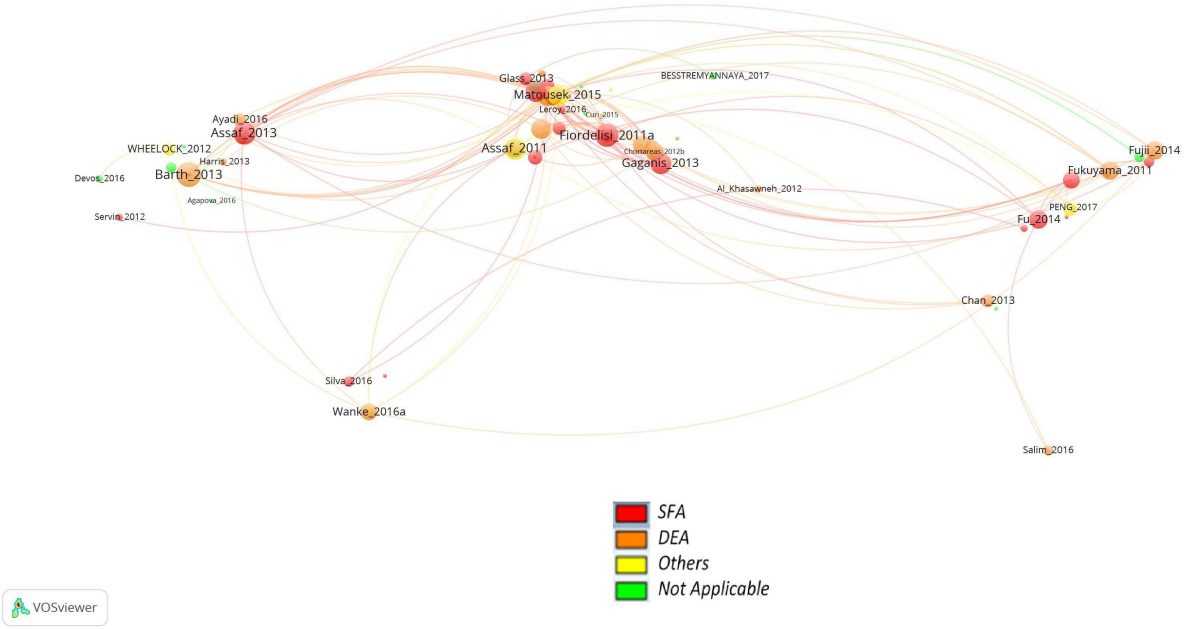

Figure 2.9: Network - main measurement technique and space.

There is also a large geographic dispersion of methods for measuring efficiency, and the institutions' geographic origins indicate no preference for particular measurement methods. The classical methods of measurement (DEA and SFA) are dispersed across continents, as are other, less well-known methods of measurement. The design clusters (see Fig. 2.10) can be used to visually verify that a study's methods tend to influence the methods in its network of citations, which indicates either a difficulty in dissemination or an interaction between the articles that use different methodological approaches.

The result was not expected in view of the highly empirical nature of banking efficiency research. Thus, the surveys were expected to communicate with greater heterogeneity regardless of the method of measurement. The literature in the area does not discuss whether any measurement method would be more appropriate for specific research subjects or topics in banking efficiency. Thus, the reason for the cohesion of studies using the same method remains a question. A possible hypothesis would be the bias of the authors regarding the method employed and, therefore, the easier and more likely citation of an article with a similar methodological process.

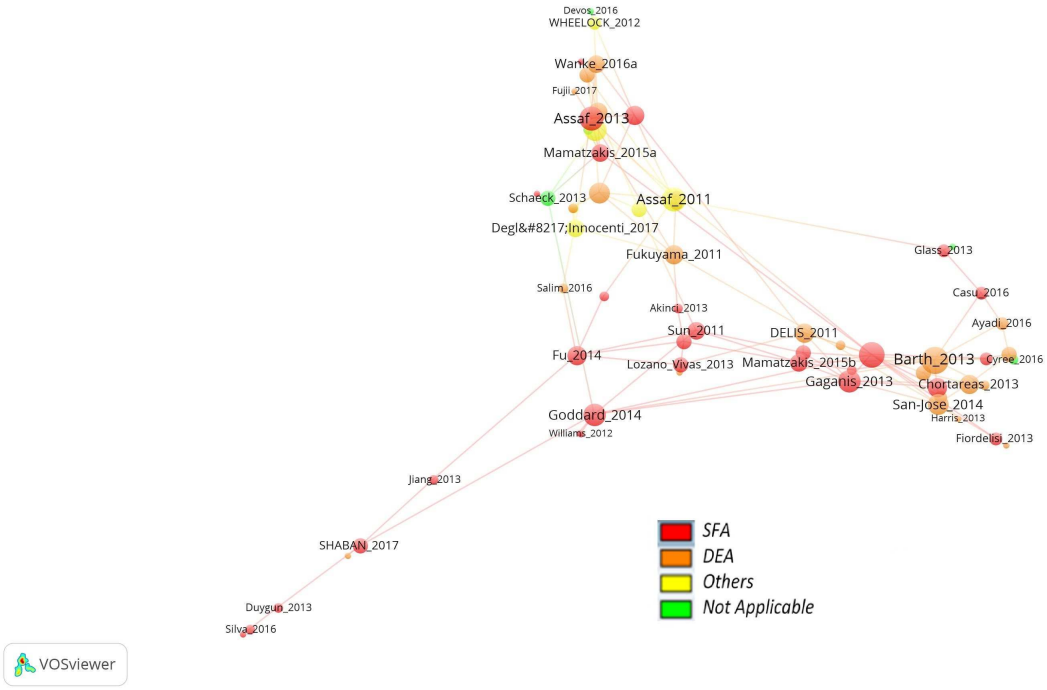

Figure 2.10: Network - main measurement technique and clusters.

The results found for the association methods are also geographically dispersed, which is illustrated in Fig. 2.11. However, Fig. 2.12 indicates that the works that use totally parametric methodologies and those that adopt non- or semiparametric methods for the tests of association of variables to banking efficiency are not totally segregated between the quotes. This tends to demonstrate the greater acceptance of methods that deviate from the classic statistical methods based on the generally accepted parametric distributions.

In contrast, studies focused on measurement, within the clusters, were also observed in the surveys with similar approaches in the method of association (see Fig. 2.12). At this point, however, the result was expected because the use of classic parametric methods depends heavily on the nature of the data used and, therefore, on the research topic.

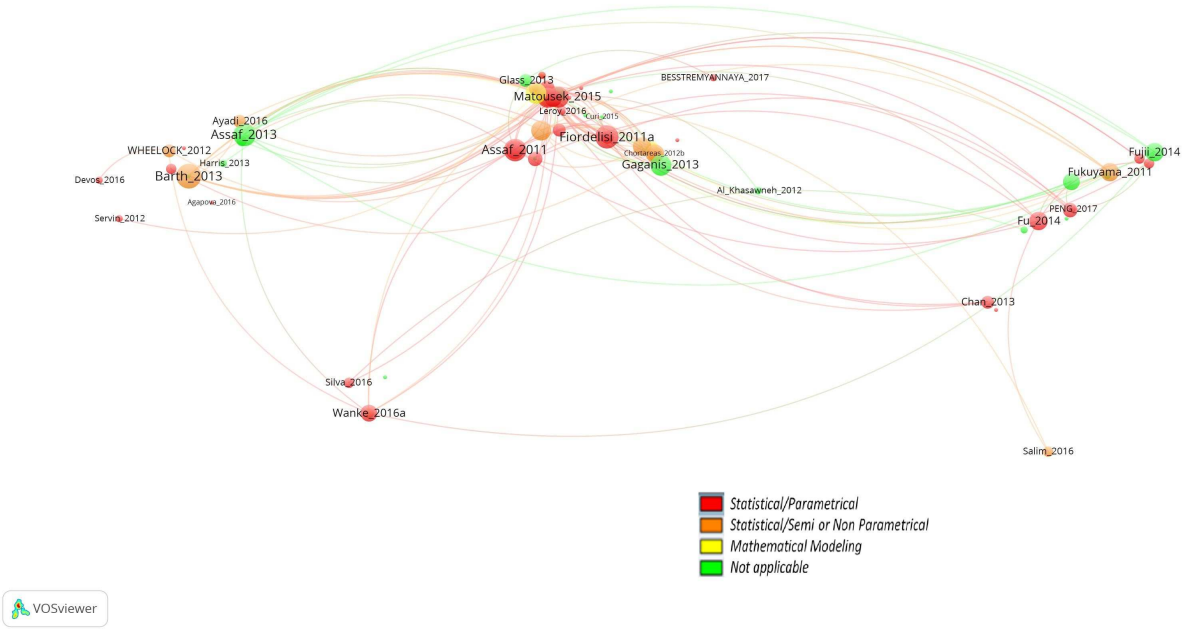

Figure 2.11: Focus of main association technique of research.

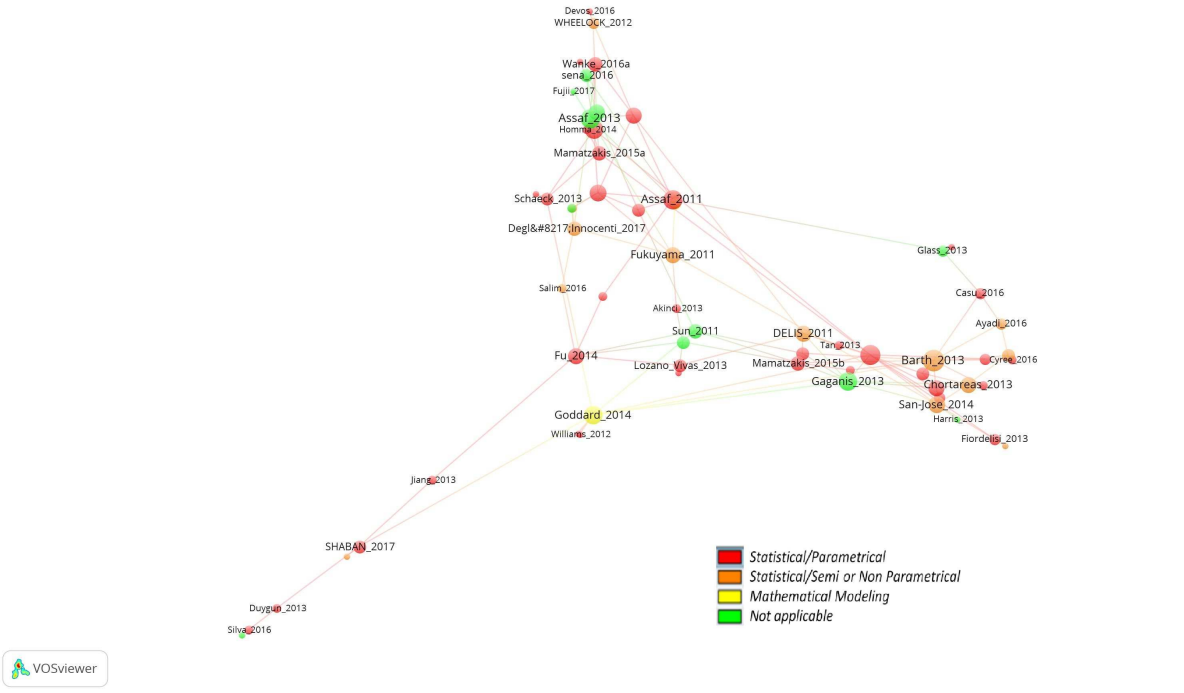

Figure 2.12: Focus of main association technique of research.

Finally, both the geographic distribution and the network design formed by clustering are well distributed, as shown in Figs. 2.13 and 2.14. However, it is possible to visualize the proximity and clustering compliance between the Supervision (black), Competitiveness (red), and Alternative Models (Purple) groups. These areas demonstrated a larger network of citations between the

studies, which theoretically indicates more mature areas of research objectives in the field of banking efficiency.

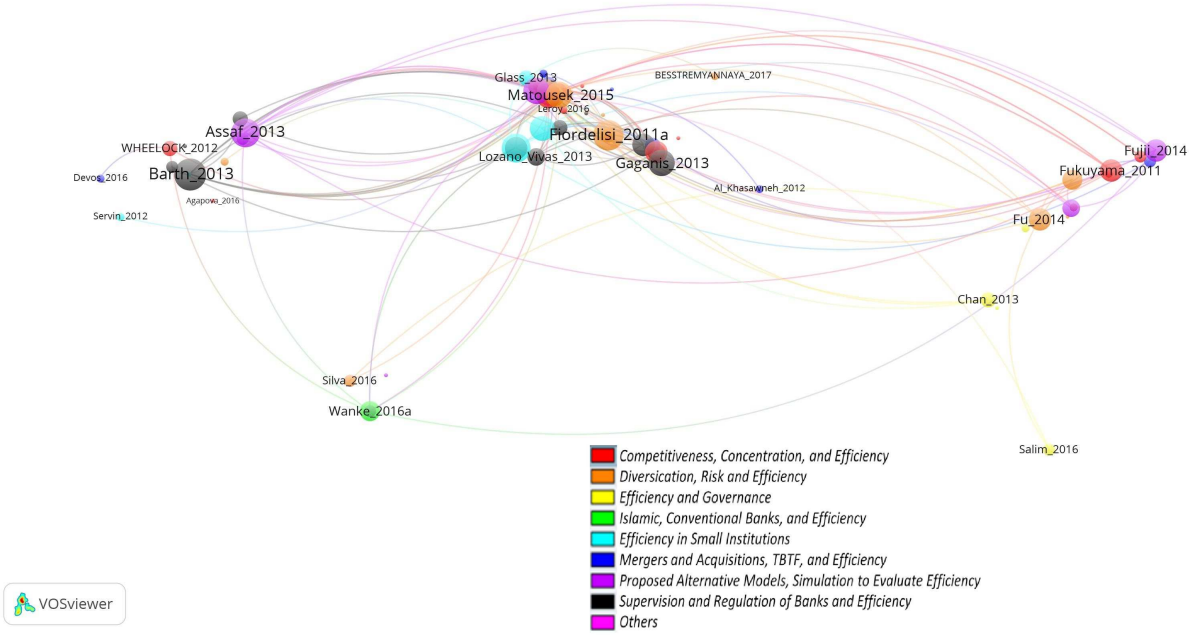

Figure 2.13: Object of study - space.

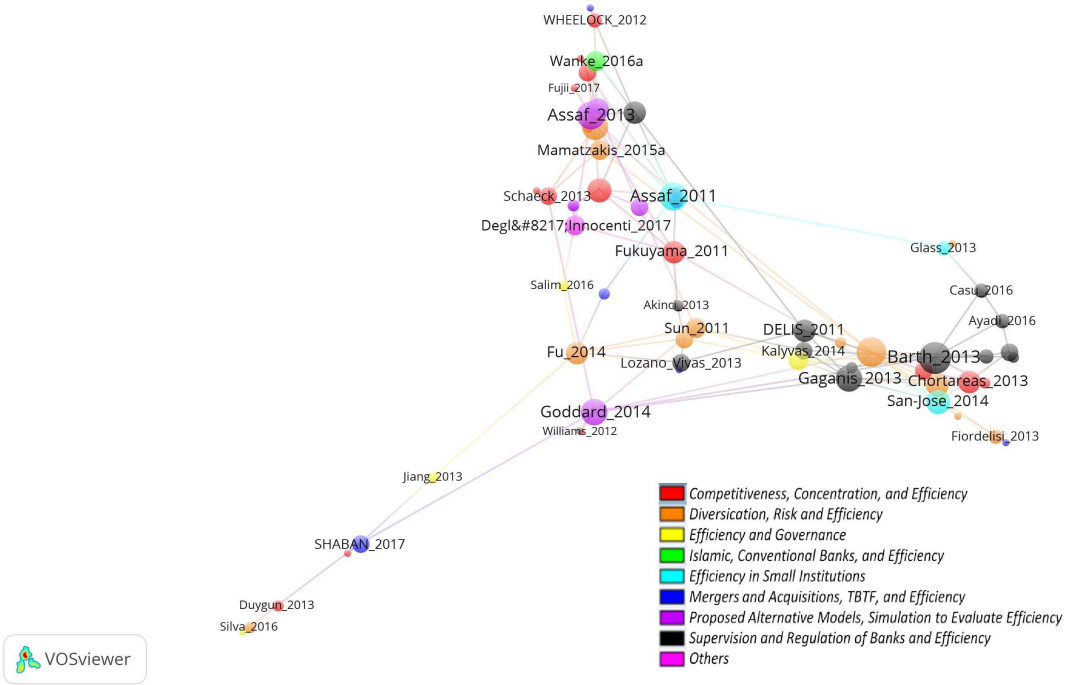

Figure 2.14: Object of study - clusters.

2.4.2 Analysis of the main research paths

We also looked for areas that had an incremental development of knowledge in the last years. We used a technique called main path analysis that was developed by Hummon and Doreian (1989). The presumption of the technique is that information flows through citations and, for that reason, the studies that are needed in many paths between several papers are treated as more crucial than those that are not necessary for connection between studies.

In our citation analyses, we found two main paths. Fig. 2.15 shows that the first path starts with Delis et al. (2011), Fiordelisi et al. (2011) and Chortareas et al. (2012b), and finally ends with Shaban and James (2017). The second and strongest path starts with Assaf et al. (2011) and Sun and Chang (2011) and ends with Sena et al. (2016), Degl'Innocenti et al. (2016) and Wanke et al. (2016b).

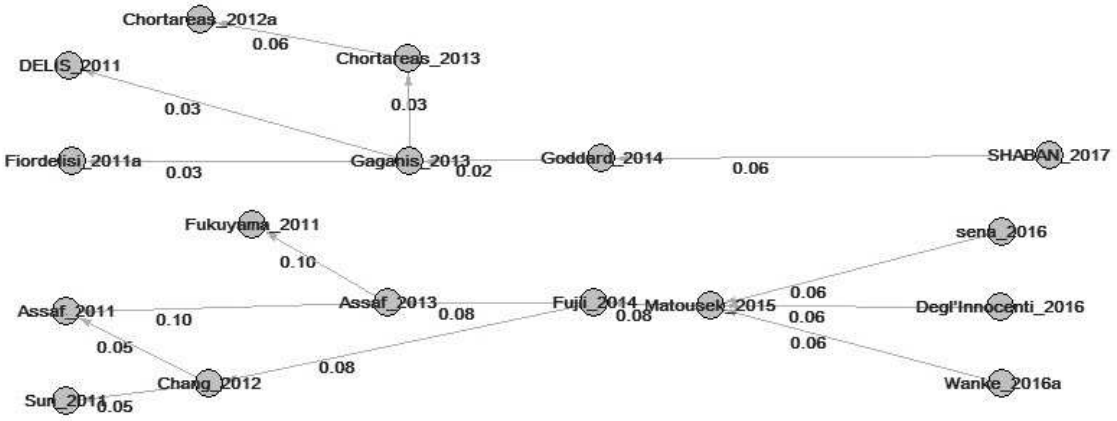

Figure 2.15: Two main research paths.

The main paths demonstrate a lack of sub-specialization in the research areas related to the efficiency of FIs. The main paths include important studies with various research objectives. However, there are two points of integration. The first relates to the measurement method used. We found that many of the participants of the main paths used the study by Simar and Wilson (2007) in their regression models after measurement using DEA models (Chortareas et al., 2013, 2012b; Delis et al., 2011). The second path refers to studies that assess the impact of banking regulation and supervision on the efficiency of FIs.

The bootstrapped truncated regression model of Simar and Wilson (2007) appears as a paradoxical method in the area where it is necessary to perform regressions from DEA models to measure banking efficiency. The authors showed through simulation that the Tobit regression model used so far yielded inconsistent and biased estimates. Currently, few studies in the major financial journals use the Tobit regression when DEA is applied to measure efficiency. A rare example of a Tobit model study was found in an article by Wanke et al. (2016b).

Regarding the effect of banking regulation and supervision, the controversial issues continue to generate a large number of studies in the banking area and also in the specific issues of efficiency in FIs. The papers in these areas participated in the first path, with great integration between the works.

One of the groups of authors who started the first path was Delis et al. (2011). They followed the method of Simar and Wilson (2007) and found that policies (incentives or regulations) that promote private monitoring and restrictions on activities have a positive impact on bank productivity. In addition, Delis et al. (2011) suggested that in moments of financial pressure, other factors such as stringent capital and supervisory standards would have positive effects on productivity as well.

The results of the study by Delis et al. (2011) were contradictory to those found by Chortareas et al. (2012b). This study analysed the association between banking efficiency and both regulatory and supervisory factors. However, the main results suggested a positive relationship between strengthening capital restrictions and official supervisory powers with operational banking efficiency. Nevertheless, interventionist policies could result in higher levels of banking inefficiency. Chortareas et al. (2012b) used DEA to measure efficiency and truncated regressions (Simar and Wilson (2007)) and generalized linear models to evaluate the association of variables.

Following this line of research, Chortareas et al. (2013) analysed the relationship between financial freedom counterparts and banking efficiency levels. The authors measured banking efficiency using DEA and the truncated regression model of Simar and Wilson (2007) to test the association between economic freedom and efficiency. The main results suggested that the degree of an economy's financial freedom is associated with better benefits for banking efficiency. These findings contradict results found in Berger and Humphrey (1997), indicating that studies with this subject still need to be deepened to establish why the different results occur.

The advantages and disadvantages associated with bank supervision were also investigated by Gaganis and Pasiouras (2013). The authors found that banking efficiency decreases as the number of financial sectors that are supervised increases. In addition, the results suggested a negative association between the efficiency and unification of supervisory authorities and central bank independence.

An issue indirectly linked to banking regulation is whether bank performance benefits from capital restrictions. In this direction, Fiordelisi et al. (2011) analysed the association of banking efficiency with capital and risk levels. Therefore, the study is indirectly important to bank supervision due to the associated financial stability with efficiency in FIs. Based on the main results, the authors suggested that lower banking efficiency increases banking risk, and that increases in bank capital precede cost efficiency improvements.

The development and application of new models have appeared in smaller number, but they are important within the line of research. Goddard et al. (2014) applied and evaluated random parameters models for SFA. The authors found that efficiencies obtained from random parameters models tend to be better than fixed or random effects. They argue that the consequence is that random parameters do not confound parameter heterogeneity with inefficiency. Similarly, Goddard et al. (2014) used the models to evaluate cost efficiency for Latin American banks.

An issue that appeared in both research paths is directly related to the first major question proposed by Bhattacharya and Thakor (1993), which continues to generate various researches in financial intermediation. This issue involves the question of determinants of FI property structures. In the first main research path, Shaban and James (2017) evaluated whether ownership could change the performance of commercial banks. The main results were that state- owned banks tend to be less profitable and more exposed to risk than private and foreign banks. A controversial result is the suggestion that domestic acquisition is associated with a decrease in the efficiency of the acquired banks; however, acquisition by regional foreign investors was associated with performance gains.

In the second main path, Fujii et al. (2014) applied a weighted Russell directional distance model to measure technical inefficiency and evaluate total factor productivity (TFP) change with non-performing loans (NPLs). The authors also showed evidence that inefficiency levels are significantly different among ownership structures of banks. In addition, the study analysed some specific issues related to FIs Indian banks .

As discussed by Fujii et al. (2014), the treatment and use of NPLs in banking performance measurement models has been important in the current discussions. However, the characteristic of NPLs is controversial in literature; studies could use it as a measurement of risk, an input (expenses), an undesirable output, or even as a control variable. The current studies usually treated it as a bad output (Assaf et al., 2013; Matousek et al., 2015).

Assaf et al. (2013) offered an unusual method that serves an alternative for analysing banking efficiency and productivity, the Bayesian stochastic frontier approach (BSF). The authors used BSF to evaluate the productivity and efficiency of Turkish banks focused on accounting for NPLs. The authors employed NPLs as a bad output and found evidence of positive productivity growth due to improvements in technology. A singular methodological piece of evidence not accounting for NPLs in estimating the frontier model might seriously distort the efficiency and productivity results. Comparisons between domestic and foreign banks were evaluated.

In contrast, Matousek et al. (2015) applied a two-step approach that treats banks' NPLs as an undesirable output as well. The point of interest in the study was the possible convergence in banking efficiency. An overall decline in efficiency and a presence of club formation with typically weak convergence was found by Matousek et al. (2015). The line of research that analyses the process of banking integration in the EU countries and the Eurozone industry has been studied extensively.

Still, in relation to the second main research path, we found a concern of many papers to evaluate specific regional situations of banking efficiency. Examples are the studies by Fukuyama and Matousek (2011), Assaf et al. (2011) and Chang et al. (2012). Assaf et al. (2011) treated the productivity and efficiency of Shinkin banks and the various prefectures in Japan. They did not find efficiency and productivity growth, but they found a homogeneous efficiency across the banks that were analysed. The study also shows some evidence of productivity and efficiency growth.

As we can see, the concern of the studies is not only restricted to specific regions, but also concerns with the integration process. Following this direction, Degl'Innocenti et al. (2016) explored the sources of growth in different stages of production using a two-stage approach. The results suggested opposite evidence: a productivity growth during the U.S. subprime crisis, but a decline during the global financial crisis. Furthermore, contrary to Matousek et al. (2015), they found a strong convergence pattern during the financial crisis.

The bank productivity growth in China was analysed by Chang et al. (2012). The main aspect investigated was the comparison of indexes and models. However, in addition, they proposed an advanced index that disaggregated total factor productivity growth into each input. With the analyses, the authors were able to show evidence that the their input slack-based productivity index provides more insight than traditional TFP indexes.

Fukuyama and Matousek (2011) analysed the cost, technical, and allocative efficiencies of the Turkish banks with a focus on changes promoted by financial crises. The authors used a network model DEA. In this kind of model, it is possible to evaluate intermediate outputs that become inputs. The study provided evidence that banking efficiency reflected the state of the economy before and after crises. Furthermore, there continues to be a gap between the best and worst performing banks.

A peculiar approach with predictive ability was applied by Wanke et al. (2016b). They used a dynamic slacks-based model (DSBM) as the first stage in a two-stage process to assess the relative efficiency of Malaysian Islamic and conventional banks by emulating the CAMEL rating systems. Monte Carlo Markov Chain was used in the second stage. The proposed models applied to generalized linear mixed models were combined with DSBM results to produce a mechanism for banking performance assessment. In addition, Wanke et al. (2016b) suggested that Islamic banks have higher inefficiency levels than conventional banks and that foreign Islamic banks have lower efficiency levels compared to their national counterparts.

Comparative analyses between different types of business and ownership structures also continue to be frequent subjects in the studies. In the main research path, Sena et al. (2016) trademarking banks. The known nonparametric metafrontier Malmquist index was used to decompose it into changes of efficiency for groups and sectors of banks. The main result found by the authors suggested that technical change works like a driver of TFP growth among non-trademarking banks; however, for trademarking efficiency, change explains most of the TFP variation.

Finally, another frequent question in the current studies is the relationship between risk and cost efficiency of banks. This stream of study has been extremely important in the modern application of efficiency analysis to banking because the standard literature does not allow bank production decisions to affect bank risk (Hughes and Mester, 2008; Mester, 1992). One of the studies that starts the second main path of research evaluates the influence of various types of risk on the efficiency of FIs. Sun and Chang (2011) analysed distinct risk aspects under a total of eight risk measures. The results suggested that risk measures have effects on both the level and variability of banking efficiency.

2.5 Conclusion

The literature on banking efficiency is very dynamic and complex and usually integrates several areas of finance and banking. In this study, we analysed the state-of-the-art in terms of the theme and some of the newer aspects addressed in the theoretical framework. We proposed and apply a method of classification in order to evaluate the recent paths of development, citation networks, coordination, and productivity of financial research in the main international financial journals.

We collected and interpreted publications from the period between 2011 and first semester of 2017 that were classified as high quality and having scientific impact by the international community through consultation with the *Academic Journal Guide 2015* of the Association of Business Schools.

Approaches that connect measurement and association had greater predominance. The results demonstrate the increased complexity of the issues addressed. Thus, studies seek to analyse factors that impact banking efficiency but at the same time use specific methods for the previous measurement of efficiency. This demonstrates a wide openness for studies that indicate integrated models of evaluation directed at FIs.

We specifically verified the predominance of the use of SFA and of the DEA for the measurement of efficiency in the various thematic approaches. The two methods currently function as paradigms for the measurement of banking efficiency. These tools in the studies that approach the subject with association and measurement tend to sometimes be used together, which allows one to evaluate the results obtained by the two different methods. This result emphasizes a research gap in the area.

The major of participants of the main paths used the method of Simar and Wilson (2007) in their regression models after measurement using DEA. The bootstrapped truncated regression model appears as a paradoxical method in the area when it is necessary to perform regressions from DEA models. Studies aim to demonstrate the adequacy of other methods to explore regression using nonparametric estimates of efficiency in two-stage procedures are a gap of research in banking efficiency.

Limitations in the methods' characteristc are still the origin of several studies in the field and provide margin for their application in banking efficiency studies. In the case of SFA, unilateral distributions of inefficiencies, that use a half-normal assumption, still dominated the studies, but models using bi-lateral distribution and more adequate types of distribution are still research gaps for the area. In the same way for DEA applications, the construction of negative borders with less restricted properties for the models still are the object of discussion and application in the banking area. Examining if the estimator's statistical properties are adequate to the banking process is as well a prominent area.

It was verified that the main objective of current research is the theme that links the efficiency of FIs with diversification and risk, which was followed by studies focused on the impacts of supervisory and regulatory actions on the efficiency of banks. These issues have probably been driven by recent financial crises and the consequent imposition of prudential regulations.

Studies with the main theme of supervision, competitiveness, or alternative models demonstrated a larger citation network, which was fitted in the clusters. This result suggests more mature areas of research objectives in the field of banking efficiency. The formulation of specific models for banking efficiency has been integrated with models with direct application in certain research topics. The evaluation of specific models for certain objectives appears as a growing theme.

The supervision and the effect of banking regulation are controversial issues and continue to be focus of a large number of studies in the banking area, as well as in the specific issues of efficiency in FIs. The new rules of Basel and new forms of control of banks have potential to generate broad areas of research.

Another important point is related to the great geographical concentration. Currently, the research on the efficiency of FIs is concentrated in Europe. The majority of institutions that contributed to the theme originated in the United Kingdom, with more than twice the number of articles of the United States. However, the networks are connected, and information reaches all the major journals, even indirectly. The citation network structure is similar to a star network, with the *Journal of Banking & Finance* holding great centrality and with a role of connection between the main studies in banking efficiency. In turn, the *Journal of International Markets, Institutions & Money* functions as an interconnection between the three network clusters observed.

We also verify that the relationships between the studies are strongly related to the origin of the journal, and the unique journal that had consistent publication over the years was the *Journal of Banking & Finance*. This result is consistent with the fact that journals have specific themes of interest.

Another important issue is concerned with the lack of information on what the determinants of efficiency are according to the approach used. Thus, although studies show that changes in the configuration of inputs and outputs generate significant changes in efficiency estimates, no robust theoretical explanations have yet been proposed.

Finally, we found low productivity in the research of banking efficiency, which was confirmed by the analyses of Lotka's Law and by the descriptive statistics. We also found a high degree of dispersion of the studies. That is, there is a relatively limited number of authors and institutions that dedicate themselves to this specific subject. This fact indicates that, in despite of the tradition of the area, banking efficiency is not yet be a well-defined area of knowledge. Most of its studies come from areas such as finance, banking or operational research.

2.6 Appendix A

Table 2.14: Articles that Compose the Sample.

Study	Study Type	Objective	Methods Used - Measurement	Methods Used - Association	Main Object of Study	Latitude	Longitude
Hartarska and Mersland (2012)	Theoretical and Empirical	Measurement	SFA	Not applicable	EPI	32.59	-85.49
Lozano-Vivas and Weill (2012)	Theoretical and Empirical	Measurement	SFA	Not applicable	C&E	36.71	-4.41
Devos et al. (2016)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	F&A	31.77	-106.50
Schaeck and Cihák (2013)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	C&E	53.22	-4.12
Mallick and Yang (2011)	Theoretical and Empirical	Measurement	Others	Not applicable	D&R	51.52	-0.13
Pasiouras et al. (2011)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	F&A	50.79	-1.09
Barth et al. (2013)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	SRB	32.59	-85.49
Holod and Lewis (2011)	Theoretical and Empirical	Measurement	DEA	Not applicable	PMA	40.91	-73.12
Chortareas et al. (2013)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	C&E	37.96	23.77
Mamatzakis et al. (2015)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	50.86	-0.08
Gaganis and Pasiouras (2013)	Theoretical and Empirical	Measurement	SFA	Not applicable	SRB	35.30	25.08
Curi et al. (2015)	Theoretical and Empirical	Measurement	DEA	Not applicable	D&R	46.49	11.35
Sun et al. (2013)	Theoretical and Empirical	Measurement	SFA	Not applicable	E&G	20.05	110.33
Matousek et al. (2015)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Parametri	D&R	51.29	1.07
Sun and Chang (2011)	Theoretical and Empirical	Measurement	SFA	Not applicable	D&R	31.22	121.40
Fiordelisi et al. (2011)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	41.86	12.47
Goddard et al. (2014)	Theoretical and Empirical	Measurement	SFA	Mathematical Modeling	PMA	52.22	-4.12
Homma et al. (2014)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	C&E	36.69	137.18
Tabak et al. (2013)	Theoretical and Empirical	Measurement	SFA	Not applicable	PMA	-14.45	-39.40
Wanke et al. (2016b)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	E&Is	-22.95	-43.17
Assaf et al. (2013)	Theoretical and Empirical	Measurement	SFA	Not applicable	PMA	42.39	-72.52

Chen and Kao (2011)	Theoretical and Empirical	Measurement	SFA	Not applicable	D&R	22.62	120.26
Fujii et al. (2014)	Theoretical and Empirical	Measurement	DEA	Not applicable	PMA	38.25	140.87
Halkos and Tzeremes (2013)	Theoretical and Empirical	Measurement	DEA	Mathematical Modeling	F&A	39.35	22.95
Qian and Yeung (2014)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	E&G	1.29	103.77
Chortareas et al. (2016)	Theoretical and Empirical	Measurement	DEA	Statistical/Parametri	C&E	51.51	-0.11
Behr and Heid (2011)	Theoretical and Empirical	Not Applicable	Others	Not applicable	F&A	52.51	13.38
Radić et al. (2011)	Theoretical and Empirical	Measurement	SFA	Not applicable	D&R	51.51	-0.06
Silva et al. (2016)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	-15.80	-47.88
Ayadi et al. (2016)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	SRB	45.50	-73.62
Luo et al. (2016)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	52.40	-1.50
Williams (2012)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	C&E	53.22	-4.12
Chortareas et al. (2012b)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	SRB	37.96	23.77
Pessarossi and Weill (2015)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	43.46	1.25
Harris et al. (2013)	Theoretical and Empirical	Measurement	DEA	Not applicable	D&R	35.60	-77.35
Salim et al. (2016)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	E&G	-32.00	115.89
Fu et al. (2014)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	22.12	113.54
Kalyvas and Mamatzakis (2014)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	50.86	-0.08
Barros and Wanke (2014)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	38.75	-9.15
Fukuyama and Matousek (2011)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	C&E	33.54	130.36
Fiordelisi and Mare (2013)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	41.86	12.47
Tan and Floros (2013)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	D&R	53.64	-1.77
Montgomery et al. (2014)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	F&A	35.68	139.52

Akinci et al. (2013)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	50.86	-0.08
Monnet and Sanches (2015)	Theoretical	Not Applicable	Not Applicable	Not applicable	SRB	46.95	7.43
Carow et al. (2011)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	SRB	39.17	-86.51
Walther (2016)	Theoretical	Not Applicable	Not Applicable	Not applicable	SRB	51.75	-1.25
Hadad et al. (2011)	Theoretical and Empirical	Association	DEA	Statistical/Semi or Non Parametrical	C&E	52.76	-1.22
Agapova and McNulty (2016)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	C&E	26.37	-80.10
Al-Khasawneh (2012)	Theoretical and Empirical	Measurement	DEA	Not applicable	F&A	29.27	48.05
Chronopoulos et al. (2012)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	F&A	56.34	-2.79
Cyree (2016)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	SRB	34.36	-89.53
De Jonghe et al. (2011)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	F&A	51.04	3.72
Halkos et al. (2014)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	F&A	39.35	22.95
Leroy and Lucotte (2016)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	C&E	47.84	1.93
Lozano-Vivas and Pasiouras (2013)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	36.71	-4.41
Mamatzakis (2012)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	D&R	50.86	-0.08
Sena et al. (2016)	Theoretical and Empirical	Measurement	DEA	Not applicable	C&E	51.87	0.94
Wanke et al. (2016c)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Semi or Non Parametrical	PMA	-22.95	-43.17
Assaf et al. (2011)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Parametri	EPI	38.75	-9.15
Wheelock and Wilson (2012)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Semi or Non Parametrical	C&E	38.62	-90.18
Chang et al. (2012)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Parametri	PMA	24.78	120.99
Delis et al. (2011)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	SRB	39.61	20.84
Servin et al. (2012)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	EPI	22.63	-101.71
Duygun et al. (2014)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	C&E	52.62	-1.12
Chan et al. (2013)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	E&G	3.12	101.65

Duygun et al. (2013)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	C&E	52.62	-1.12
Chronopoulos et al. (2011)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	F&A	56.34	-2.79
Jiang et al. (2013)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	E&G	51.58	-0.22
Degl'Innocenti et al. (2016)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	50.93	-1.39
Chortareas et al. (2012a)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	37.96	23.77
Mamatzakis et al. (2015)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	E&G	50.86	-0.09
Shaban and James (2017)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	F&A	53.38	-1.49
Peng et al. (2017)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	24.99	121.58
Besstremyannaya (2017)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	D&R	55.70	37.39
Koetter and Noth (2013)	Theoretical and Empirical	Association	Not Applicable	Statistical/Parametri	C&E	53.22	6.56
Tanna et al. (2017)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	52.41	-1.50
Degl'Innocenti et al. (2017)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Semi or Non Parametrical	EPI	43.33	-2.97
San-Jose et al. (2014)	Theoretical and Empirical	Measurement and Association	Others	Statistical/Semi or Non Parametrical	Others	50.94	-1.40
Kalyvas and Mamatzakis (2017)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	51.98	-0.01
Davies and Tracey (2014)	Theoretical and Empirical	Not Applicable	Not Applicable	Not applicable	F&A	51.51	-0.01
Chortareas et al. (2011)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	37.96	23.77
Glass et al. (2014)	Theoretical and Empirical	Measurement	SFA	Not applicable	EPI	55.15	-6.67
Davutyan and Yildirim (2017)	Theoretical and Empirical	Measurement and Association	DEA	Statistical/Parametri	C&E	41.02	28.96
Casu et al. (2016)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	SRB	51.53	-0.10
Fujii et al. (2017)	Theoretical and Empirical	Measurement	DEA	Not applicable	C&E	32.78	129.86
Fiordelisi and Ricci (2011)	Theoretical and Empirical	Measurement and Association	SFA	Statistical/Parametri	C&E	41.86	12.47

Chapter 3

Determinants of Efficiency in State-Chartered Financial Institutions: Why Financial Education and Freedom Matter

3.1 Introduction

The literature on banking efficiency has strongly debated the determinants of efficiency and the productivity of different financial institutions (FIs). The permanent research and discussion in this area can be explained by different factors, but today, the great technological change stands out due to the strong use of information technology by the financial service industry and the change in the structures of the markets and institutions with differentiated factors of competitiveness. In theory, this new industry configuration could indicate new determinants of the institutions' productive process.

Not only has the FIs productive process changed rapidly, but so have the forms and the models of evaluation of their performance, which have undergone considerable advances. Parametric and non-parametric models have evolved with new machine learning (ML) and artificial intelligence (AI) methods that provide new insights into the factors that could significantly influence the financial markets' efficiency at the regional, national or international level.

This change in the nature and competitiveness of the sector brings conflicts between FIs that, although they often provide similar banking services, are subject to attributive factors that affect their respective production processes differently. Thus, by way of example, different types of FIs, size and geographical location may determine a regulatory, taxation or even technological environment that is more or less beneficial. Thus, to assess the FIs' efficiency, first is finding out which are the qualitative attributes that are significantly related to banking efficiency and productivity.

However, the mere indication of the relationship between qualitative attributes and efficiency does not bring substantial answers to the initial origin on the different levels of productivity. It is necessary also to know which variables lie behind these attributes. In other words, the fact that an FI is a commercial bank or a credit union does not explain why these institutions have differentiated averages of efficiency. Possible reasons for this hypothetical difference may be due to different issues, such as governance models, regulatory regimes or even fiscal issues.

The answers to these questions are not trivial, but they have the potential to help market decision makers, government agencies and so many other stakeholders look for ways and models that are more appropriate and efficient for their environment. In this way, we try to present some answers to current discussions on banking efficiency from a methodology that can be divided into three

phases. The first phase aimed to measure the level of efficiency of each FI. The second objective was to establish which attributive criteria were significantly linked to the more or less efficient of these institutions. And last but not least, the third phase aimed to test whether theoretical variables linked to the attributes could explain the efficiency levels of institutions.

In the first phase, we measured the efficiency of a sample composed of approximately 4,000 FIs, totalizing more than 60,000 observations in a time series (2003-2017). The set is formed by different sets of FIs that had the characteristics of local activities (state-chartered). In this phase, we applied a two-stage SBM network data envelopment analysis (NDEA) model with the banking intermediation approach. The results indicated a constant productivity distribution over the time series (2003-2017) and that efficiency scores behave differently from studies that assess the large banks that control the market or that include national banks in their sample.

In the second phase, we use the efficiency scores to divide institutions into more and less efficient ones and compare them with their attributive variables. From this classification, we applied a linear discriminant analysis (LDA) and ML methods (SVM, random forest [RF] and Bagging) to verify which attributive variables were able to predict efficient institutions. The results showed that variables linked to political-administrative localization criteria were able to predict if the FI was in the efficient group.

Last, we applied a fractional logistic regression to test which variables could be behind the fact that FIs located in certain regions had more efficient scores on average. In general, the results confirm the recent findings of the literature, which states that less governmental influence (freedom) is related with more efficient institutions. In addition, we found that states with a population with higher financial education have FIs with higher levels of efficiency, although the formal education level had no significant effect.

This paper is organized as follows. After this introduction, a brief review of the recent related literature is provided in Section 2, followed by a description of the three data sets and methodology adopted in our study in Section 3. The results are shown and discussed in Section 4. Finally, the conclusions drawn from this study are presented in Section 5.

3.2 Literature Review

Banking efficiency studies usually explore two main questions. The first asks what the most adequate way to measure FIs' productivity and efficiency is. This initial concern is about how to measure the efficiency of each FI. This question is far from being simple or consensual in the specialized literature, as it currently uses a wide range of approaches, methods and tools (de Abreu et al., 2018). The second question concerns the association of measured efficiency with some endogenous or exogenous variables to FIs. This issue is also quite complex, with few consensual issues in the literature about the main determinants of banking efficiency or productivity (de Abreu et al., 2018).

To measure the efficiency, currently structural approaches that design some efficiency frontier or a set benchmarks dominate the main literature (Hughes and Mester, 2012). The frontier, or even benchmarks, represent a maximum efficiency for a given amount of inputs (or outputs) established, meaning that the lower (higher) the inputs (outputs) amount to, the better it is the efficiency (Berger et al., 1995). In short, FIs that achieve higher efficiency, consuming fewer resources or producing more products, will be closer to the efficiency frontier. The border can be constructed parametrically or non-parametrically. The parametric approach imposes a functional form. That is, it uses a function that determines the resources needed to reach a product. Non-parametric methods do not specify functional form since they construct the frontier or define the benchmarks directly from the available data (Hughes and Mester, 2012). A second difficulty in the measurement

question is about the definition and the nature of the set of inputs and outputs. The studies usually take a position by choosing a sort of approach that represents the study's objective. Currently, production (Benston, 1965; Wanke et al., 2016b) and intermediation (Sealey and Lindley, 1977; Chortareas et al., 2016) approaches are the most commonly used.

It should be clarified that currently some studies have treated deposits as an intermediate product in a two-stage process (Fukuyama and Matousek, 2011; Holod and Lewis, 2011). In the first stage the deposit would be an output and the following an input. The idea is that the deposits would be acquired from the usual factors of production (capital, labor) and later would serve to generate loans, or even profits. Some argue that such process would be a kind of model of the other intermediation approach that would be a new approach.

In relation to efficiency determinants, three issues are generally debated in the literature. First, one of the areas discusses whether the incorporation of business models can influence the capacity of institutions (Curi et al., 2015). Another important subject is related to how unequal regulation and supervision structures - that come from by different countries, regions and rules - impact the institutions' efficiency (Chortareas et al., 2012b; Delis et al., 2011). Finally, a discussion of the different property structures and the level of efficiency of FIs is also widely debated. The specific evaluated aspects are the most diverse possible and usually come from the construction of previous clusters or are already indicated by the data available. It is common to compare FIs with a different degree of diversification, primary activities or differentiated market niches.

On the other hand, studies that link regulation and efficiency usually seek to identify how the exposition about different regulatory structures impacts the FIs' efficiency (Delis et al., 2011; Lozano-Vivas and Pasiouras, 2013). It is also common to assess how specific regulatory reforms impact the efficiency of institutions (Casu et al., 2016). There is no consensus in the area, existing studies that found policies promote a positive impact on bank productivity (Delis et al., 2011), and others that suggested that interventionist policies could result in high levels of banking inefficiency (Chortareas et al., 2012b).

Others studies also demonstrated that financial freedom has the capacity to positively impact the efficiency of banking institutions (Chortareas et al., 2013, 2016). The intuitive notion suggests that states with less government interference promote the efficiency of FIs. The influence of this freedom implies several aspects, such as taxation, governmental participation and level of regulation, among others.

Another determinant that is currently presented in the literature concerns the effects of different ownership structures on the management and FIs' efficiency, including FIs controlled by minorities groups (Kashian et al., 2017; Hasan and Hunter, 1996; Iqbal et al., 1999). Governance aspects would thus play a key role in the performance of FIs, including the addition of some mechanisms of corporate governance. Usually, the justifications for this influence are linked to agency problems and to the different contours of the governance structures of these institutions. On the other hand, more specific aspects, such as government incentives and subsidies, may also be tied to different ownership structures.

A study area that is related to all those research areas concerns the possible significant influence of a geographical location on the performance of institutions (Degl'Innocenti et al., 2017). That is, it seems clear that geographical location itself appears to be a secondary factor originating from others that influence more directly on performance in the production of financial services. Therefore, these studies usually need to use control variables to identify the true determinant of the findings. For example, the difference in efficiency between institutions with locations in large and small urban centers may be due to the social, economic and technological level, as well as to banking and tax regulations, in those regions.

We call these FIs individual qualitative characteristics (e.g. location or business type) "qualitative attributes". In the second phase of this study we will assess the importance of some of the

main and then test potentially related explanatory variables.

3.3 Empirical Methodology and Data

3.3.1 Data

Our sample focused only on US state-chartered FIs. This selection is especially interesting because it allows us to verify possible influences from different structures of regulation, supervision and even geographical criteria. That is, our research covered all depository and lending institutions. The main objective was to obtain a set of information that had different typologies that was delimited by its location and was in its regulations of different forms.

An important aspect is that the United States, mainly due to the degree of autonomy of the states, has different levels of banking regulations that can be national- or state-chartered FIs. Depending on the choice of actuation, a FI may have national or statewide operations only. These different levels of regulatory spheres give the state-chartered FI in specific quite different legal, regulatory and supervisory structures because these activities are carried out by different agencies ("Department of Banking/Financial Institutions").

For example, the Department of Banking's functions achieve the establishment of differentiated rules and supervision, auditing and monitoring. In addition to this local oversight, most banks that have Federal Deposit Insurance Corporation insurance are also subject to federal monitoring. In addition, state-chartered FIs may choose to belong to the Federal Reserve System, which, in such cases, usually increases the degree of regulation in return for access to larger resources.

This large number of regulatory institutions covering different geographic areas, in addition to the large number of institutions and legal systems, confers on the set of the American state-chartered FIs an environment significantly different from those that are usually evaluated in traditional banking efficiency studies. That is, the analysis usually focus on the major banks that control the markets or on institutions listed in the stock market. Beside that, the regulatory requirements in the banking market have become especially strict for large banks that are relatively homogeneous due to the international standardization of the Basel Accords.

For example, Chortareas et al. (2016) used a set of data that covers all American commercial banks, including national banks, to evaluate the relationship between banking efficiency and level of freedom. In our opinion, this is not adequate for our purposes because the selection could cause great bias. National banks, including the largest ones, such as Bank of America (ISSN 480228) or City Bank (ISSN 476810), have clients at the national and international level, and their assets and liabilities are not concentrated in one region. We highlight that the five biggest banks in the United States control about 40% of the deposits.

To evaluate the state-chartered FIs, we use data from three different databases, each related to the three phases of the research. The first one provides the necessary data related to the inputs and outputs required to measure the FIs' efficiency. The second base provides information about the characteristics of the institutions that served as a proxy for the evaluation of efficiency determinants. Thus, we combine the financial information with the information regarding the attributes of each bank to evaluate the level banking efficiency linkage with determinants present in the banking literature. The last base gives data to test variables linked with the significant attributes found.

For the measurement of efficiency, we use data obtained from the Uniform Bank Performance Report (FFIEC). More specifically, we use the Reports of Condition and Income (Call Reports) and Uniform Bank Performance Reports (UBPRs). This database is used for an efficiency measurement in other studies (Chortareas et al., 2016). The database covers an unbalanced series from 2003 to 2017, allowing the temporal productivity analysis. The decision-making units (DMUs) are

represented by each state-chartered FI that was part of the sample, and the efficiency scores for each year were calculated.

From this base, 6 variables were generated, as described in Table 3.1. Further information about the each metric can be obtained at FFIEC (2017).

Table 3.1: Variables for Mensuration (First Phase of Analysis)

Variables	Description and Source
Input 1:Labor	Measured by the number of full-time equivalent employees on the payroll at the end of the period. Source: Federal Reserve Board.Call Report, 4 qt. (2 of 2). Code: RIAD4150.
Input 2:Capital	The book value of premises and fixed assets. All premises and fixed assets, including capitalized leases, are included. Value expressed in dollars. Source: Federal Reserve Board.UBPR Balance Sheet (page 4). Code: UBPR2145.
Intermediate: Deposits	Total deposits. Source: Federal Reserve Board.UBPR BalanceSheet (page 4). Code: UBPR2200.
Output 1:Loans	For the sake of coherence with the criteria used by Fukuyama and Matousek (2011), we have used consumer and business loans in the same variable. Source: Federal Reserve Board.UBPR Balance Sheet (page 4). Code: UBPRD665+ UBPRE117 + UBPRE116.
Output 2:Securities	Sum of all securities, interest-bearing bank balances, federal funds sold and trading account assets. Source: Federal Reserve Board. UBPR Balance Sheet (page 4). Code: UBPRE122.

Note: Monetary values expressed in dollars (thousands USD).

We used two variables to measure inputs (capital and labor), an intermediate variable (deposits) and two variables to measure outputs (loans and financial assets). The variables are usually used to measure efficiency based on the literature that uses the intermediation approach in two stages (Fukuyama and Matousek, 2011).

For the sake of comparability between the FIs' activities, we withdraw from the base the FIs that declared variables to be 0 or not available. That is, it is important that all are actively taking deposits, granting credit operations and generating in financial assets. FIs that declared 0 or unavailable inputs were also eliminated in view of the low probability that a regular institution would not have at least one full-time employee and fixed-capital amounts, eliminating data with evidence of error.

On the other hand, the second data was obtained from the National Information Center, a repository of the financial information and characteristics of the institutions that is collected by the Federal Reserve System. Five attributes were used to evaluate if they could significantly predict the efficiency levels. For the second phase of analysis, from 66,855 observations, 49,167 were used for training the models and 17,688 were used for testing them.

Table 3.2: Attributive Variables (Second Phase of Analysis)

Variables	Definition
Primary Federal Regulator	The Primary Federal Regulator contains the agency that is the primary regulator of the bank.
Physical State	The physical state indicates the state of the United States or a US territory in which the FI is physically located.
ARDF	The Federal Reserve District of the regulatory authority indicates the specific authority for institutions.
Entity Type	Cooperative bank, foreign banking organization, federal savings bank, non-member bank, savings and loan association, state member bank and state savings bank.
Subsidiary Holder	The financial subsidiary holder indicates whether a bank conducts expanded financial activities through its direct or indirect ownership and control of an approved "financial subsidiary", as defined in the Gramm-Leach-Bliley Act and in Section 4(k) of the Bank Holding Company Act. It is a dummy variable.
Minorities Owners	The majority owned by minorities or women is a code indicating whether a bank, savings and loan association or non-FBO bank holding company is more than 50% owned by one or more minorities or women with identification of the minority.

Source: All variables come from the Bulk Data Table "Attributes" (Active). More information can be obtained at NIC (2016).

Finally, to obtain the variables for the third phase, we had to search for information in different databases, as shown in Table 3.3. In the regression evaluation, the time series was limited until the

year 2015 due to the unavailability of data. The data cover information about activities subnational levels, as it will be seen in Section 3.4, the most important attributes were linked to the political-administrative location of the FIs.

Table 3.3: Variables for Regression (Third Phase of Analysis)

Variables	Description and Source
Efficiency Measure	Dependent variable. Source: Scores calculated by the authors in the first phase of analysis.
Financial Literacy	Combine variables as: WalletHub's "WalletLiteracy Survey" Score, Financial Planning & Habits and Financial Knowledge & Education. Source: WalletHub. Most & Least Financially Literate States.
Formal Education	Combine variables as educational attainment, school quality and achievement gaps between genders and races. Source: WalletHub. Most & Least Educated States in America.
Government Spending	Subnational Index. Combine variables as consumption spending (% of personal income), transfers and subsidies (% of personal income) and insurance and retirement payments (% of personal income). Source: Fraser Institute. Economic freedom of North America. Area 1.
Taxes	Subnational Index. Combine variables as income and payroll tax revenue (% of personal income), top income tax rate, top income tax threshold, property tax and other tax revenue (% of personal income) and sales tax revenue (% of personal income). Source: Fraser Institute. Economic freedom of North America. Area 2.
Labor	Subnational Index. Combine variables as minimum-wage income (% of per capita personal income), government employees (% of total employees) and union density (% of total employees). Source: Fraser Institute. Economic freedom of North America. Area 3.
Per Capita Personal Income	Control variable. Personal income divided by population. Source: Bureau of Economic Analysis.
Logarithm of Total Assets	Control variable. Source: Federal Reserve Board. Balance Sheet (page 4). Code: UBPR2170
Quadratic Term of Total Assets	To test non-linearity in the relationship assets and efficiency scores. Source: Federal Reserve Board. Balance Sheet (page 4). Code: UBPR2170
Capitalization	Control variable. Equity divided by total assets. Source: Federal Reserve Board. Balance Sheet (page 4). Codes: UBPRG105, UBPR2170.

Note: Fraser Institute measures variables as a percentage of income. All scores used were normalized between 0 and 1.

3.3.2 Empirical Methodology

As briefly mentioned, our study uses three main procedures to evaluate the impact of qualitative variables on banking efficiency. First, to have an efficiency measure for each FIs, we applied a two-stage SBM NDEA model. Then, to evaluate which qualitative variables had the best predictive capacity of the efficiency scores (best and worst efficiencies), we applied one traditional method and three ML techniques. Finally, in the last procedure, we test some hypotheses that are presented by the literature and that are linked to the attributed political-administrative (the most relevant found) using an fractioned logit regression controlled by financial variables.

The efficiency measurement phase aimed to assess the performance of each FI. We used a model that considered the two main stages of production of financial services. For this, we applied a two-stage SBM NDEA model with the approach proposed by Tone and Tsutsui (2009) and a method for epsilon and weights by Tone and Tsutsui (2010).

A data envelopment analysis model is an operational research technique, which is based on linear programming, and whose objective is to comparatively analyze independent units (in our study, each American state-chartered FI) usually called DMUs with respect to its performance. It provides a measure to evaluate the relative efficiency and to obtain benchmarks (Zhu, 2014). Each FI (DMU) is represented by a set of outputs and a set of inputs. The basic idea is to compare the outputs with the inputs. Our outputs represent the two main products generally generated by FIs: loans and financial assets. However, to produce them, FIs need to use production factors. As shown in Table 3.1, our study used two proxies for the two main factors of production as inputs: fixed capital and labor. In addition to these, we used an intermediate input/output represented by the total deposits.

For an input-oriented efficiency (θ_o^*), Tone and Tsutsui (2009) solve the following linear problem:

$$\theta_o^* = \min_{\gamma^k, s^{k-}} \sum_{k=1}^{k} W^k \left[1 - \frac{1}{m_k} \left(\sum_{i=1}^{m_k} \frac{s_i^{k-}}{x_{io}^k} \right) \right], \tag{3.1}$$

where $\sum_{k=1}^{k} W^k = 1, W^k \geq 0 (\forall k)$ and W^k is the relative weight of Division k (Tone and Tsutsui, 2009, pag. 246).

Our first methodology approach has two main advantages for the traditional literature models. That is, banking efficiency studies that use nonparametric DEA efficiency techniques mostly use a radial approach (e.g., Charnes et al. (1978) or Banker et al. (1984)) and consider a single-stage structure (black box). The biggest criticism of radial models is that the inputs and outputs are proportionally adjusted. As Tone and Tsutsui (2009) notes, the relationships of inputs that use capital and labor are often substitutive and do not change proportionally. In relation to the black-box models, deposits can be characterized as either inputs or outputs, generating what is commonly called the deposit dilemma. As a rule, intermediation approach studies use deposits as inputs because deposits represent resources that are used to generate loans. On the other hand, in production approach studies, deposits are usually treated as outputs because they represent a service offered to bank customers.

Thus, the application of the SBM-NDEA model of Tone and Tsutsui (2009) allowed us to overcome both problems. First, we did not restrict the adjustments between inputs and outputs to only proportional changes. In other words, since a non-radial approach was used, simultaneous increases or decreases in the outputs (final outputs or intermediate) were allowed. Second, we were able to break down the FI production process into two phases. In the first phase, FIs need capital and labor to capture deposits. In the second phase, deposits serve as input for the generation of assets, such as loans and securities. This allows using an approach that overcomes the deposit dilemma in the banking efficiency literature (Holod and Lewis, 2011). In addition, the two-stage DEA provides a more accurate analysis, allowing, for example, evaluating efficiency in a segregated way. However, it should also be noted that there are other DEA models that allow division into two stages, but each will have an advantage or disadvantage. The well-known model by Kao and Hwang (2008), for example, has the disadvantage of only allowing constant return of scale; however, it has the advantage of being particularly intuitive, as the product of the individual phase scores is equal to the total efficiency score.

The DEA model was input-oriented and was generated under the variable return to scale hypothesis in the both stages of the analysis. The variable return to scale hypothesis was assumed, since the literature in the area already has some consensus regarding the existence of significant gains in scale in the production of financial services for smallest banks (Berger and Humphrey, 1994). In addition, input orientation was used to identify those that can reduce at least one of its inputs, avoiding idleness or the poor choice of capital and labor. Input orientation is also usually used because of the high degree of competition in the banking sector, with inputs being more discretionary than the possibility of changes in the offering of financial services that are more restricted by the market (Chortareas et al., 2012b).

After obtaining the efficiency scores, we proceeded to the second methodological procedure. To verify that the prediction of efficiency would be possible from the unique use of qualitative attributes of the FIs, we applied a traditional method - LDA - and three ML methods: bootstrap aggregating (bagging or BG), RF and linear vector machine support (LSVM). The main objective was to find evidence of relationships between qualitative institutional attributes and to compare the methods and results found.

To implement the models, we divided the FIs into two groups: efficient and non-efficient. We used a dummy variable, in which the 50% that had the highest scores were classified in the efficient

group, while the other 50% were classified as non-efficient. The dummy variable thus served as a dependent variable that is predicted with the methods listed above from the qualitative attributes of each FI. Qualitative attributes are described in Table 3.2.

The LDA is a model traditionally used for the classification of observations in well-defined groups, in our case efficient and non-efficient FIs, from a discriminant function whose desired result is to obtain coefficients for each of the independent variables and to determine in which group the individual will be classified. The discriminant classification function explained by n independent qualitative variables have the following form described in Equation 3.2:

$$Y = b_0 + b_1 X_1 + ... + b_n X_n, \tag{3.2}$$

where Y is the dummy variable that segregates efficient and inefficient FIs (the dependent variable); b_n are the coefficients that weight the independent variables X_i; and X_i are the discriminatory variables.

The classification of each individual is made by calculating the estimated discriminant function. The FI is classified as efficient if it is closer to this group than to the inefficient group. That is, if the distance between its discriminant score and the centroid of the efficient group is less than the distance between its score and the centroid inefficient group in the opposite case. We use the R software package "MASS" to execute the method.

RF is a classifier consisting of a collection of structured classifying trees $h(x, \Theta k), k = 1...$; where ΘK are independent and identically distributed random vectors and each tree casts a single vote for the most popular class from the input data x (Breiman, 2001). We use the "randomForest" and "H2O" packages of the R software to perform the RF model.

To use the Bagging model we follow an algorithm as described by Breiman (1996), follows these steps: (1) construct a random sample, t, selected from the data set; (2) calculate the C_t estimator using the data set from step 1; (3) repeat the first and second steps with $t = 1...T$ (T is the total of iterations defined); and (4) each classifier determines one vote where x holds the data of each element of the training set, according to Equation 3.3. After this algorithm, the highest voting class is chosen as the classification for each element of the data set. We use the "ipred" package of the R software to perform the method.

$$C(x) = T^{-1} \sum_{t=1}^{T} C_t(x) \tag{3.3}$$

The last ML model used was based on the support vector machine (SVM). An SVM creates a hyperplane, which leads to partitions of the data on approximated homogeneous sides. The construction of a separation hyperplane is given by a Kernel function K (xi, xj), which is the product of the input vectors xi and xj, according to Equation 3.4.

$$k(x_i, x_j) = \Phi(x_i)\Phi(x_j) \tag{3.4}$$

The SVM model used in this study (SVML) associates a Kernel function with a linear function (Equation 3.5). We use the "parallelSVM" and "e1071" packages of the R software to perform the method.

$$K(x_i, x_j) = x_i^T x_j \tag{3.5}$$

To evaluate the second phase models, we applied different methods of analysis. We use the receiver operating characteristic (ROC) curve to analyze the usually antagonistic relationship between the probability of correct classification of efficient institutions (true-positive rate) and the probability of classifying them as efficient or inefficient institutions (false-positive rate). We also

used the Brier score (BS) to evaluate the predictions of probability of more inefficient institutions. Finally, we used the Kolmogorov-Smirnov (KS) test to measure the distance between the cumulative distribution between efficient and non-efficient institutions. For operation of these models, we use the "ROCR" and "verification" libraries of R.

In the results presented in Section 3.4, we verify that the best attributes of FIs to predict their efficiency are linked to political-administrative locational criteria. From this finding, we move on to the third stage of evaluation, which is to test what underlying factors lie behind the influence of location on banking efficiency. For this, we have tested some hypotheses that are presented by the literature and that are linked to the attributed political-administrative location of the state-chartered FIs. These variables are listed in Table 3.3.

To test the variables hypothetically related to location attributes, we regressed the efficiency scores calculated in the first methodological phase using a fractional logistic regression. The proposed equation is presented below.

$$EFS_{k,t} = \alpha + FLS_{k,t}\beta + FES_{k,t}\gamma + GSS_{k,t}\delta + TXS_{k,t}\xi + LAS_{k,t}\lambda + CVS_{k,t} + u_{k,t}, \quad k = 1, ..., n; t = 2003 : 2015, \tag{3.6}$$

where $EFS_{k,t}$ is the efficiency of FI k at time t, $FLS_{k,t}$ is the financial literacy score, $FES_{k,t}$ is the formal education score, $GSS_{k,t}$ is the government spending score, $TXS_{k,t}$ is the taxation score, $LAS_{K,T}$ is the labor intervention score, and $CVS_{K,T}$ is a vector of control variables with characteristics that may have an effect on the efficiency. Lastly, $u_{k,t}$ is the random error.

Importantly, we clarify that we use a fraction logit regression because as Chortareas et al. (2016) pointed out DEA scores are more a outcome of a fractional logit process than the outcome of a truncated process. We use the "frm" package of the R as base to perform the regression.

3.4 Results

The results referring to the efficiency scores for state-chartered FIs show the great dispersion among efficiency scores, with few institutions setting up between the benchmarks and a remote group with averages close to 11% of the benchmarks. The result clearly contrasts with the usual studies that evaluate banking efficiency from a sample of the top US banks that control most of the assets of the banking system. The mean and standard deviation of the efficiency scores show a relatively constant behavior during the 2003-2017 series, as shown in Figure 3.1.

Another important point is that the results of the descriptive statistics show evidence of exogenous influences and possibly regulatory and legal issues. That is, US FIs in general do not present large enough technological differences to justify the wide dispersion of results. Significant differences in attributive variables are the most likely cause to be verified in subsequent association procedures. This means, as we mentioned before, that the purposely heterogeneous sample that we selected has the potential to support attributive characteristics that affect the FIs' efficiency scores.

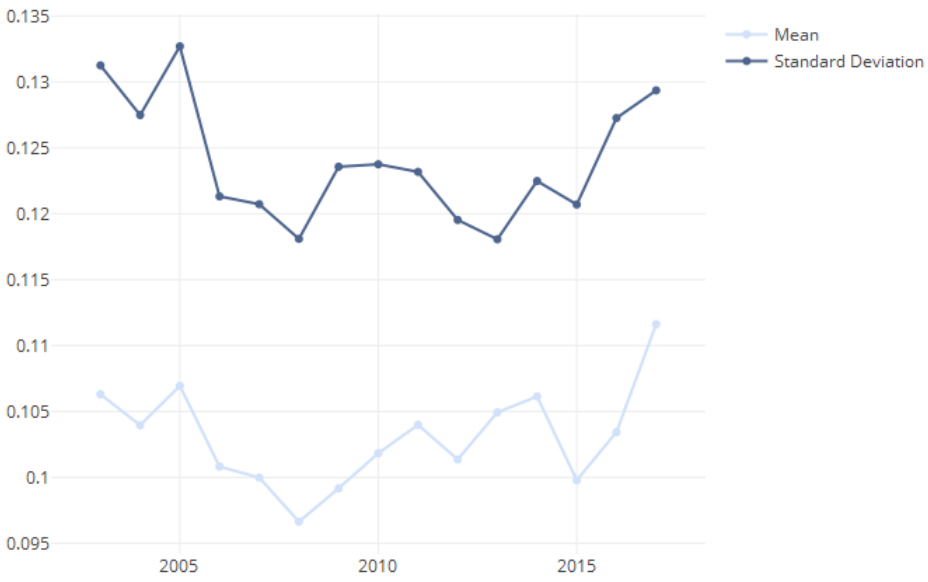

Figure 3.1: Scores and Productivity Index

The histogram shown in Figure 3.2 demonstrates the exponential format of the frequency curve. It is worth noting the concentration of a small group of FIs that stand as benchmark of the group. A group of approximately 1% of the institutions represented the benchmark of the sample by about 3,500 institutions, a number that depends on the year of analysis, since the series is not balanced.

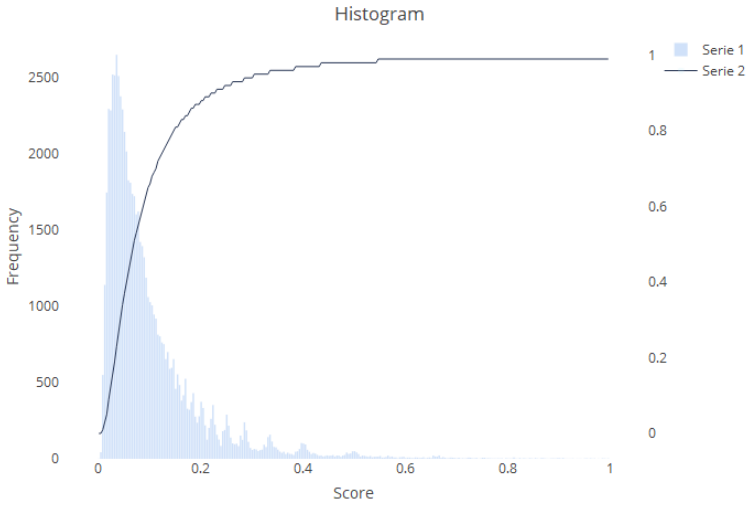

Figure 3.2: Efficiency Scores - Histogram

As an example, Table 3.4 shows two FIs that are between the benchmarks and two FIs that are close to the score average. The first two cases contrast two FIs that use quantities of near inputs with much higher results in the outputs generated by the benchmark FI. The last two FIs also compare two cases where the benchmark FI has a much higher result, despite the close use of labor and the much lower use of fixed capital. The examples illustrate how there are large differences in the processes of US FIs when we look at the group of state-chartered FIs.

Table 3.4: Examples - Benchmark vs Average FI

2017 Report	RSSD ID	Score	Labor	Fix.Capital	Deposits	Loans	Securities
TEXAS EXCHANGE BANK	822556	1.00	23	1,212	556,957	217,293	765,646
LYTLE STATE BANK OF LYTLE	830252	0.11	22	1,152	73,334	20,737	54,144
UBS BANK USA	3212149	1.00	382	39	47,989,027	32,016,036	9,525,804
LUTHER BURBANK SAVINGS	497570	0.10	263	22,452	3,990,163	103	582,001

Note: Dollar amounts in thousands.

Using Figure 3.3, we can evaluate the productivity behavior with the Malmquist Index, technical change and efficient change. Thus, the analysis of the Malmquist Indices variation reveals a constant average behavior, with some slight additions over time. The variations are considered to be reflections of compensations between changes between the mean indices of efficiency and technicality. Thus, the sector presents maintenance characteristics of the structural levels in the state-chartered FIs. The results confirm the maintenance of the structures of a few leading FIs with a great difference of means that was verified in the analysis of the global scores found. In short, the efficiency/productivity analysis over time corroborates the analysis previously made from the average efficiency scores and indicates that the sector has maintained constancy in its structures.

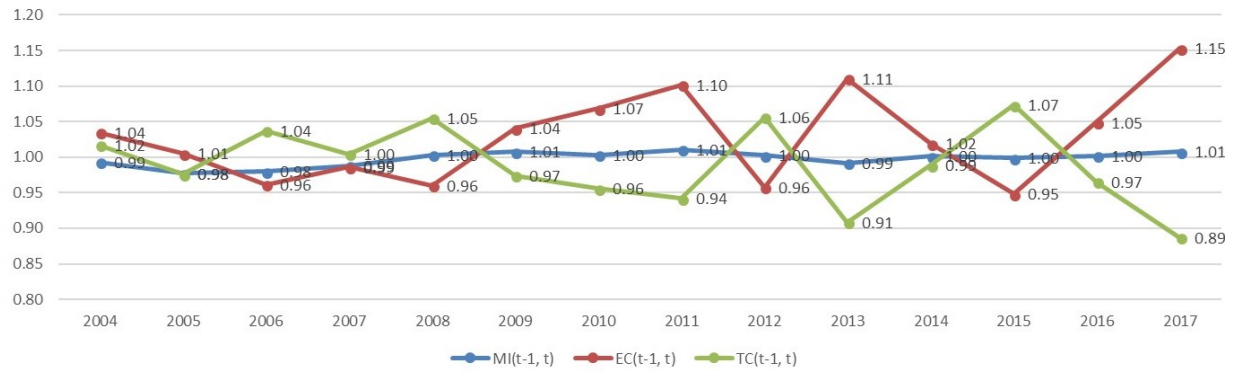

Figure 3.3: Productivity Evolution

As a second methodological procedure, we used the available attributive variables described in Table 3.2 to verify if ML methods could discriminate the most efficient FIs from the least efficient FIs. We use a traditional model (LDA) and three ML models (RF, BG and SVML) and compare the performance of each. Of the 17,688 separate observations for evaluation, the LDA model correctly predicted 6,121 inefficient and 5,484 efficient FIs, resulting in an average accuracy of 65.60%. The RF correctly predicted that 7,542 FIs are efficient and 3,737 FIs are inefficient, resulting in an average accuracy of 63.76%. The BG model correctly predicted 6,206 inefficient and 5,546 efficient FIs, resulting in an average accuracy of 66.44%. In sequence, the SVML model was able to correctly predict 5,665 efficient and 5,723 inefficient FIs, resulting in an average accuracy of 64.38%. We summarize the accuracy data along with each type of error, false positive rate (FPR) and false negative rate (FNR), BS and KS in Table 3.5.

Table 3.5: Models' Evaluation

Model	Precision (%)	FPR (%)	FNR (%)	BS	KS
DA	65.6	31.5	37.3	31.2	31.49
RF	63.76	58.2	13.8	21.25	32.87
BG	66.44	30.6	36.6	29.11	32.96
SVML	64.38	36	35.2	31.44	29.94

Note: FPR (False Positive Rate), FNR (False Negative Rate)

We observed a relative convergence of the results of the BS and KS indices. Bagging obtained the best value for the KS test (32.96%), followed by RF with 32.87% and DA with 31.49%. The BS index presented a better result for RF (21.25%), followed by BG (29.11%) and AD (31.20%). The results are convergent with the observation of the ROC curve available in Figure 3.4.

Figure 3.4 shows the benchmarking of the ROC curves for the models under evaluation. The LDA model and the other three ML models had very close behaviors. It should be noted that the ROC curve compares rates referring to the correct values (false and true positive); that is, they do not focus on errors, such as TNR and FNR.

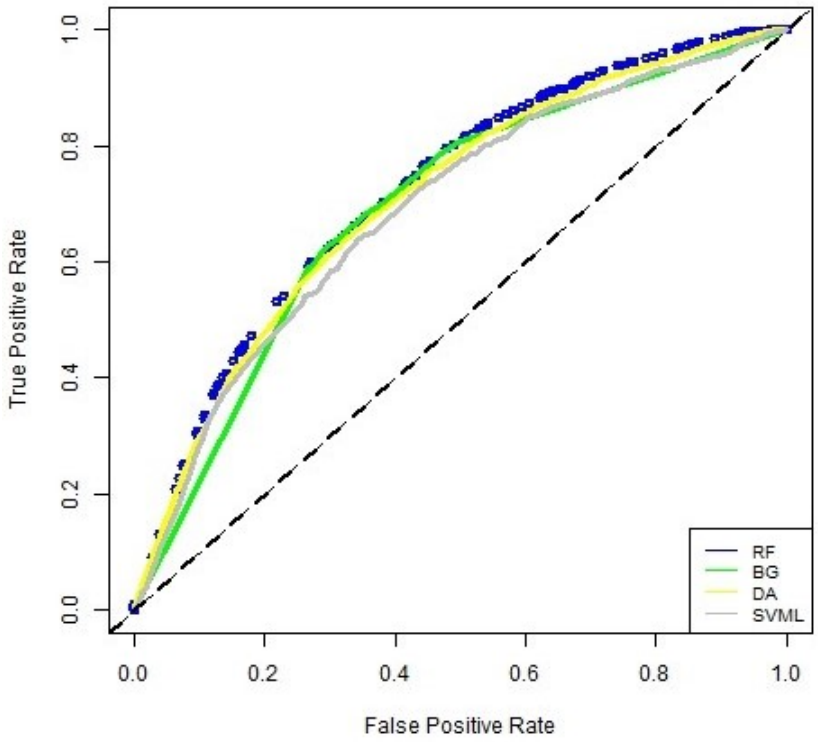

Figure 3.4: ROC Curve - Benchmark

The most important attributive variable for the predictions of the most efficient and least efficient classifications was the location in a certain state of the state-chartered FI. The second most important attribute was the Federal Reserve District of regulatory authority for institutions. The other variables had little importance in the classification of the models. It should be noted that issues normally considered important had little classificatory impact, such as the type of entity and the primary activity performed by the institution. Table 3.6 shows the results for the RF model in the evaluated variables.

Table 3.6: Attributes Importance

Variable	Relative Importance	Scaled Importance	Scaled Importance
Physical State	588200.2	1	0.597517
ARDF	261776.9	0.445047	0.265923
Primary Federal Regulator	58341.15	0.099186	0.059265
SUBSIDIARY HOLDER	26729.26	0.045442	0.027153
Entity Type	17794.29	0.030252	0.018076
Minorities Owner	17600.57	0.029923	0.017879
Primary Activity	13965.68	0.023743	0.014187

The two main attributes used by the models to predict the efficiency of FIs are directly related to political-administrative territorial divisions. However, this fact alone does not answer many questions. Another important issue is what the factors behind this geographic influence are. In this way, as mentioned in the Subsection 3.3.2, we performed a fractional logistic regression, as proposed by Chortareas et al. (2016), to test possible variables that are linked to the geographic location and could theoretically affect the efficiency of FIs. The regression results are available in Table 3.7.

Table 3.7: Regression Results

	Estimate	Std. Error	t value	Pr(> $\|t\|$)
Intercept	27.43489	0.333711	82.212	0.000 ***
Government Speeding	-0.51579	0.082586	-6.245	0.000 ***
Taxes	0.58207	0.079087	7.36	0.000 ***
Labor	-0.15765	0.135877	-1.16	0.246
Financially Literate	1.627734	0.210505	7.733	0.000 ***
Formal Education	-0.02205	0.071158	-0.31	0.757
Control:				
LnAs (Assets)	-4.74464	0.051969	-91.298	0.000 ***
LnAs2 (Quadratic Assets)	0.17253	0.002179	79.163	0.000 ***
EqAs (Capitalization)	1.977038	0.162785	12.145	0.000 ***
Per capita personal income	0.020634	0.001138	18.130	0.000 ***

Note: Robust standard errors; Number of observations: 54077; R-squared: 0.559.

The results are consistent with the hypothesis that subnational governments have a significant influence on the banking efficiency of institutions with a strict location in their territory. Subnational competence activities were mostly considered significant. Only the variables of labor and formal education were not shown to be significant, and the others showed a significantly probable relationship.

Two points deserve attention in the variables of labor and government expenditures. The first one was not significant in our analysis, although studies that evaluated this issue have already found a relationship with little labor market freedom and lower banking efficiency level (Chortareas et al., 2016). Obviously, our test cannot find statistical evidence alone, nor does it serve to refute the relationship between the two questions. Regarding government spending, the result was diametrically opposite. We found an inverse relationship between lower levels of subnational spending and the FIs' efficiency. We emphasize that the variables of government spending, taxes and labor measure the level of freedom of each state; that is, they measure the little governmental activity in these areas. Thus, the evidence is that states with greater relative participation in their spending have more efficient FIs. One possible explanation is that these states, on average, can bring greater

financial activity through subsidies to the less-affluent population. However, this result contrasts with the results found in Chortareas et al. (2016).

It should also be noted that the results found for the government speeding variable do not indicate that states with more rigid or bureaucratic taxation generate more banking efficiency. This issue was evaluated by the variable of taxes, which had the opposite result. Subnational entities with tax activities with higher levels of taxation and with more bureaucratic fiscal structures presented more inefficient FIs. This result is in line with national and international studies that indicate that greater tax freedom generates more efficient institutions.

The two variables related to the education level of the population of each subnational entity confirmed the great importance of the financial education of individuals for banking efficiency. It should be noted that the level of formal education did not have a significant impact, showing that pure and simple formal education does not have the capacity to influence the behavior of banking clients to the point of influencing FIs' activities. On the other hand, the level of the financial education of the population was significant. The result strengthens the hypothesis that a financially educated population can seek better financial services and options within the market. The activities of more financially conscious individuals have the ability to influence the productive activities of FIs.

3.5 Conclusion

We measured the efficiency of a sample composed by approximately 3,500 state-chartered FIs that formed 66,855 observations in a time series (2003-2017). The results indicated a constant productivity distribution over the time series (2003-2017) and that efficiency scores behave differently from traditional studies that assess the large banks that control the market or include national banks in their sample. The main result indicates that the behavior of the banking market at the subnational level presents significant differences in its operating structure and in its national-level competitiveness. Future research investigating these differences is necessary to better understand their origins.

Using LDA and ML methods (LSVM, RF and bagging), we verified that variables linked to political-administrative localization criteria could predict if the FI was in the efficient group. However, other variables usually considered to be important were not crucial for classification methods, demonstrating that other attributes, such as type of institution or main regulator, have secondary importance. Considering that the study only covered the US market, research in other markets is suggested to evaluate if the behavior is similar.

Last but not least, the fractional logistic regression tested which variables could be behind the fact that FIs located in certain regions had more efficient scores on average. The results confirmed the recent findings of the literature that states with less governmental influence (more freedom) are related to having more efficient FIs. In addition, we found that the states with a population with higher financial education have more efficient FIs, although the formal education level had no significant effect.

A possible extension of this work is to incorporate stochastic frontier analysis or even convex nonparametric least square (Kuosmanen, 2008) methods in the mensuration phase to deal with some source of bias (e.g. noise terms, Heteroskedasticity), evaluating if the FIs behavior remains the same. Future research also includes the application of Game Cross Efficiency models (Liang et al., 2008), incorporating some competition among the FIs based long-term optimization of the total period, and confronting the results with traditional methods.

Chapter 4

Is The Choice Between Stability and Efficiency a Catch 22? A Prudential Approach for Evaluation of Banking Efficiency

4.1 Introduction

The banking efficiency theory has progressed over time by aggregating diverse approaches of analysis. These approaches privilege specific views of the production function, productive process, and behavior of financial institutions. In this way, what is generally called “bank efficiency" actually incorporates different concepts and structures, seeking to define ideal functioning for firms that involve multiple interests and objectives. In other words, the definition of what is efficient depends on the type of choice that needs to be made and, concomitantly, the purpose of the object of analysis.

Currently, we can indicate four main approaches used by banking efficiency theory to understand and analyze the productive process of financial institutions: production, intermediation, profit orientation, and value-added approach. Each of these presents two main differences: the definition of the main objective of a financial institution and how the institution should meet that objective.

Based on this conceptualization, the function of a bank can be understood as the offering of banking services to clients, as the intermediation of resources between deficit and surplus agents, as the generation of profit to the owners, or even as the generation of value for the economy. The application of each of these approaches depends on the analysis that is proposed, but each of them transmits a need for specific decision making.

Among these key approaches, we can observe that none of them aim to evaluate banks from the point of view of the two main bank supervisor goals: stability and efficiency. As a result, bank supervisors and regulators usually apply a nonstructural approach to capture aspects of performance. In addition, it is commonly understood that these two objectives are trade-offs and, consequently, they are analyzed separately. In other words, supervisors usually use multiple financial indicators that try to achieve indirectly a measure of efficiency or incorporate some indicators in one of the known approaches. However, such procedures are not capable of measuring objectively the capacity to generate financial services and, at the same time, prudential issues related mainly to the stability and safety of the financial system.

In this study, we propose a prudential approach to banking efficiency. In short, we consider a financial institution as an asset and risk manager that aims to maximize future benefits that come from the applied resources. However, as an initial phase of this process, the bank needs to maintain adequate levels of capital and mitigation procedures to support the levels of risk retained by the

business.

After a theoretical justification, we apply our approach empirically through a two-stage network DEA using data from Brazilian commercial banks. The initial inputs are composed of different kinds of risk-weighted assets defined according to the Basel Committee. The intermediate variable is represented by measures of regulatory capital. Finally, the output is composed of main revenues from banking activities.

The results were analyzed and compared with an intermediation model usually applied by banking efficiency studies. Finally, we evaluate efficiency and productivity of Brazilians banks in the crisis period and we test if risk asset diversity, capital diversity, and activity diversity are determinants of banking efficiency.

4.2 Banking Efficiency Approaches and Literature

The most basic way to segregate the models used to address the problem of evaluating banking efficiency is to divide them into structural and nonstructural methods (Hughes and Mester, 2012; San-Jose et al., 2014). The main difference between the two approaches is the necessity or not of linking to a theoretical model, which usually presupposes the construction of production frontiers and production functions and the optimization of the variables evaluated. Without a benchmark or a theoretical estimated frontier to evaluate the efficiency, a nonstructural approach compares indirectly the efficiencies using a set of performance indicators (Hughes and Mester, 2012). As a consequence, structural models have the advantage of a greater objectivity of analysis and better theoretical sensitivity.

However, within the structural models, it is necessary to establish the approach to the process of functioning of financial institutions. Usually the traditional literature uses a classic microeconomic theory in its studies of banking efficiency (Sealey and Lindley, 1977). However, modern works have combined microeconomics with the view that managing risks and improving symmetric information are the main function of a bank (Bhattacharya and Thakor, 1993; Allen and Santomero, 1997). Actually, the four main approaches are production (Wanke et al., 2016b; Glass et al., 2010), intermediation (Peng et al., 2017; Tanna et al., 2017), profit orientation (Salim et al., 2016; Davutyan and Yildirim, 2017), and value-added (San-Jose et al., 2014; Hermes et al., 2011).

The correct definition of the approach that is being used is fundamental for the theoretical and empirical analysis of the determinants of bank efficiency. Empirically, the approach defines the use of the set of input and output variables that are adopted. Thus, the application of the model chosen is likely to lead to different results. In other words, different approaches represent phenomena and points of view of different economic agents; consequently, they lead to different rationalities.

In this way, the choice of a specific approach to evaluating banking efficiency has consequences that go far beyond theoretical issues, overcoming measurement models, and the results that are obtained with its application. Thus, for example, comparing results that came from studies that use different approaches should only be done in an indirect way, but never as if the object of analysis were the same. Many researchers have considered the approach definition one of the “biggest challenges" of the bank efficiency-based studies (Halkos and Tzeremes, 2013, pg. 1660).

Some works justify the choice from the analysis dimension of the process. For example, it is common to justify that, in the evaluation of branches of financial institutions, it is preferable to use the production approach, while the intermediation approach would be more appropriate to the entire financial institution (Davutyan and Yildirim, 2017; Berger et al., 1987). It is clear as well that, beyond the objective intended in the analysis, the approach also depends on the availability of data (Berger et al., 1987; Salim et al., 2016).

The fact that the choice of approach should not elude the objectives of the analysis is already

well indicated by many studies. Despite this, many researches still choose their banking approach by disregarding the intended objective with the desired efficiency assessment. Some authors argue that the choice of approach usually is arbitrary and driven by personal preferences (Holod and Lewis, 2011, pg. 2802).

4.2.1 Production Approach: The Customer and Employee View

Initially, the production approach was focused on several outputs that were represented by the services offered to formal costumers of financial institutions. In reason of that, this approach is also known as a service-oriented approach (Benston, 1965) or even a user-costs approach (Hancock, 1985, 1986). In other words, from this point of view, the purpose of a financial institution is to serve customers, whether they are borrowers, lenders, or just financial transaction customers. That explains why Sealey and Lindley (1977) describe the production approach as purely technical.

In the user-oriented approach, the most models treat deposits as outputs and other funds as inputs within the same process. The outputs are proxies to measure the level of service offered to customers and can be evaluated using monetary amounts or even numbers of users served. However, in a simplified way, we can illustrate according to Figure 4.1 the production approach.

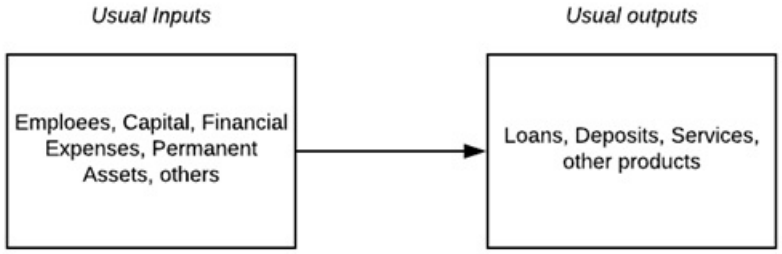

Figure 4.1: Production Approach

The production approach continues to be used and has studies with several research focuses (Wanke et al., 2016b; Devaney and Weber, 2002; Glass et al., 2010).

4.2.2 Intermediation Approach: The Financial Firm's View

The intermediation approach seeks to adapt the activities of a banking institution to the methodology of an economic production process through the use of microeconomic methodology to develop a "positive theory of the operation of the financial firm" (Sealey and Lindley, 1977, pag. 1253). Thus, from this point of view, the lenders would be the suppliers of the banking industry, and the borrowers would be the real customers of that industry. In this case, the behavior of the banking industry would be the same predicted by the theory of the firm and its concepts.

In this point of view, the value is created when the financial institution reduces transactional costs between lenders and borrowers. In the models that use this approach, deposits along with capital, labor, and other resources are considered inputs of the process, while loans and other investments are outputs because they mean money transference.

The intermediation approach is very interesting for evaluating efficiency in the economic sense of the banking institution because, in essence, what is done is an analysis of the capacity to generate loans in relation to the factors of production (mainly labor and capital) used in the activity. In addition, this approach is the most common in studies on banking efficiency (Ahn and Le, 2014, pg. 9-18).

However, it should be noted, for example, that this approach is not concerned with assessing whether the resources specifically allocated by the owners are being efficiently used for the generation of profit. In other words, using the intermediation approach, a financial institution could be considered highly efficient, but at the same time not generate value for the business owner. This can occur basically because the outputs are not actually transferred to the clients as happens in a usual firm, where the firm consumes inputs and transfers the output's ownership to clients.

We simplify the process of the intermediation approach in Figure 4.2.

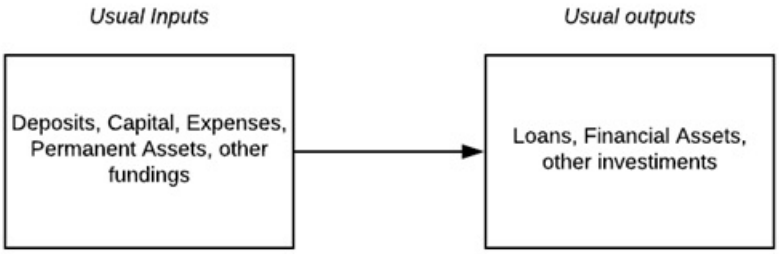

Figure 4.2: Intermediation Approach

As we can see, the intermediation approach is asset oriented, since the production of the assets would be configured as the banking products themselves. For this reason, many also call it the asset approach.

It should be clarified that currently some studies have treated deposits as an intermediate product in a two-stage process (Fukuyama and Matousek, 2011; Holod and Lewis, 2011). In the first stage the deposit would be an output and the following an input. The idea is that the deposits would be acquired from the usual factors of production (capital, labor) and later would serve to generate loans, or even profits. Some argue that such process would be a kind of model of the other intermediation approach that would be a proprietary approach.

Nowadays, the intermediation approach is the most used and has studies within several research areas (Tanna et al., 2017; Peng et al., 2017; Fujii et al., 2017; Degl'Innocenti et al., 2016; Sena et al., 2016; Chortareas et al., 2016; Curi et al., 2015; Halkos et al., 2014; Chan et al., 2013; Halkos and Tzeremes, 2013).

4.2.3 Profit-oriented approach: The owner view

The profit-oriented approach can be understood as a variation of the intermediation approach. However, instead of considering lending as a final objective, this approach sees maximizing profit as the ultimate goal of banks, just as it is for any other firm. Thus, studies that use this approach still visualize the banks as intermediation channels; however, the emphasis and the main output is the profit, not the assets. It is important to note that the profit itself does not need to be set directly as an output. In fact, most studies in this line use the juxtaposition of expenses (inputs) with revenues (outputs) (Kamecka, 2010, 34-40). For this reason, many call this the cost-revenue approach.

Studies that use this approach often justify the choice with the fact that the ultimate goal of a bank is to maximize the profit of its owners (Salim et al., 2016). However, it should be remembered that while financial institutions actually seek profit, this does not mean that only the owners of the banks have decision power and act for the institution to achieve certain goals.

We can verify that this approach evaluates the ability of the financial institution to generate profit, that is, it address the concerns of the bank's owners. On the other hand, this information is

achieved at the expense of the economic information that was provided by the traditional approach to intermediation.

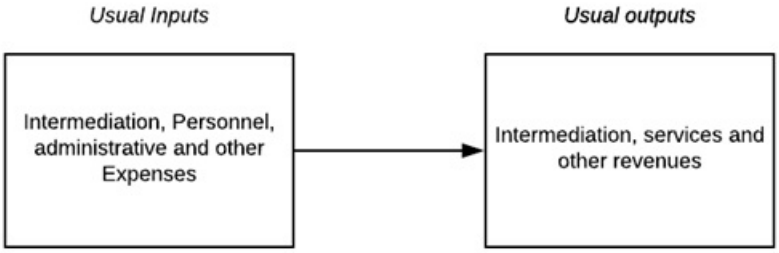

Figure 4.3: Profit-Oriented Approach

The profit-oriented approach is widely used and has studies with several research areas (Salim et al., 2016; Harris et al., 2013; Al-Khasawneh, 2012; Chronopoulos et al., 2012; Barth et al., 2013; Davutyan and Yildirim, 2017).

4.2.4 Value-added approach: The Competitor View or Value Generation Perspective

This approach seeks to measure the value created by the financial institution. It is an economic view of the process that focuses on the value that goods and services acquire when they are transformed during the bank production process. This approach is of special macroeconomic importance. Usually, the beginning of studies with this approach is attributed to the work of Berger et al. (1987).

The value-added approach is not concern with economic agent benefits, but about the value generated by the bank in the economy. However, from this perspective, a financial institution could generate great added value for the economy as a whole using minimal inputs, and still, for example, generates great losses for its owners or unreasonable risk to economic stability.

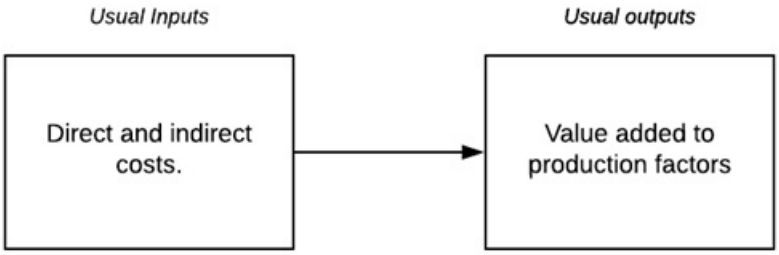

Figure 4.4: Value-Added Approach

For a good use of this perspective, it is necessary to have singular access to the bank's cost data and to adequately segregate the activities of a value chain. As we note, the use of a value-added approach involves a further exploration of the bank processes and links between activities. However, the value-added approach is used in some studies (San-Jose et al., 2014; Hermes et al., 2011).

4.2.5 A Prudential Approach: The Supervisor View

The analysis proposed in this study deals with bank efficiency based on a model that evaluates the achievement of the objectives as the maximization of benefits generated by the assets, with efficient use of resources allocated by the owners, considering the level and allocation of risk by the financial institution. In short, we seek to overcome the existing trade-off in the quest for financial stability and bank “efficiency" (BIS, 2009). We clarify that we used the word “efficiency" in brackets because in our view the cost and results of financial stability should also be considered as inputs and outputs in the calculation of bank efficiency, and not as something segregated from the concept of efficiency.

Stulz (1984) already has explained why a firm’s managers, who work on behalf of firm owners, must be concerned with both expected profit and the distribution of firm returns around their expected value. Classical works have also justified why the function of trading, transferring, and eliminating risks constitutes the main role of a modern financial institution (Merton, 1989; Allen and Santomero, 1997). Despite this, many studies in the area of measuring bank efficiency still build models neglecting that the main role of a modern financial institution is the risk management.

It is also common to apply the intermediation or production approach directly, without the inclusion of metrics that lead with the level of risk retention of the financial institution (Al-Khasawneh, 2012; Salim et al., 2016; Peng et al., 2017). These sorts of approaches do not consider the various types of risks retained as part of the productive process of financial institutions. This is to some extent understandable since, when a financial institution manifests major risk management problems, it ends up out of traditional efficiency studies, especially since these banks end up side leaving the databases because of bankruptcy, merger and acquisitions processes, or even government bailouts.

Thus, the theory of intermediation, evaluated in itself, is not capable of an accurate regulatory analysis of efficiency. It seems clear that, economically, banks can be seen as transferors of resources from lenders to borrowers. However, the true value of the current banking service lies in the risk management of the funds raised. The most efficient financial institution from a supervisor’s point of view is the one that manages to get cheaper resources and transform them into maximum benefits while integrating a prudential activity.

In addition, among the approaches that we briefly reviewed, none privilege the point of view of the bank supervisors. As a result, bank supervisors and regulators usually apply nonstructural approaches to capture aspects of performance, at the same time using one of the existing models. However, this procedure is unable to give an objective measure integrating a theoretical analysis.

Seeking to fill this gap, our approach esteems the point of view of the financial institution supervisor and understands that the main role of a bank is managing risks. In this way, our model does not seek the usual economic point of view. In other words, in our model, the fundamental activity of a financial institution is receiving resources from the market and managing them in the best possible way, ultimately guaranteeing the maximization of benefits generated by the bank’s assets.

This management involves the decision of operational and risk allocation of these financial resources and is overseen by both market agents and government regulators. Therefore, within this model, the stability and functioning of the financial institution depend on the demonstration of a capital structure that supports the risks of the applications of resources made.

We start from the fact that, by theoretical and technical definition, an asset is a resource controlled by the entity and from which future economic benefits are expected to flow to the entity (IASB, 2010). Therefore, the definition of asset derives from its function of generating benefits for the entity, in our case commercial banks. That means that the whole process of a firm basically consists in the administration of assets for the generation of benefits for the entity.

However, unlike other firms, the main role of a bank is to select a set of available assets by adjusting its expected benefits to the different types of risks. In addition to this, to avoid bankruptcy due to unexpected losses, or even regulatory imposition, the bank needs to adjust its capital levels during this process. We consider this phase of asset adjustment to the capital as the first stage of the banking process.

On the other hand, capital represents the assets of the owners and, in a final analysis, it is the owner's objectives that are pursued by managers by delegation. In this way, capital allocation is a necessary output to support the risk coming from the assets and also the input needed to generate benefits for the shareholders. This phase of capital allocation that brings benefits for the bank is the second phase of the process.

Fig. 4.1 shows our proposed approach of a bank's production process.

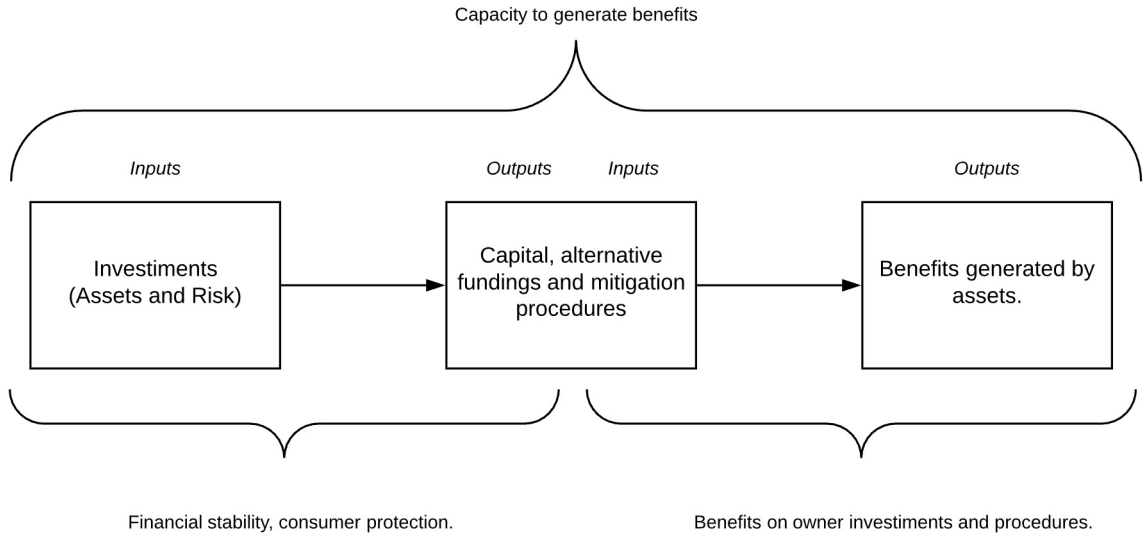

Figure 4.5: Prudential Approach

The first stage of the model could be sufficient from the point of view of stability. However, it does not contemplate the goal of maximizing benefits of the invested capital. So, we move on to the second stage of efficiency measurement. At this stage, the manager seeks to use the capital in the best way possible to generate results for the owners.

The whole process represents the objective of regulators to establish a system capable of providing services, but keep the bank in a resilient condition. In other words, they want stability and risk levels be consistent with the remuneration paid to the capital invested by owners.

This theoretically explains why in our model a bank does not seek to maximize value, profits and products or to minimize production factors, expenses, and others.

4.3 Application: Methodology

4.3.1 Efficiency and Productivity Mensuration

The sample is represented by the existing Brazilian financial commercial banks at the end of 2017, using an annual series from 2015 to 2017. In December 2017, there were 107 commercial banks in Brazil according to the list of "IF.data" of the Central Bank of Brazil (BACEN). "IF.data" is a database of selected information on supervised institutions by the BACEN. The data are the responsibility of the institutions; however, the BACEN monitors the quality of the data, which confers a good margin of quality to the data.

All the financial information on the banks was collected on the BACEN database through “IF.data" (reports: assets, liabilities, income statement, and capital information), which enabled the selection of statements of financial institutions sent to the BACEN. The reports were obtained from data of the institutions considered as prudential conglomerates and independent institutions.

To measure efficiency, we adopted scores generated by the non-parametric Data Envelopment Analysis methodology (DEA) as a proxy for efficiency. In the DEA analysis, the decision making units (DMUs) refer to management units that decide similarly and therefore are compared to each other to find one or several reference units called benchmarks. DEA methodologies continue to be used in the recent banking efficiency literature (Sena et al., 2016; Chortareas et al., 2016; Ayadi et al., 2016; Degl'Innocenti et al., 2016; Salim et al., 2016; Peng et al., 2017; Tanna et al., 2017; Fujii et al., 2017; Wanke et al., 2016b).

For the use of DEA, linear programming techniques and duality theory allow the construction of the best-practice frontier (empirical efficient frontier) for a given technology from a set of observations and calculate the distance of the border for each of the DMUs (Zhu, 2014).

In the envelope model, the spatial projection of the inefficient units at the boundary is delimited by a reference set of efficient units. However, the analytical power of the technique can be amplified by the multiplier model in which, for each DMU to be analyzed, an optimization problem is formulated to determine the values that this DMU assigns to multipliers u and v (weights) to be as efficient as possible, as shown below:

$$\frac{\sum_j^n u_j.Y_{jk}}{\sum_i^n u_i.Y_{ik}} = \frac{uY_k}{vX_k}, \tag{4.1}$$

where u e v are the weights and, by convention, $\frac{uY_k}{vX_k} =\leq 1$, so we have a score between 0 and 1.

Since production is a process in which resources (X_k) are used to generate products (Y_k), the productivity frontier can be defined as the maximum quantity of outputs obtained from the inputs used. The efficiency of each DMU is the weighted sum of the outputs divided by the weighted sum of the inputs, the distribution of the weights occurring without any interference of the decision maker.

We highlight that usually a production process in its strict sense meaning is more related to the intermediation or production approaches. In our study, perhaps the most suitable term for the DEA function is as MCDM (multiple criteria decision making) tool. The DEA will be used to benchmarking the performance of bank service, generating a "best-practice frontier" rather than a "production frontier" (Zhu, 2014, pag. 6).

We choose a DEA model capable of linking the two sub-processes (prudential risk control and benefits generation), and at the same time, the whole process could be calculated in an integrated way. To this end, we used the model proposed by Kao and Hwang (2008) and called centralized model by Liang et al. (2008). In short, the model is as follows:

$$E_k = \frac{\sum_{r=1}^s u_r Y_{rk}}{\sum_{i=1}^m v_i X_{ik}} \leq 1, E_k^1 = \frac{\sum_{p=1}^q w_p Z_{pk}}{\sum_{i=1}^m v_i X_{ik}} \leq 1, E_k = \frac{\sum_{r=1}^s u_r Y_{rk}}{\sum_{p=1}^q w_p Z_{pk}} \leq 1, \tag{4.2}$$

Where u_r, v_r , and w_r are non-negative multipliers that DMU (in our case, a commercial bank) k has selected to calculate its overall efficiency E_k and sub-process efficiencies E_k^1 and E_k^2. The centralized model permits us to calculate the efficiency of the whole process (transformation of assets in benefits to the bank) and the two sub-processes (generation of prudential control, and production of benefits for the capital) in an integrated way.

Thus, the model takes into account the fact that risky assets produce the necessity of capital in the first sub-process, and then invested capital can be generated in the second sub-process. In this way, under this model, the overall efficiency is the product of the efficiencies of first and second

sub-processes, $E_k = E_k^1.E_k^2$.

The main advantage of using Kao and Hwang (2008)'s model is the possibility of decomposing the entire process into the product of the efficiencies of the two sub-processes. This is possible since the multipliers of the intermediate measures are equal in the first and second phase. However, this model only allows constant returns of scale (CRS). Further technical details about the model can be obtained in Kao and Hwang (2008).

The application of the DEA methodology also implies the arbitration of the orientation to be used, since it is a mathematical programming model of multiple inputs and products. Optimization can be operated in three ways: input-oriented, when the goal of DMUs is the minimization *ceteris paribus* of consumed inputs; output-oriented, when it is desired to maximize *ceteris paribus* of the products; and non-oriented, when it is a combination of the two previous ones.

We have used an output-orientated model. As we discussed before, all aspects of the model, inclusive orientation choice, should be consistent with the context of the study. It is not enough to affirm the DMUs goal and the market conditions. Since the Bank's objective is a relative concept, the most crucial question is defining the main goal of the stakeholder that is the object of the study. In this study, we seek to analyze the point of view of the bank regulators, which needs to aggregate the bank function of risk management.

We based the inputs up the concept of risk-weighed assets. It should be noted that for the inputs, the two models used identical variables: personnel and administrative expenses and total assets, as shown in Table 2.

In addition, to analyze the impacts of the Brazilian fiscal crises in the productivity of its banks, we applied an adjacent Malmquist with geometric mean of 2 TFP indices to our balanced panel data. The Brazilian economy has been in recession since the end of 2014. The Brazilian per capita product fell about 9% between 2014 and 2016, and the risk of insolvency has increased (Barbosa Filho, 2017).

Our goal with the procedure is to evaluate the total factor productivity change of each bank between the periods of 2015-2016 (fiscal crises). There is a quantitative relation among Malmquist index (MI), efficiency change (EC), and technical change (TC) represented by MI = EC.TC. Thus, we can analyze not only the Brazilian commercial bank's productivity change, but also their efficiency and technology changes.

In addition, under the assumption of constant returns of scale (CRS), TC can be decomposed as TC = IBTC.OBTC.MC, where MC = magnitude or neutral component (measure of Hicks neutral technological change), IBTC = input biased technological change, and OBTC = output biased technological change (Färe et al., 1997).

When $EC > 1$,the efficiency is rising, largely due to the reform of the institute or the increase in production scale, which usually is not sustainable. TC is the movement in the production frontier in the period from time t to time $t + 1$, resulting from innovation or the application of new technology. When $TC > 1$, usually we say that technical merit rises along with efficiency, which brings an more sustainable economic growth.

To define our inputs and outputs, we adopted our proposed approach in the early sections. After that, we use a traditional intermediation approach to compare the results. As we have discussed before, banks are asset and risk managers; thus, they should focus on the benefits generated by the assets, controlling their risks.

4.3.2 DEA Framework

First, to apply the prudential approach, we use 6 kinds of risk-weighted assets (RWAs) as proxies for the level of the risks and species of assets invested by the bank. Each RWA will thus represent an input in the DEA model. The RWA measurement methods have the advantage of international

standardization and easy understanding of their criteria (BCBS, 2004, 2011).

As proxies for the quality of the capital invested by the owners, we use Tier I and Tier II capitals. Thus, these regulatory capital represent both the output from the risk retention process and the input invested by the owners. It should be pointed out that these capital specimens have direct interest in the bank's performance, since they depend on profit for their remuneration. Regulatory capital also has the advantage of being monitored by BACEN and of having international criteria for its specification (BCBS, 2004, 2011)

Finally, as the final output of the process, we use as proxy the three main types of revenues that a bank can obtain: intermediation, services, and fees. With this separation, it will be possible to later test whether there are some business models that are more efficient than others.

Fig. 4.5 summarizes our proposed model of a bank's production process.

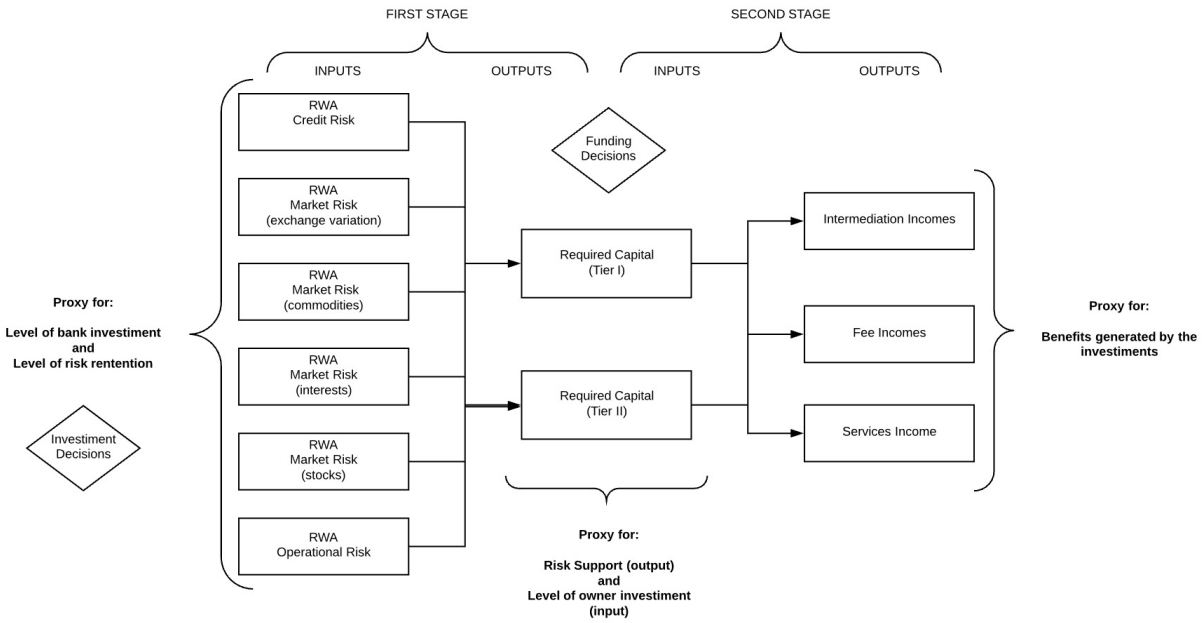

Figure 4.6: DEA Model

4.3.3 Input Description: Risk-Weighted Assets

RWA allocations works as a proxy which reveals the bank's preferences and strategies. In other words, it reflects decisions about allocation in different kinds of risks and operations. Another advantage is that the RWA is expressed in price (weighted value) and, for this reason, it possibilities allocative efficiency analysis.

Banks can choose from standardized, internal ratings based (IRB), and advanced IRB approaches; however all follow the same principles (BCBS, 2004, 2011). As in Brazil, the standardized approach is used by most commercial banks, we will describe their formulas. The objective is to demonstrate how the RWA variable works a risk and asset profile. The standardized approach is based on a combination of fixed asset risk weights and other ratings.

- RWA_{cred} (Input 1)

The standardized approach for the calculation of the risk-weighted assets for exposures to credit risk (RWA_{cred}) is equal to the sum of products of the credit exposures by the respective risk-weighted factors (F) (BCBS, 2004; BRAZIL, 013j)

$$RWA_{cred} = \sum_{i}^{n} (EXP_i.Fi), \tag{4.3}$$

where F_i = risk-weighted factor predetermined for the asset i; EXP_i = credit exposure i.

For further information, see BRAZIL (013a) and BCBS (2004).

Market exposures are formed by exchange (RWA_{exc}), interests (RWA_{int}), stocks (RWA_{stk}), and commodities (RWA_{com}) exposures.

- RWA_{exc} (Input 2)

The risk-weighted assets for exchange variation exposures (RWA_{exc}) is the portion for exposures in gold, foreign currency, and assets subject to exchange variation.

$$RWA_{exc} = \frac{F^{'}.EXP}{F}, \tag{4.4}$$

where F = Basel risk factor; F' = factor applicable to exposures in gold, foreign currency, and assets and liabilities subject to exchange variation, and EXP = exchange exposure calculated according to the following formula:

$$EXP = Exp_1 + H.Exp_2 + G.Exp_3, \tag{4.5}$$

where G = factor applicable to the amount of the opposite positions in gold, foreign currency, and assets and liabilities subject to exchange variation, in Brazil and abroad; $Exp1$ = exposure calculated according to the following formula:

$$Exp_1 = \sum_{i}^{n} |EC_i - EV_i|, \tag{4.6}$$

where n = number of currencies, including gold; ECi = total exposures purchased in currency i; EV_i = total exposures sold in currency i;

and Exp_2 = exchange exposure calculated according to the following formula:

$$Exp_2 = min \left\{ \sum_{i=1}^{n_1} |ExC_i| ; \sum_{i=1}^{n_1} |ExV_i| \right\}, \tag{4.7}$$

where n_1 = number of currencies, taking into account only the exposures in US dollar, euro, Swiss franc, yen, pound sterling, Canadian dollar, and gold; $ExCi$ = excess of exposure purchased in relation to the exposure sold, calculated for the i currency; and $ExVi$ = excess of the exposure sold in relation to the exposure purchased, calculated for the i currency; and Exp_3 = exchange exposure calculated according to the following formula:

$$Exp_3 = min \left\{ \sum_{i=1}^{n_2} |EIB_i| \sum_{i=1}^{n_3} |EIE_i| \right\}, \tag{4.8}$$

where n_2 = number of coins, including gold, for which exposures in Brazil are calculated; n_3 = the number of currencies, including gold, for which the exposures abroad are determined, including for subsidiaries and dependencies located abroad; $ElBi$ = net exposure in Brazil in the i currency, resulting from the difference between the total of the positions purchased and the total of the positions sold in Brazil; and ElE_i = net external exposure in the i currency resulting from the difference between the total of the long positions and the total of the positions sold abroad, including subsidiaries and branches located abroad.

For further information, see BRAZIL (013i) and BCBS (2004).

- RWA_{com} (Input 3)

The standardized risk-weighted assets for commodities exposures (RWA_{com}) is calculated as follows:

$$RWA_{com} = \frac{1}{F}\left[\left(F'.\sum_{i=1}^{n}|EL_i|\right) + \left(F^{IV}.EB\right)\right], \tag{4.9}$$

where F = Basel risk factor; F' = predetermined factor applicable to the sum of net exposures (EL_i); n = number of types of goods in which the exhibitions; F^{IV} = factor applicable to gross exposure (EB); EL_i = net exposure of the commodity i, representing the value, expressed in reais, calculated by the absolute value of the sum of all the positions purchased minus the absolute value of the sum of all the positions sold referenced in the type of merchandise i, including those held by means of derivative financial instruments; and EB = gross exposure, representing the sum of the absolute values, expressed in reais, of each long position and each position sold referenced in commodities.

In short, the formula is applied to transactions subject to changes in the price of goods traded on the stock exchange or organized exchange markets, including derivative financial instruments, with the exception of transactions referenced in gold financial assets or foreign exchange instruments.

For further information, see BRAZIL (013h) and BCBS (2004).

- RWA_{int} (Input 4)

The standardized risk-weighted assets for interest exposures (RWA_{int}) is the sum of each kind of interest exposure.

The calculation of the daily value of the portion of RWA for exposures subject to the variation of fixed interest rates denominated in reais that capital requirement is calculated using a standardized approach RWA_{INT1} is based on the following formula:

$$\begin{aligned} RWA_{INT1} = \frac{1}{F}.\{\, max\left[\left(\frac{M^{pre}_{t-1}}{60}.\sum_{i=1}^{60} Var^{Stand}_{t-1}\right), VaR^{Stand}_{t-1}\right] + \\ max\left[\left(\frac{1}{60}.\sum_{i=1}^{60} sVar^{Stand}_{t-1}\right), sVaR^{Stand}_{t-1}\right]\,\}, \end{aligned} \tag{4.10}$$

where F = Basel risk factor; $Mpret$ = multiplier for day "t", determined as a decreasing function of volatility, whose value is between 1 and 3; VaR^{Stand}_{t-1} = value at risk, expressed in reais, of all specific exposures.

The calculation of the daily value of the RWA portion of exposures subject to change in the rate of foreign currency coupons whose capital requirement is calculated using a standardized approach (RWA_{INT2}) is made based on the following formula:

$$RWA_{INT2} = \frac{M^{ext}}{F}.\left[\sum_{k=1}^{m1}\left(\left|\sum_{i=1}^{11} EL_i\right| + \sum_{i=1}^{11}|DV_i| + \sum_{i=1}^{3}\left|DHZ_j\right| + DHE\right)_k\right], \tag{4.11}$$

where F = Basel risky factor; M = multiplier factor per exposure subject to variation of the coupon rate of foreign currencies; m = number of foreign currencies in which there is exposure subject to variation of the coupon rate of foreign currencies; ELi = net exposure at vertex i and

in foreign currency k; DV = vertical mismatch in vertex i and in foreign currency k; DHZ = horizontal mismatch in the foreign currency k within the maturity zone j; and DHE = horizontal mismatch in the foreign currency k between the due date.

Adding RWA_{INT3}, variation of coupon of price indexes, and RWA_{INT4}, variation of interest rate coupon rates, we complete the standardized RWA_{INT}. Both are calculated in the same way of the RWA_{INT2}, basically changing the rate.

For further information, see BRAZIL (013b), BRAZIL (013d), BRAZIL (013f), BRAZIL (013g), and BCBS (2004).

- RWA_{stk} (Input 5)

The standardized risk-weighted assets for stock exposures (RWA_{stk}) is calculated as follows:

$$RWA_{STK} = \frac{1}{F}.\sum_{j=1}^{n} RWA_{STK_{[j]}}, \tag{4.12}$$

where F = Basel risk factor; n = number of countries in which the institution carries out operations subject to stock price variation; $RWA_{STK_{[j]}}$ = portion related to the risk of operations subject to the stock price variation, in country j, calculated based on the following formula:

$$RWA_{STK_{[j]}} = F^{V}.\left|\sum_{i=1}^{n2_j} NES_{i,j}\right| + F_j^{VI}.\left|\sum_{i=1}^{n2_j} NES_{i,j}\right| + F_j^{VII}.\left|\sum_{i=1}^{n3_j} NEI_{k,j}\right|, \tag{4.13}$$

where $n2$ = number of issuers to which the institution is exposed in country j; $n3$ = number of stock indexes to which the institution in the country is exposed j; NEI = net exposure in contracts referenced to the stock index k in country "j"; F^V = general risk factor, applicable to the absolute value of the sum of net exposures in shares (NES); F^{VI} = specific risk factor in country j, applicable to the sum of absolute values of net equity exposures (NES); and F^{VII} = specific risk factor in country j, applicable to the sum of the absolute values of the net exposures in contracts indexed to stock indexes (NEI).

For further information, see BRAZIL (013c) and BCBS (2004).

- RWA_{oper} (Input 6)

The risk-weighted assets for operational risk (RWA_{oper}) aggregates exposures in the following business lines: retail; commercial; corporate finance; negotiation and sales; payments and settlements; financial agent services; asset management; and retail brokerage.

For the basic indicator approach, the following is as follow:

$$RWA_{opert} = \frac{1}{F}.\frac{\sum_{t=1}^{3} max\left[0.15 \cdot IE_t; 0\right]}{n}, \tag{4.14}$$

where F = Basel risk factor; IE_t = indicator of exposure to operational risk in the annual period t; and n = number of times in the last three annual periods, where the IE value is greater than zero.

EI is the operational risk exposure indicator. It corresponds to the sum of the half-yearly amounts of financial intermediation revenues and revenues from services rendered, net of financial intermediation expenses, for each annual period.

For the standard alternative approach, the following formula is used:

$$RWA_{oper} = \frac{1}{F}.\frac{\sum_{t=1}^{3} max\left[\left(\sum_{t=1}^{2} AEI_{i,t} \cdot \beta_i\right) + \left(\sum_{t=3}^{8} EI_{i,t} \cdot \beta_i\right); 0\right]}{3}, \tag{4.15}$$

where F = Basel risk factor; $AEI_{i,t}$ = alternate operational risk exposure indicator, in the annual t period, calculated for the i business lines; $EI_{i,t}$ = operational risk exposure indicator, in the annual t period, calculated for the i business lines; and β_i = weighting factor applied to the i business line.

AEI is the Alternative Operational Risk Exposure Indicator. It corresponds, for each annual period, to the arithmetic average of the semiannual balances of credit operations, leasing operations, and other operations with characteristics of credit granting and securities not classified in the trading portfolio, multiplied by the factor 0.035.

For the simplified standard alternative approach, the following formula is used:

$$RWA_{oper} = \frac{1}{F} \cdot \frac{\sum_{t=1}^{3} max\left[\left(AEI_{i,t} \cdot 0.15\right) + \left(EI_{i,t} \cdot 0.18\right); 0\right]}{3}, \tag{4.16}$$

where F = Basel risky factor; $AEI_{i,t}$ = alternative indicator of exposure to operational risk, in the annual period t, calculated in aggregate form for the lines of business $EI_{i,t}$ = operational risk exposure indicator, in the t annual period, calculated in aggregate form for operations not included in the business lines used before. All operations of the financial institution should be distributed between the AEI and the EI.

For further information, see BRAZIL (013e) and BCBS (2004).

4.3.4 Intermediate Input/Output Description: Regulatory Capital

The regulatory capital (RC) consists of the sum of Tier I and Tier II. Tier I consists of the sum of principal capital and complementary capital (BCBS, 2004, 2011; BRAZIL, 013a).

- Tier 1 (Intermediate 1): formed primarily by stocks, capital reserves and retained earnings, thus representing a higher quality portion and more apt for retain losses. On this amount they are all made as regulated deductions. Its complementary capital is composed of perpetual subordinated debt instruments.
- Tier II (Intermediate 2): composed of subordinated debt instruments with a period of more than 5 years (BRAZIL, 013a).

The eligible instruments, as complementary capital of Tier I and those eligible for Tier II require the extinction or conversion of debt into shares eligible for principal capital in the difficult situations faced by the institution.

As we can see, the two intermediate variables are composed of the capital of owners or creditors with remuneration that is dependent on the bank's results. In this way, this capital serves as a proxy for the risk mitigation of assets (first sub-process) and as capital belonging to owners in the bank's financial results (second sub-process).

See BRAZIL (013a) and BCBS (2004) for further information.

4.3.5 Output Description - Revenues

The final outputs of the process are formed by the three main income classes of a commercial bank: intermediation, service and tariff revenues.

- Intermediation revenues (Output 1): total revenue from credit, leases, securities, financial derivative, mandatory reserve incomes and foreign exchange net income;
- Service revenues (Output 2): income for payment services; administration of investment funds, funds and programs, lotteries, investment companies; technical advice, consortium

administration, coverage, title placement committees, exchange ratings, asset administration, corrections of operations in stock markets, custody service income, etc.

- Fee revenues (Output 3): guarantees, packages of services, special services, corporate services, specific services, etc.

4.3.6 Variables Description of Intermediation Approach

Finally, the variables used in the intermediation approach are formed by three inputs (total costs, deposits, capital) and three outputs (loans, other earning assets, gross incomes).

- Total Costs (Input 1): Personnel, administrative and interest costs,;
- Deposits (Input 2): total deposits, including demand deposits, saving deposits, interbank deposits, special deposits, etc.;
- Capital (Input 3): capital equivalent to the sum of common equity tier I and additional tier I.
- Loans (Output 1): total loans minus loan loss allowance;
- Other Earning Assets (Output 2): other assets plus interbank transactions and interbranches transactions.
- Gross Income (Output 3): Total from Credit, Leases, Securities, Financial Derivative, BCB Mandatory Reserve Income and Foreign Exchange Net Income.

Access Central Bank of Brazil site for further information about the metrics used by "IF.data".

4.3.7 Descriptive Statistics

In the following tables we provide descriptive statistics for the variables used in this research. One point worth mentioning is that although all banks present assets with credit risk, many institutions do not present other forms of risk exposure. The same happens with the intermediate variables and the final outputs. Tier II capital is not used by all banks, and revenues with services and fees are also not practiced by all institutions.

Table 4.1: Descriptive Statistics - Inputs (RWAs)

RWA	Credit Risk	Exchange	Commodities	Interests	Stocks	Operational
Mean	37081585	511894	130582	1345782	247539	3140454
Standard Deviation	128811147	1855381	1094229	3711935	1263014	10080567
Kurtosis	16.8	45.0	185.5	15.0	51.5	18.2
Skewness	4.2	6.3	13.0	3.8	7.0	4.3
Minimum	3966	0	0	0	0	0
Maximum	785773084	16416423	16396582	22378573	11328525	63276519

Source: Monetary figures are expressed in thousands Brazilian reais. IF.DATA (Central Bank of Brazil).

Table 4.2: Descriptive Statistics - Intermediate variables (Capital) and CAR

	Capital (Tier I)	Capital Tier II	CAR
Mean	5712013	1546323	0
Standard Deviation	18864124	6114481	0
Kurtosis	18.6	23.6	16.0
Skewness	4.3	4.8	3.0
Minimum	-293664	0	-1
Maximum	122453327	40283462	3

Source: Monetary figures are expressed in thousands Brazilian reais. IF.DATA (Central Bank of Brazil).

We also included descriptive statistics of the capital adequacy ratio (CAR) of the sample banks. Our objective is to point out that there are several banks with very high levels of capital. This may indicate a lack of capacity to generate results and market failure indices.

Table 4.3: Descriptive Statistics - Outputs (Revenues)

	Intermediation Revenues	Service Revenues	Fee revenues
Mean	4544243	550215	235573
Standard Deviation	15598283	2007867	926865
Kurtosis	17.21	18.40	20.02
Skewness	4.23	4.34	4.53
Minimum	-110651	0	0
Maximum	94633881	12858344	5803289

Source: Monetary figures are expressed in thousands Brazilian reais. IF.DATA (Central Bank of Brazil).

4.3.8 Efficiency Association

As a second phase of the study, we evaluated whether certain business models had an association with assessed efficiency over the prudential approach. We tested whether the level of risk diversification, capital composition, and banking activity correlated with verified efficiency scores. We used the follow regression:

$$EBS_{k,t} = \alpha + RAD_{k,t}\beta + RCD_{k,t}\gamma + IND_{k,t}\delta + CVS_{k,t}\xi + u_{k,t}, \quad k = 1, ..., n; t = 2015, 2016, 2017 \tag{4.17}$$

where $EBS_{k,t}$ is the efficiency of bank k at time t, $RAD_{k,t}$ is the RWA diversification variable, $RCD_{k,t}$ is the capital diversification variable, $IND_{k,t}$ is the income diversification variable, and $CVS_{k,t}$ is a vector of control variables with characteristics that may have an effect on the efficiency. Lastly, $u_{k,t}$ is the random error.

Importantly, we clarify that it is important to perform a bootstrap procedure before the Tobit regression to avoid autocorrelation problems between efficiency scores. We perform the procedure using the first algorithm proposed by Simar and Wilson (2007) and a fractional logit regression, as proposed by Chortareas et al. (2016). We use the R software packages "rDEA" and "frm" to execute the method.

We measure risk diversification, regulatory capital diversification and income diversification with a modified Herfindahl-Hirschman index (HHI). Following Elsas et al. (2010), we define diversification (DIV) by subtracting HHI from unity so that it increases with diversification.

$$RAD_{k,t} = 1 - \left(\frac{RWA_{cred}}{RWA_{tot}}\right)^2 - \left(\frac{RWA_{exc}}{RWA_{tot}}\right)^2 - \left(\frac{RWA_{com}}{RWA_{tot}}\right)^2 - \left(\frac{RWA_{int}}{RWA_{tot}}\right)^2 - \left(\frac{RWA_{stk}}{RWA_{tot}}\right)^2 - \left(\frac{RWA_{oper}}{RWA_{tot}}\right)^2 \tag{4.18}$$

The RAD index provides a measure of how much the bank is focused or not among the six existing asset classifications. Thus, for example a low RAD index bank is highly concentrated. The lowest possible diversification index is 0, when a bank would only have assets with exposures to a single type of risk.

$$RCD_{k,t} = 1 - \left(\left(\frac{RC_{tier1}}{RC_{tot}}\right)^2 + \left(\frac{RC_{tier2}}{RC_{tot}}\right)^2\right) \tag{4.19}$$

The RCD index evaluates the degree of use of subordinated debt instruments in the composition of the bank's regulatory capital. It should be recalled that this type of instrument has limited participation for purposes of the composition of regulatory capital for prudential purposes.

$$IND_{k,t} = 1 - \left(\left(\frac{INC_{int}}{INC_{tot}}\right)^2 + \left(\frac{INC_{ser}}{INC_{tot}}\right)^2 + \left(\frac{INC_{fee}}{INC_{tot}}\right)^2\right) \tag{4.20}$$

Finally, the IND index indicates the level of diversification among the three sorts of usual incomes available to banks. It is worth noting that the revenues of the Brazilian banking system is usually characterized by a significant contribution of incomes that do not came from interests.

4.4 Main Results

4.4.1 Efficiency Mensuration (DEA Model Scores)

Table 4.4 shows the efficiency scores achieved by the IFs, under the prudential approach during the three years of analysis (2015, 2016 and 2017), as well as the overall average efficiency for each stage. The efficiency of the whole process evaluates the ability to manage a set of risk assets (RWAs) to generate benefits (revenues). However, initially the efficiency scores of the first stage measure the performance in adjusting capital to level of exposures of assets to different kinds of risk. Last, the second stage measures the performance in generating revenues from the owner's capital allocated. The product of the efficiencies of the two sub-processes is the efficiency of the whole process.

First of all, a technical note must be made. Since overall efficiency is the product of first and second-stage efficiencies, the overall score can never be greater than the partial scores. Thus, since on average the scores of the second stage were low, it was expected that the general scores, in turn, would be even lower. Thus, the descriptive analysis of the results of this model should rather analyze the position or of the list of benchmarks found than the value of the score (Kao and Hwang, 2008). However, the analysis of Tables 4.4 and 4.5 shows that the scores referring to the financial efficiency model are much lower than those found in studies with traditional approaches.

Table 4.4: Descriptive Statistics - Scores

	Stage 1	Stage 2	Whole Process
Mean	0.40	0.29	0.10
Median	0.23	0.22	0.00
Standard Deviation	0.43	0.29	0.20
Kurtosis	-1.66	0.12	5.22
Skewness	0.36	0.97	2.32
Minimum	0.00	0.00	0.00
Maximum	1.00	1.00	1.00

We have also included Table 4.5 with descriptive statistics of the values obtained when adopting the intermediation approach. The results of the scores were close to those usually verified in the efficiency studies of Brazilian banks. As can be seen, they have average efficiency scores well above the values for the prudential approach.

Table 4.5: Descriptive Statistics - Intermediation Approach

	Scores Painel	MI(t-1, t)	EC(t-1, t)	TC(t-1, t)	201512	201612
Mean	0.75	0.99	1.08	0.922	0.77	0.77
Median	0.77	0.98	1.01	0.910	0.73	0.81
Standard Deviation	0.21	0.34	0.25	0.29	0.21	0.21
Kurtosis	0.45	10.10	4.39	24.168	0.53	0.51
Skewness	-0.78	2.17	1.42	4.12	-0.70	-0.88
Minimum	0.071	0.39	0.55	0.415	0.071	0.092
Maximum	1	2.90	2.12	2.89	1.00	1.00

The mean indexes found for stage 1 were the highest and with the right asymmetry, indicating that the indicators in this phase are close to 40% of the benchmarks. The graded difference of scores found in this phase was to some extent expected, given the large dispersion of the CAR levels verified in the description section of the variables.

The difficulty of adjusting the allocations between the different types of risk and the possibility of allocating capital may also partially justify the degree of efficiency of this phase. This initial phase corresponds to the stage of adjustment of capital levels to the different types of risk retained by the bank.

The scores also show that, even considering the best fit weight for most efficient risk exposure for the bank, there is still a great distance from the safest institutions to the border of Basel CAR. On the other hand, the result shows that the benchmark institutions have capital ratios much higher than required, which may reveal a deficiency in the fund-raising process by institutions or an above-average preference for low-risk assets.

The differences in efficiency scores become more pronounced in the second phase of analysis that demonstrates the relationship between capital and the income generation capacity of FIs. Additionally, these factors combine in a high degree of difference also in the results found in the general efficiency index. In other words, Brazilian commercial banks have very uneven risk-weighted asset-generation capacities, showing a large margin for better allocation of assets in the financial system.

On the other hand, another question that may be debated is whether the Basel criteria for indicating the degree of risk of the assets actually reflect the perceived risk of the market. However, even considering only the cost of equity allocation, the results show that Brazilian institutions still have assets allocated asymmetrically. Institutions that have very low overall efficiency scores, already have solvency problems, or have a high probability of presenting, since the assets that make up their portfolios are not able to generate compatible revenues.

Given the above, it can be said that the findings of this study corroborate the thesis there is a lack in efficiency of the Brazilian IFs, if compared with banks of developed countries. In addition, we show that the problem is even worse when we consider a prudential approach. In other words, the Brazilian banks are not remunerated by the risk level of the assets they are carrying. This evidence is consistent with other data regarding interest rates, compulsory deposits, bank concentration, and subsidy operations for some sectors that are characteristic in the country. This raises the question whether efficiency problems are more related to IF management criteria or whether they are due to institutional problems of functioning of the country's financial system that would put the institutions under unequal conditions.

4.4.2 Bank Productivity and Fiscal Crises in Brazil

On average, Brazilian banks did not have a marked change in their productivity in the adjustment between RWA and capital (Stage 1) between 2015 and 2016. Thus, on average, the Malmquist indexes remained practically equal to 1. A small improvement, however, was verified by some institutions, which reflected an average increase of about 13 in the capital-RWA ratio. The result is interesting, showing that the efficiency differences verified, on average, did not come from a change in the benchmark frontier (TC).

Table 4.6: Descriptive Statistics - Productivity Analysis (First Stage)

	MI(t-1, t)	EC(t-1, t)	TC(t-1, t)	OBTC(t-1, t)	IBTC(t-1, t)	MATC(t-1, t)
Mean	1.01	1.13	0.94	1.10	1.08	1.04
Median	0.89	1	0.85	1.02	0.98	0.85
Standard Deviation	0.84	0.64	0.47	0.34	1.04	0.82
Kurtosis	44.49	11.25	20.50	12.30	71.62	15.02
Skewness	5.96	2.87	3.61	3.07	8.11	3.66
Minimum	0.01	0.26	0.01	0.45	0.22	0.00
Maximum	7.60	4.35	4.03	2.81	10.23	5.47

It should be remembered that, as we verified in the variable statistics of variables, there were many institutions with very high capital ratios. The results seem to show that the fiscal crisis accentuated in the year 2015 appears to have contributed to the capital adjustment levels of the institutions. In addition, the OBTCs also remained very close to indicating inputs (RWAs) and outputs (RCs) neutral TC.

It is important to note that the values of the tables are averages of the indexes of financial institutions, so the properties of MI = EC.TC or TC = IBTC.OBTC.MC do not hold when multiplying their averages.

In contrast, in the second stage of the process, sharp changes in the benchmark frontier and in technical efficiencies were observed on average. Although the MI has remained stable on average, there was a large reduction in the average of the technical efficiencies, while there was an adjustment derived from the benchmark border shift.

Table 4.7: Descriptive Statistics - Second Stage

	MI(t-1, t)	EC(t-1, t)	TC(t-1, t)	OBTC(t-1, t)	IBTC(t-1, t)	MATC(t-1, t)
Mean	1.02	0.40	3.83	1.69	0.66	4.36
Median	0.95	0.25	3.21	1.66	0.59	3.26
Standard Deviation	0.75	0.35	2.46	0.53	0.28	5.92
Kurtosis	41.17	3.70	4.87	1.97	5.12	65.02
Skewness	5.44	1.63	1.59	0.90	1.75	7.51
Minimum	0.11	0.03	0.84	0.82	0.14	0.39
Maximum	6.81	1.93	15.83	3.87	1.95	55.61

In addition, the change in the border had an output bias. The average of the upper OBTC indicates that there was an increase in revenue in 2016, perhaps evidencing the adjustment of the reduction of billing in the year 2015.

As expected, the results of the whole process are derived from the combination of the two phases that compose it. It should only be noted that the positive asymmetry of the data distribution was not as high in the whole process. This is one of the explanations that the mean of the MIs could decrease in the whole process.

Table 4.8: Descriptive Statistics - Productivity (Whole Process)

	MI(t-1, t)	EC(t-1, t)	TC(t-1, t)	OBTC(t-1, t)	IBTC(t-1, t)	MATC(t-1, t)
Mean	0.83	0.41	3.29	1.79	0.63	3.43
Median	0.80	0.29	2.71	1.72	0.56	2.75
Standard Deviation	0.40	0.37	2.10	0.54	0.25	2.25
Kurtosis	6.31	7.40	0.74	-0.27	2.79	-0.18
Skewness	1.51	2.06	1.04	0.59	1.43	0.80
Minimum	0.10	0.04	0.044	0.99	0.31	0.01
Maximum	2.82	2.33	9.71	3.34	1.65	10.24

4.4.3 Association: Regression Results

In this way, as performed in the previous chapter, we used a fractional logistic regression, as proposed by Chortareas et al. (2016), to test if diversified banks are more efficient. We did not find support for that hypotheses. On the contrary, there was a negative relation between RWA diversification and the prudential scores of efficiency (see Table 4.9). In addition, we could not find significant results for the hypothesis of diversification in sort of capital instruments and in different kinds of revenues.

Table 4.9: Fractional logit regression Results

Variable	Estimate	Std. Error	t value	Pr (>/T/)
INTERCEPT	-2,996710	1,152959	-2,599	0.009
RAD RWA Diversification	-2,253227	0,820068	-2,748	0.006
RCD Capital Diversification	0.469681	0,818992	0,573	0.566
IND Income Diversification	0.634191	0,607448	1,044	0.296
Ln Assets (control)	0,090568	0,073295	1,236	0.217
C2 Profit1 (control)	0,000000	0,000000	-3,662	0.000
C3 Profit2 (control)	-0,000001	0,000001	-1,550	0.121

As an additional robustness test, we also perform a truncated regression.The results are in Table 4.10.

Table 4.10: Truncated Regression Results

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.191572	0.031782	6.027743	0
RAD	-0.320579	0.085183	-3.763406	0.0002
RCD	-0.065072	0.073957	-0.879863	0.3789
IND	0.135804	0.085858	1.581722	0.1137
C1	-3.98E-11	6.89E-11	-0.576973	0.564
C2	-8.95E-10	1.22E-08	-0.073467	0.9414
C3	-2.44E-09	3.53E-08	-0.069095	0.9449
	Error Distribution			
SCALE:C(8)	0.1572	0.008468	18.56474	0
Mean dependent var	0.103439	S.D. dependent var	0.161506	
S.E. of regression	0.160782			

The lack of significance of the results verified for the diversification of capital instruments in the Brazilian context is not surprising. As we could see in the descriptive statistics and in the score values in the first phase process, Brazilian banks still have high average values of regulatory capital. This fact partially explains the non-use and low influence of subordinated debt instruments (Tier II) by Brazilian banks. We highlight that the sample used by the present study covered all the Brazilian commercial banks with adequate data to the methodology and subordinate debts are only being used meaningly by the largest banks in Brazil.

4.5 Conclusion

The main objective of this article was to propose an approach to evaluate bank efficiency that could add to the need to maintain the stability of financial institutions. The proposed approach indicates in its first phase that the levels of investment and risk exposure of institutions should be compatible with the capacity to absorb shocks. In the second phase, the approach indicates the levels of investments of partners and risk mitigation costs should be compatible with the generation of results of the bank. The approach was empirically feasible with the application of a two-stage DEA Network model that used Basel prudential metrics and balance sheet variables.

It should be clarified that the application of the proposed approach carried out in this paper constitutes only one of many possible ways. The process of managing assets and risks as the initial phase of a process that generates benefits for the financial institution can be measured by several methodologies depending on the analyst's objectives. We used the DEA Network in two stages, called centralized model, mainly because of its property of decomposition of the whole process in the product of two subprocesses which allowed us to have an intuitive notion of the generated residuals in the two phases.

Regarding the results of the approach application in Brazilian banks, the results show that the first stage benchmark institutions had Basel CAR much higher than required, fact that may reveal a deficiency in the fund-raising process by institutions or an above-average preference for low-risk assets. In other words, Brazilian commercial banks have very uneven risk-weighted asset-generation capacities, showing a large margin for better allocation of assets in the financial system.

Using the intermediation approach, our findings also corroborate the thesis that Brazilian banks have a level of efficiency lower than developed countries, with average scores lower than the usual seen at developed banks. In addition, we show that the problem is even worse when we consider a prudential approach. In other words, the Brazilian banks are not remunerated by the risk of the assets they are carrying, having an excessive volume of capital in relation to their risk exposures and high gap between benchmarks and inefficient financial institutions. However, further research

will be needed to thoroughly evaluate the reasons for the occurrence of such dispersions.

Regard the productivity in the crisis period, Brazilian banks did not have a marked change. The results did not show an adjustment between RWA and capital (Stage 1), the Malmquist indexes remained practically constant, fact that evidences a good degree of resilience of the Brazilian banking system to drastic reductions in levels of economic activity.

An important and significant finding was the inverse relationship between the diversification of asset exposures to the different types of risk and the efficiency of financial institutions. We interpret this result as an evidence that more specialized institutions have in Brazil a greater ability to generate results compatible with their levels of capital. Thus, the use of simpler portfolios could generate better results due to the advantages generated by the specialization and greater knowledge of certain markets. Finally, we were not able to verify significant impacts due to the focus on financial intermediation revenues or the use of subordinated debt instruments.

As a guide for future research, we suggest the use of other efficiency measurement tools based on the proposed approach, the conducting of in-depth research on the reasons for efficiency differences in the Brazilian market, and the new applications in less concentrated markets. The results verified may give greater clarity on the conditions of application of the approach as a multiple criteria decision tool for bank supervisors.

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