EXAMINING OPERATING PERFORMANCE IN AN INSULAR BANK OLIGOPOLY THE CASE OF PUERTO RICO

by

Jorge C. Herrera, BS, MS, MBA, JD

DISSERTATION
Presented to the Swiss School of Business and Management Geneva
In Partial Fulfillment
Of the Requirements
For the Degree

DOCTOR OF BUSINESS ADMINISTRATION

SWISS SCHOOL OF BUSINESS AND MANAGEMENT GENEVA

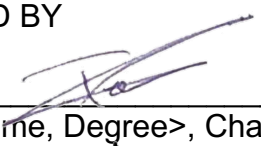
May 2022

EXAMINING OPERATING PERFORMANCE IN AN INSULAR BANK OLIGOPOLY
THE CASE OF PUERTO RICO

by

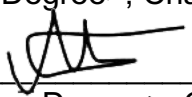
Jorge C. Herrera

APPROVED BY



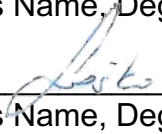
_____

<Chair's Name, Degree>, Chair



_____

<Member's Name, Degree>, Committee Member



_____

<Member's Name, Degree>, Committee Member

RECEIVED/APPROVED BY:

_____

<Associate Dean's Name, Degree>, Associate Dean

Dedication

This dissertation is dedicated to my family, colleagues, and friends who were supportive throughout this long and satisfying journey.

Acknowledgements

There are fortunately many individuals to thank for the assistance and guidance received during the process of conceiving and writing this dissertation. I would be remiss if I did not name Professors N'Cho, Wydick, and Faher who were particularly helpful in this endeavor.

ABSTRACT

This study examines the operating efficiency of the Puerto Rican banking sector as it coalesced into an oligopoly. Notably, contravening institutional precepts, consolidation activity was sanctioned by a regulator overtly concerned with stemming rapidly deteriorating macroeconomic conditions. No other research is known to have investigated the locality's unique circumstances nor a dramatically contracting marketplace in the United States. Statutory guidelines designed to preclude excessive market concentration ensure the *sui generis* nature of the setting. The main research questions considered are whether the emergence of an oligopoly affected the system's operating performance, were institutions impacted in a similar manner, and was the regulatory objective of concocting a more resilient banking sector achieved. To address these inquiries, the dissertation is guided by the conceptual framework advanced by real resource theory, as manifested by both the intermediation and production approaches. Performance of the banking system is measured by applying quantitative methods designed to gauge the individual participants' ability to convert or transform inputs into outputs. The non-parametric approach advanced by Data Envelopment Analysis estimates the operating efficiencies for each commercial bank. The Malmquist Total Factor Productivity Index then segregates the contributors to performance between technological innovation and managerial effectiveness. Finally, the parametric method associated with the Tobit model assesses the relative contribution to productivity of specific endogenous and exogenous parameters. Congruous with recent research devoted to oligopolistic market structures, the results reveal an improvement in systemic performance although with asymmetric reverberations. Consequently, for policymakers, the study concludes that under certain conditions fomenting a highly concentrated marketplace is advisable. However, heightened monitoring would be warranted to prevent abusive anti-competitive practices. For practitioners, the findings highlight the importance of technology implementation in driving performance and advocate particular close scrutiny of expenses pertaining to interest cost and premises on account of their assessed statistically significant contribution to profitability.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviations

AE	Allocative Efficiency
BCC	Barnes – Charnes - Cooper
CCR	Charnes – Cooper – Rhodes
CDEA	Centralized Data Envelopment Analysis
CR	Concentration Ratio
CRS	Constant Returns to Scale
CRTS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DFA	Distribution Free Approach
DMU	Decision Making Unit
DRTS	Decreasing Returns to Scale
FDIC	Federal Deposit Insurance Corporation
FDH	Free Disposal Hull
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschman Index
OCFI	Office of the Commissioner of Financial Institutions
PA&A	Purchase & Assumption Agreement
TARP	Troubled Asset Relief Program
TE	Technical Efficiency
TFP	Total Factor Productivity
Q-Q	Quantile-Quantile
SE	Stage Efficiency
SFA	Stochastic Frontier Approach
TFA	Thick Frontier Approach
VRS	Variable Returns to Scale
XE	X-efficiency

CHAPTER I: INTRODUCTION

1.1 Overview

On account of its transformative role in the allocation of economic resources, the banking sector constitutes an area of justifiable and abiding research appeal (Henriques et al., 2020). King and Levine (1993) find that a locale's material development seems to be inexorably wed to the sophistication of its endemic financial institutions. Similarly, Ouenniche and Carrales (2018) highlight the role banks play in facilitating the cohesiveness of societal organizations and their ability to adjust to unexpected circumstances. That is, the externalities ascribable to the sector extend far beyond readably observable and measurable repercussions. Consequently, on account of the irrefutably desirable objective of improving social well-being, gaining a better understanding of the factors that contribute to operating performance in financial institutions is a subject matter worthy of a doctoral dissertation.

The elements that dictate operating performance in financial institutions are not always easily discernible and may differ from those consequential in other types of business enterprises. Mishkin (2007) highlights the complexity of the sector on account of its many interactions with both public and private entities. Banking firms possess unique characteristics that for examination require conceptual frameworks distinct from those applicable in alternative settings (Swank, 1996). A salient feature often cited to account for this idiosyncratic nature is the heavy

burden imposed on management by the need to comply with significant international and national statutes and often scrupulous regulatory oversight (Barros et al., 2012). Since these themselves are far from homogeneous across jurisdictions, not surprisingly, the scope of investigation is frequently circumscribed geographically. Another confounding consideration is the absence of universal consensus as to the most appropriate manner of modeling bank performance (Avkiran, 2014). A factor that may be decisive in one locality at any given time may be irrelevant in another. As noted by Jian et al. (2016), much needs to be done to remove the opacity surrounding operating performance. Notwithstanding the daunting task at hand, the subject matter is simply too important for practitioners and regulators to ignore. After all, credence to the axiom that profit maximization is the objective of business enterprises entails identifying those initiatives most effective in reining expenses while growing revenues.

In order to make a contribution to both knowledge and practice, this thesis examines the efficiency of a banking system in a particular setting seldom studied, the Commonwealth of Puerto Rico. The island, a possession of the United States since 1898, has been facing a protracted economic depression for over a decade. Growth in Gross Domestic Product (GDP) has only been recorded twice in the past fourteen years.[1] In turn, this has resulted in significant migration to the mainland thus further exacerbating the erosion in factors of production. Moreover, the disproportionate loss of younger citizens not only shrinks the locale's tax base

[1] Source: Statistical Institute of Puerto Rico

but augments the burden imposed by a relatively greater share of older individuals.[2] Natural disasters further compounded the delicate situation; in 2017, Hurricane Maria, the most destructive storm to hit the island in centuries, was followed in 2019 by a series of eleven earthquakes with magnitude in excess of 5 in the Richter scale.[3]

Thus, the study considers the combined effects of a sharp retrenchment in demographic and macroeconomic conditions on operating performance in the banking sector. Another salient motivation of the study is the unique opportunity to investigate the impact of the emergence of an oligopoly in an insular marketplace; the regulator actively assisted consolidation to avoid systemic collapse.

This research endeavor relies on various quantitative techniques designed to investigate different aspects of operating performance. First, estimates of the soi-disant "best practice" frontiers are derived in order to ascertain the relative efficiencies of market participants. Specifically, the thesis makes use of Data Envelopment Analysis (DEA), a non-parametric technique that has been widely applied in multiple settings and business sectors.[4] A major advantage of such an approach is the avoidance of presumptions concerning the relationships between various measurable input and output variables (e.g., net income and personnel expenses). This is of particular importance given the lack of consensus as to the

[2] Federal Reserve Bank of New York (2014). *Current Issues in Economics and Finance*, 20(4).

[3] The economic damage exceeded $100 billion. Source: Pasch, J., Penny, A. and Berg, R. (2019). *Hurricane Maria*, AL152017, National Hurricane Center.

[4] Kaffash and Marra (2017) identified 620 papers published from 1985 to 2016 in which the performance of financial institutions was examined using the DEA method.

form of the production function applicable to a commercial bank. A Tobit regression model then helps identify the principal determinants of banking efficiency. Further insight as to the inter-temporal variations in performance is derived by computing the Malmquist Total Factor Productivity (TFP) index over the observed period. In addition to identifying for practitioners areas most responsible for improving managerial effectiveness (e.g., branch footprint), the thesis develops policy recommendations to assist regulators in monitoring the soundness of the overall banking system, assess impacts of initiatives undertaken, and predict the potential consequences of actions under consideration.

1.2 Research Problem

On account of its importance to the welfare of a corporate entity, optimizing operating efficiency remains an abiding and primordial objective of a firm's management. In the banking industry, this endeavor attains heightened relevance given the manner economic externalities affect numerous sectors of social organizations. Notwithstanding the myriad of studies dedicated to the subject matter, there are still identifiable and notable gaps in knowledge. These derive from idiosyncrasies ascribable to a bank's unique operating circumstances (e.g., extant regulatory and supervisory framework). Hence, much remains to be learned concerning the best practices that need to be implemented in order to determine the optimal mix of available inputs that yields the maximum plausible profit level.

The socio-economic conditions prevalent in a particular marketplace constitute a determinant factor in influencing operating performance. Consequently, and unsurprising, researchers have generally examined the latter on a national level on account of regulatory uniformity within a country's borders. This however may not be an apposite approach when isolated banking markets emerge driven by such unique circumstances as geographical barriers or significant divergence in regional macroeconomic performance. The case under consideration moreover involves the seldom studied situation in which an oligopoly surfaces during a clearly identifiable time period. Thus, the research problem considered by the thesis is the lack of understanding of the operating performance associated with a specific banking market place under circumstances of notable interest. Having completed an extensive period of oligopolistic formation, the setting presents *sui generis* conditions ideally suitable for conducting novel research.

This study addresses several research questions that have remained hitherto unanswered in the literature. Namely,

1. Has the emergence of an oligopoly, on account of the initiatives instituted by regulators, benefited the aggregate operating performance of the banking sector in Puerto Rico?
2. Has this transformation impacted equally the surviving banking entities?
3. Is the effect from the departure of foreign players similar to that associated with the liquidation of autochthonous banks?
4. How do individual inputs affect specific performance measures?

1.3 Purpose of Research

This research contributes theoretical knowledge that could be of use to both practitioners and regulators. To the former, the dissertation identifies and measures those discretionary inputs that affect operational performance in a banking enterprise. For example, management could assess the gains to be derived from an expanded branch network. As to policymakers, the study ascertains the impact of initiatives promoting market consolidation on the behavior of those entities benefiting from such actions. For instance, the Federal Deposit Insurance Corporation (FDIC) could corroborate that systemic efficiency improved by the implementation of loss-sharing agreements designed to encourage acquisition of troubled mortgage portfolios.

The specific objectives achieved are as follows,

1. To assess the aggregate operating performance of the banking sector in Puerto Rico, derived summary statistics from the mean estimated efficiency scores using DEA and gauged technological progress for the system applying the methodology advocated by Malmquist;
2. To determine the impact of consolidation on individual bank productivity, estimated annual efficiency scores relying on DEA and Malmquist indices for each market participant during the observation period;
3. To compare the effect of the departure of domestic vs. foreign institutions on systemic strength, identified the timing of their exit and then evaluated the mean sector efficiencies observed before and after the relevant dates; and,

4. To identify principal determinants of performance, constructed the base specification of a Tobit model and then proceeded to test for statistical significance of various endogenous and exogenous parameters.

1.4 Significance of the Study

The thesis contributes both to the research literature and practice in the following manners:

- Conducts the first comprehensive examination of the setting's banking sector during a time period deemed transcendental on account of the fundamental shift that takes place in its configuration;
- Expands the understanding of the inherent market dynamics of an insular marketplace by providing an alternative assessment of operating performance using methodologies which are distinct from those regularly applied by regulators, policy makers, management, and the investment community;
- Identifies for management key drivers of efficiency which can be then used to provide guidance when devising and implementing best practices;
- Assists investors in ascertaining the relative attractiveness of the securities issued by commercial banks and the effectiveness of their management teams;
- Furnishes to regulators an independent evaluation of the effectiveness of the various initiatives executed to enhance systemic resiliency, highlights the need to implement bespoken solutions that take into account the

asymmetrical effects of regulatory interventions, suggests parameters that warrant heightened scrutiny due to their predictive value of deteriorating trends; and supplies measurements of market concentration directly emerging from public sector initiatives.

1.5 Research Approach

As the study is guided by a positivist theoretical framework, the research questions are addressed by applying quantitative techniques and examining numerical data. Specifically, the analysis entails the use of non-parametric models, namely DEA, to estimate the operating efficiencies of the commercial banks that operated in Puerto Rico during the period between 2010 and 2020. This is complemented with derivations of the Malmquist TFP index which provide an assessment of technological progress. A parametric model named Tobit regression is then employed to calculate the relative contribution of various inputs and outputs to overall performance. Finally, concentration indexes are used to measure the extent of market concentration observed during the period of observation.

1.6 Limitations

Estimates of operating performance are derived from quantitative techniques, each of which assumes behavior that may be unrealistic or difficult to test. For example, the consistency of the estimators of a Tobit regression depends on multicollinearity, heteroskedasticity, and endogeneity. DEA ignores measurement errors. Malmquist TFP index assumes a particular functional form to represent the underlying technology. Moreover, the study examines a specific geographical

location during a well-defined, limited time period. The number of commercial banks operating in the market place is relatively small.[5] Furthermore, the conditions which allowed rapid consolidation activity are deemed to be unique and unlikely to be replicated in other settings.[6] Hence, caution is advised in generalizing or extrapolating the findings.

1.7 Ethical Considerations

The data utilized in this study is obtainable from publicly available sources either thru correspondence with the regulator or published reports. Hence, no entity or individual is known to have been harmed by the research conducted or the results hereby disclosed.

1.8 Structure of the Thesis

This thesis consists of seven chapters which are organized in the following manner. The next chapter considers the theoretical framework and empirical literature review necessary for guiding the research endeavor including selection of apposite methodology. Chapter III describes and provides background information pertaining to the setting of the study. The next chapter applies the methodology selected by resorting to various quantitative techniques that measure operating efficiency at the individual bank and systemic level, technological changes, market concentration, and contributors to total productivity growth. Chapter V presents the results obtained by applying the DEA framework,

[5] During the period of observation, the number of commercial banks operating in the island declined from fifteen to six. Source: Puerto Rico Office of the Commissioner of Financial Institutions.

[6] The United States did not experience such contraction in economic activity or population between 2010 and 2020. Source: Federal Reserve Bank of New York.

Malmquist TFP index, concentration ratios, and Tobit regression models. The subsequent chapter then discusses the findings and answers the specific research questions hereby considered. The thesis concludes in Chapter VII by summarizing the results, identifying implications, and advancing recommendations for future study of this topic.

CHAPTER II: REVIEW OF LITERATURE

2.1 Theoretical Literature

The theoretical framework constitutes the perspective or lens adopted for observing a particular social phenomenon (Bryman, 2016). It connects existing knowledge and theory with the aims pursued and questions addressed by the thesis. Moreover, the theoretical framework justifies the methodology followed. The objective of this literature review is to identify such conceptual lodestar.

The thesis follows the guiding principles for constructing an effective literature review outlined by Bryman (2016). Namely, this chapter aims to provide a critical examination of existing research in the field and the relevant theoretical ideals. Completion of the task requires addressing the following questions:

- *What is already known about the subject*
- *What concepts and theories have been applied to the topic*
- *What research methods have been used for its examination*
- *What controversies exists about the matter*
- *Who are the key contributors to knowledge in this area.*

The section first considers general theories of operating performance in banks before addressing the more practical matters regarding definition and measurement of efficiency.

2.1.1 General Theories Pertaining to the Operating Performance of Banks

A survey of apposite literature reveals the existence of four major theoretical frameworks that attempt to explain the behavior of a banking firm on a microeconomic level (Swank, 1996). First, risk management theories assume a bank's main focus is to manage the two principal types of risk it faces, namely

credit and funding. The various models associated with this position aim to derive an optimal capital structure, pricing for loan commitments, and size of loan portfolio given a certain level of risk tolerance. For example, DeAngelo and Stulz (2015) aver that a bank's leverage is determined by its ability to produce liquidity. Second, portfolio theory perceives banks as investors concerned with the manner in which balance sheet items are determined on account of regulatory requirements. The latter are perceived as imposing an exogenous constraint on managerial decisions. For instance, Shaban et al. (2014) explain the manner in which capital practices affect lending practices of Islamic banks. Third, imperfect-market models posit banks maximize profits by setting their own loan and/or deposit rates when faced with market demand and supply functions. Kopecky and Van Hoose (2012) ascribe variations in market competition in retail markets to the observed levels of both rates. Finally, under real resource theory, corporations are deemed producers of financial services; inputs, such as labor and capital, are converted into outputs, such as loans. This conceptual framework proposes two alternative views to account for this transformation process. Under the intermediation view, the principal function of a bank is to convert deposits into loans; thus, proxy inputs are usually income statement items such as income expense and non-interest income (Avrikan, 2014). A bank performs three roles in the economy through three major intermediation functions: liquidity intermediation, risk intermediation and information intermediation (Servigny & Renaul, 2014). Liquidity intermediation refers to the reallocation of money from depositors to

borrowers; risk intermediation is the collection of various types of risks from the economy (e.g., credit) and then transforming them into new securities with different risk profiles; information intermediation entails balancing the interests of well-informed entrepreneurs and less-informed savers on account of information asymmetry (Freimanis & Senfelde, 2019). This theory is portrayed in Figure 2-1.

Figure 2-1: Real Resource Theory - Intermediation Approach[7]

In contrast, under the production approach, banks are regarded as production units. They utilize labor and physical capital to execute transactions and provide document processing services for customers (Freixas and Rochet,1997). This framework is depicted in Figure 2-2.

Figure 2-2: Real Resource Theory - Production Approach[8]

[7] Freixas & Rochet, 1997.
[8] Ibid.

As noted by Okeahalam (2006), the two positions are not mutually exclusive on account of a bank's dual role of both producer of services and intermediary in transferring funds between lenders and borrowers. In the section summarizing empirical results, reference is made to studies that incorporate this view by implementing two-stage models for ascertaining efficiency scores.

While the financial intermediation theory of banking constitutes presently the dominant framework applied to understand the role and function of banks, it is not considered unassailable dogma by some researchers (Freimanis & Senfelde, 2019; Werner, 2014; Biondi, 2018). In particular, two competing conceptual views have gained increasing attention by elucidating the manner in which a banking system creates money. Under traditional financial intermediation theory, the latter occurs outside the core of banking activity; a firm gathers deposits and then simply lends them to its clients, bereft of the ability to influence the money supply. In contrast, according to fractional reserve theory, commercial banks are financial intermediaries which collectively can achieve the latter due to the effect of the money multiplier (Werner, 2014).[9] The credit creation theory of banking adopts an even more extreme posture.[10] Individual commercial banks are able to generate credit unaided and without the intervention of the central banks that impose reserve requirements. According to Mishki and Eakins (2012), the introduction of

[9] In a fractional reserve system, banks can redeploy their excess reserves thus augmenting the money supply (Carpenter, S., & Demiralp, S., 2012).

[10] Interestingly, Werner (2016) avers that this theory is not a recent development but rather represents a reconstitution of an opinion widely held by prominent researchers a century ago.

new financial instruments after the 1960s provides banks with additional flexibility in managing their liabilities that allow the formulation of asset growth targets; in essence, a bank can determine the desired level of loans and then seek the required funding. Similarly, Schumpeter (2016) perceives banks not as passive accumulators of deposits but as active creators of such funds. Biondi (2018) develops a comprehensive model that promulgates three key functions of commercial banks. Namely, financial institutions act as ledger keepers (e.g., maintain accounting records), treasury managers (e.g., monitor liquidity reserve requirements), and manufacturers of money (e.g., establish credit control requirements). Unlike the stand of financial intermediation theory in which the flow of deposits collected matches the loans extended, commercial banks are perceived as inherently structurally unbalanced entities due to the concomitant effects associated with money generation. Hence, there is a continuous need for inter-bank coordination supported by the active participation of the central bank. The role of the latter is critical not on account of its discretion to solely determine reserve requirements but as primary overseer of a permanently in motion funds flow system.

As Werner (2014) asserts, the validity of these three conceptual frameworks of banking theory has been the subject of limited empirical scrutiny; thus, there is scarce evidence to support any of them. To address this situation, Werner conducts what is professed as the first experimental tests of these theories. After listing the flaws of financial intermediation and fractional reserve principles, he

provides findings that are interpreted as evidence of an individual commercial bank creating money by itself. Thus, the postulates of credit creation theory are corroborated. The policy implications of these results are so profound as to undermine the regulatory tenets endorsed by most developed economies. A revision of the current regulatory regime is advocated due to the limited effect of reserve requirements in checking recidivistic practices (e.g., excess borrowings by near insolvent entities). Specifically, central banks should be concerned about monitoring the credit extension function at the individual firm level instead of setting system-wide reserve requirements. As per Werner (2016), the former and not the latter are more determinant in ensuring the overall resiliency of a banking sector and its constituents.

2.1.2 Oligopolistic Market Structure Models

This survey of the theoretical literature which aims to explain operating performance of banks in a concentrated marketplace begins with the general theory of oligopolies proposed by Stigler (1964). Accepting *a priori* the tenet that the profits of all the firms in an industry are maximized when they act together, he endeavors to identify and assess the conditions that permit such collusive behavior. The rejection of the principle that product homogeneity is a *sine qua non* for the formation of an oligopoly permits a revision of the neoclassical theory of competition. A new theoretical framework aims to explain why collusion is not possible for some firms and under what conditions it is more effective. Three behavioral patterns derive from the problem of policing a collusive agreement.

First, on account of the cost of acquiring information regarding current market prices, larger buyers are usually better able to detect any form of price discrimination and impose remedial actions. Hence, oligopolistic collusion will often be successful only against smaller clients. Second, collusion is severely limited when buyers constantly change identity; the seller is unable to assess the importance of the transaction and thus the willingness to accept the terms offered. Third, collusion will always be more effective against buyers who report accurately and fully the prices tendered to them; the seller can detect any deviation from a collusive scheme reached with a competitor. The differences in business strategies observed in the Puerto Rican banking system (e.g., niche vs universal players) adumbrate the absence of product homogeneity; and thus, Stigler's insights as to the behavior of firms in an oligopoly are apposite.

A theory acknowledging the nexus between market structure and operating performance in a banking system is first introduced by Klein (1971). Unlike his predecessors, he does not embrace the belief that commercial banks should be studied as rational investors making decisions based on perceived risk and uncertainty (i.e., portfolio theory). Instead, they are entities affected by variations in the number of market participants and the degree of existent competition (i.e., neoclassical analysis of a firm). For financial institutions, the nature of this operating environment is greatly driven by regulation. A theoretical model is then constructed by introducing external economic and market structure variables to a neoclassical model of profit maximization (e.g., by deriving the optimal return on

equity given the amount of loans and deposits selected). The solution avers that the proportion of available funds allocated to loans is determined by equating the marginal return on this asset class to the average return on government securities. To arrive at such a conclusion, the model incorporates environmental factors (e.g., reserve requirements) that transcend considerations pertaining solely to assessing credit risk and return expectations. As admitted by its author, the usefulness of the microeconomic model is severely constrained by the simplistic assumptions adopted (e.g., the specifications of the deposit demand and loan supply functions).

Combining the series of equations developed by Klein (1971) to model bank behavior with those proposed by Monti (1972), Freixas and Rochet (1997) produce the Monti-Klein model for a bank operating in an oligopoly. The mathematical representation is as follows,

$$\boxed{\pi = \pi(L, D) = \left(r_{L\,(L)} - r\right)L + \left(r(1-\alpha) - r_{D(D)}\right)D - C(D, L)}$$

Where *L* is loans, *D* is deposits, *r* is interbank market rate, r_D is the rate payable on deposits, r_L is the interest rate earned on loans, demand for loans is $L(r_L)$; supply of deposits is $D(r_D)$; α is compulsory reserve requirement, *C* is cash reserves; and π is profits. According to this theory, the bank's profits are thus the sum of the intermediation margins on loans and deposits minus management costs. The solution, which can be derived by equating marginal revenue and marginal cost, indicates that an increase in interbank interest rates leads to wider margins for both loans and deposits. The number of market participants may be inversely related to profitability. As discussed in section 2.2, empirical studies of

competition in the banking industry provide both corroborating and contravening evidence of the behavior and results predicted by this theoretical framework.

Attempts to expand the applicability of the Monti-Klein model have included introducing modifications which relax some of its most stringent assumptions. Yamazaki and Miyamoto (2004) extend the framework by considering the case in which deposit and loan decisions are not made simultaneously. Moreover, they examine the impact of scope economies between deposits and loans by relaxing the assumption of linearity in the cost function adopted by Freixas and Rochet (1997). The cost function now takes the following nonlinear form.

$$\boxed{C(L_i, D_i) = \theta(D_i)L_i + \phi D_i}$$

Where $\theta(D_i)$ is the marginal cost of loans and Φ is the unit cost of deposits. The revised model no longer asserts that in all situations fewer market participants result in wider margins on account of strategic considerations driving managerial decisions. The Monti-Klein model is thus modified to accommodate the less than optimal systemic equilibriums predicted by Nash's game theory. If loans are determined only after selecting the amount of deposits, Yamazaki and Miyamoto assert that managers will reach a subgame-perfect equilibrium in which deposit margins may decrease, even if interbank rates move higher. That is, there may be a strategic interest to curtail liability growth that outweighs the objective of gross revenue growth. To conclude, the validity of the Monti-Klein model rests on postulates that may be difficult to either affirm or confirm; and therefore, its ability to account for the effect of an oligopoly on operational performance is limited.

Despite the generally negative connotations associated with oligopolies, as vehicles permissive of consumer abuse and undesirable corporate enrichment, certain theoretical models find them the market structure that optimizes societal efficiencies. A dynamic general equilibrium model developed by Cetorelli and Peretto (2000) demonstrates that, under certain conditions, an economy's steady-state income per capita is maximized by adopting an oligopolistic framework, rather than a pure monopoly or unfettered competition.[11] This constitutes a significant departure from the more widely held view that market power translates into fewer loans and higher prices. According to Cetorelli and Peretto (2000), the credit market is deemed to be composed of two distinct segments. In the first, banks transact only with borrowers that have been identified as desirable counterparties. In the second, firms lend indiscriminately to all entrepreneurs. The number of banks in the system determines the size of each segment; and hence, impacts both the level of funds available to clients and amount of costly information to be collected for each credit applicant. The latter is considered the key determinant of efficiency in the credit market. The mathematical formulation of the model is as follows,

$$\boxed{K_t = X_t^S + \Theta X_t^U}$$

Where, K_t represents capital and X_t^S and X_t^U stand for credit allocated to screened and unscreened borrowers, respectively. Of note, unlike Klein (1971), the formation of an oligopoly is not predicated on express or implicit collusive

[11] Their theory essentially views financial institutions as behaving in the manner proposed by Cournot. Namely, firms compete based on the level of output and not prices; production decisions are made devoid of collusion.

agreements. In the relatively small banking market prevalent in Puerto Rico, the expense associated with weeding out prospective customers should be small and the imposition of discriminatory pricing less concealable. Under these conditions, this theoretical framework would predict both systemic and individual benefits to be extracted from the presence of an oligopolistic market structure.

2.2 Empirical Literature

This section of the literature review explores findings of past studies which are relevant to answering the research questions considered by the thesis. First, studies broad in scope serve to introduce the investigation of operational performance in commercial banks by identifying key issues and causal relationships deemed important. Second, on account of the consolidation activity experienced in the setting examined, consideration is then given to observed ramifications from prolonged merger activity on efficiency. Third, for similar reasons, the determinants of productivity in an oligopoly are investigated. Fourth, the literature review proceeds by scrutinizing the unique contribution of entities controlled by foreign owners on productivity. The section concludes with a summation of findings and identification of research gaps.

2.2.1 Attributed Determinants of Operational Performance

The comprehensive study of efficiency in the banking sector mostly dates from the end of the past century. Berger and Humphrey (1997) note in early studies that productivity in financial institutions deviates considerably from optimal levels. Such deficiencies are still detected across multiple countries in much later investigations

regardless of type and size of entities sampled (Kwan, 2006). Hence, research to identify and correct shortcomings in performance constitutes a worthwhile pursuit. An initial preference to identify economies of scale and scope as the primary sources of inefficiency has been slowly replaced by focusing primarily on production processes and its two components, technical and allocative efficiencies (Kwan, 2006; Yao et al., 2007). A survey of 130 papers examined by Berger and Humphrey (1997) reveals that the main determinants of productivity have been an area of considerable disagreement. A contributing factor to the lack of consensus regarding the subject is the plethora of approaches applied to measuring operational performance as they often produce inconsistent results (e.g., Ouenniche and Carrales, 2018). These include both parametric and nonparametric methodologies; each in turn rests on a different set of assumptions imposed on the data. Moreover, empirical results also indicate that exogenous factors (e.g., differences in regulatory and economic environments) are likely to influence the measurement of efficiency in a manner which varies considerably depending on the jurisdiction examined and the governing regulatory regime (Berger and Humphrey, 1997).

The various components that together comprise the concept christened total efficiency have dissimilar contributions to overall performance. In general, technical efficiency – the ability of optimal utilization of available resources either by producing maximum output for a given input bundle or by using minimum inputs to produce a given output – is found to be more determinative than allocative

efficiency, the ability to achieve the optimal combination of inputs and outputs for a given level of prices (Yao et al., 2007; Chen et al., 2005)[12]. In the case of the highly concentrated Australian banking sector, Sathye (2001) shows that productivity gains are best achieved by optimizing three specific inputs: capital, labor, and loanable funds. On account of its already elevated level, further improvements in allocative efficiency supply less to overall operational effectiveness. Isik and Hassan (2002) concur in this assessment[13]. In their examination of Turkish banks, they find that allocative (regulatory) inefficiency is always smaller than technical (managerial) inefficiency, a situation ascribed to underutilization of resources rather than selection of incorrect product mix. Relevant to the thesis for their presence in Puerto Rico, the researchers believe that the entrance of smaller institutions is detrimental to the productivity of the sector on account of the idle capacity added. These banks do not appear to be able to reach the optimal operating size (i.e., scale efficiency). With respect to profit efficiency (i.e., the extent a bank maximizes profits given certain output levels rather than output prices) and cost efficiency (i.e., the level of expenses required to produce outputs at the operating level exhibited by the best practice bank), the distortions introduced by data collection errors and off-balance sheet items render estimations unreliable. These findings explain the decision of many

[12] Chao et al. (2005) support this view with respect to joint-equity banks in China but disagree concerning state-owned institutions.

[13] Cf., Rezvanian and Mehdian find that in Singapore cost inefficiency is caused equally by allocative and technical inefficiencies. Exploring the case of the United Arab Emirates, Al Shamsi et al. (2009) identify allocative inefficiency as the dominant source of overall inefficiency.

studies to focus primarily on technical efficiency, an area of practical application to both management and policymakers.

The effect of economies of scale on efficiency remains a subject of abiding controversy. Rezvanian and Mehdian (2002) and Nair and Vinod (2019) declare that the causal relationship exists regardless of the size of the commercial bank considered (i.e., magnitude does matter). Specifically, cost efficiency is positively correlated with the amount of assets managed. Girardone et al. (2004) concur and note that the strength of the interaction is a function of the type of corporate organization (e.g., credit co-operative vs. savings bank) and risk factors (e.g., willingness to engage in speculative lending). Not surprisingly, they also discover strong correspondence between profitability and inefficiency[14]. Okeahalam (2006) attributes the depressed cost efficiency exhibited by South African bank branches to observed increasing returns to scale; in a market dominated by four entities, incentives to expand physical presence appear to be absent. In China, Chen at al. (2005) perceive evidence of greater efficiency for larger and smaller entities but not for medium sized banks. Chortareas et al. (2009) obtain mixed results for Greek banks; cost but not profit efficiency advances as organizations grow. By contrast, other studies, mainly those sampling exclusively American banks, do not detect correlation between economies of scale and efficiency.[15] For example, Berger et al. (1987) find slight diseconomies of scale on the order of 1 to 3

[14] This finding supports the use of traditional profitability benchmarks (e.g., ratio analysis) as a form of triangulation in the thesis (see Chapter VI).

[15] Few researchers investigating settings outside the United States concur with this assessment (e.g., Kwan (2006)).

percent, which they posit may be due to demand-side influences. Once again, and given the miniscule effect detected, the correspondence between returns to scale and efficiency could be imputed to measuring errors or application of different estimating methodologies[16]. Since the setting of the thesis falls under the jurisdiction of an American regulator, Berger's findings would appear to be more apposite.

The contribution of technology to a bank's productivity is an axiomatic tenet. Kwan (2006) finds that technological innovations allow Chinese entities to operate closer to cost frontier regardless of size, corporate structure or product mix. In the case of U.S. community banks, DeYoung et al. (2007) detect evidence that internet adoption increases revenues from fee businesses, improves product mix, and enhances service quality. Berger and DeYoung (2006) ascribe a bank's ability to expand geographical coverage, and thus support revenue growth, to its espousal of information and communications innovations. Asaftei (2008) posits that the main effect of technical change on efficiency derives from enhanced flexibility in expanding and rebalancing the output portfolio. As per Rezvanian et al. (2011), deregulation incentivizes competition which in turn promotes the acquisition and more intense implementation of information technology. The main problem with the literature is the absence of a consistent and lucid definition of the

[16] When using different methodologies and model orientations to estimate efficiencies from the same data set, Ouenniche and Carrales (2018) report variances that lead to distinct conclusions. Similarly, Tortosa-Ausina (2002) reports that efficiency scores exhibit a dynamic pattern; two moments of the distribution (e.g., mean and standard deviation) are insufficient to capture the underlying behavior. Barnum and Gleason (2006) demonstrates that intra-input aggregation causes downward bias in reported technical efficiency scores, with variations in bias unrelated to true technical efficiency.

term “technological innovation.”[17] Similarly, the studies do not consider the cost of such investments as an input in assessing the determinants of productivity (e.g., independent variable in a regression model). On account of its wide adoption by researchers exploring the subject, the thesis employs the analytical framework named the Malmquist TFP index to gauge the effect of technological change on corporate efficiency.

2.2.1.1 On Defining and Measuring Productivity for a Banking Firm

Research literature advances multiple approaches to study the determinants of a bank’s productivity. The most popular of these focuses on evaluation and measurement of “efficiency”, a term seldom afforded a consistent definition or treatment. For Chen et al., (2005), efficiency denotes the extent to which a decision-making unit (DMU) can increase its outputs without lifting its inputs, or reduce its inputs without lowering its outputs. The term is defined as the ratio of output to input. As such, researchers are free to consider either profit efficiency, a bank’s ability to maximize profits or output (e.g., Aggarwal et al., 2006), or cost efficiency, the success in minimizing costs (e.g., Chronopoulos et al., 2013). Cost efficiency in turn can be decomposed into three distinct manifestations: allocative, technical, and scope. Allocative efficiency gauges the ability of a firm to select the cost minimizing combination of inputs, as for example in attracting deposits and advances (Chen et al., 2005). Technical efficiency denotes the proportional reduction in input usage that can be attained by operating at the efficient frontier

[17] For example, according to Asaftei (2008), technical change effect measures the increase (decrease) in output not induced by a change in resource use.

(Isik et al., 2002). Scope efficiency refers to the consequences of increasing the variety of goods produced and not their volume. Economies of scope are present when the cost of joint production is lower than the sum of the expenses associated with creating each good separately (McGee, 2015).[18] Optimal performance can be achieved by varying technology (pure technical efficiency) or production size (scale efficiency). Of note, only a bank that is both technically and allocative efficient can be deemed cost efficient (Nair and Vinod, 2019).

The focus of productivity research has evolved significantly over the last forty years. Earlier studies mainly consider scale and scope efficiencies, frequently by making use of the Cobb-Douglas production function (Sathye, 2001). As indicated by Lester (1996), gradual shift takes place with the emergence of theory expounded by Leibenstein (1966). Contrary to hitherto economic orthodoxy, he avers that market participants are not always rational; and therefore, other forms of inefficiency beyond allocative need to be considered. New prominence is ascribed to the nexus between a firm's overall operating performance and managerial competence in deploying a firm's resources. That is, internal operating shortfalls emerge from a firm's inability to minimize costs of production by employing more inputs than is technologically necessary. Liebenstein (1996) posits four reasons for the emergence of the phenomenon: a) labor contracts are incomplete (i.e., terms of employment cannot be delineated in advance); b) not all factors of production are marketable (e.g., access to clean air); c) the production

[18] Cf., Economies of scale which refers to cost advantage from producing more goods.

function is not specified; and d) interdependence and uncertainty lead competing firms to both cooperate and imitate each other with respect to processes (e.g., management fails to select the best suited technology due to entrenched marketplace practices). On account of its divergence with conventional theory, this proposition is christened X-efficiency (XE). Under this conceptual framework, one unit of input does not necessarily translate into an equal amount of output. Moreover, operating performance can influence the range of potential outputs for any given type of input. Researchers have tended to concentrate on XE as the preferred form of productivity measure due to its relative contribution to overall productivity *vis a vis* scale and scope efficiencies. For example, Frantz (2018) finds that on average firms produce 20% below their efficient frontiers. In the specific case of a marketplace subject to horizontal (within-market) merger activity, thus akin to the setting under consideration, Rhoades (1993) cites numerous studies that concur with the assessment that XE is critical in measuring operating performance in financial institutions.

2.2.1.2 Impact of Consolidation Activities on Operating Efficiency

Recent literature is almost in universal agreement on the opinion that mergers have a discernible effect on a commercial bank's operating performance[19]. Dissent emerges when advancing the reasons and manner the latter is altered. As asserted by Rhoades (1993), earlier postulations ascribe economies of scale to the observed variations in efficiency; current views assign such roles to

[19] The reader should not presuppose that gains in efficiency scores are concomitant to a more pluralistic marketplace (e.g., Rezvanian et al., 2011).

improvements in management and operations. One of the earliest studies regarding this subject comes from Cornett and Tehranian (1991). In an examination of both intra and interstate acquisitions, they detect improved profitability in a sample containing thirty large institutions. The drivers for such development are endogenous factors rather than less competition. Specifically, efficiency gains emerge from the ability to attract more loans and deposits, asset growth, and labor productivity. To this list, Penas and Unal (2003) add cheaper costs of funds. The bond market perceives the acquirer to be a safer investment on account of increased diversification, too-big-to fail status, and synergy gains. In conclusion, empirical results assign to multiple factors the variations in efficiency observed after consolidation.

Analogous to the controversy surrounding the relation between organizational size and efficiency, the correlation of transaction size and productivity changes remains an open debate. When examining the case of Taiwan, Peng and Wang (2004) qualify the conclusions asserted by Penas and Unal (2003) by noting that their application is circumscribed to certain institutions. The ability to realize cost efficiencies is a function of the size of the merger; smaller transactions yield the most returns. Looking at the experience of the United States and covering a much longer observation period, Cornett et al. (2004) conclude the opposite – large bank mergers produce superior performance gains. Also refuting the contention regarding diversification advanced by Penas and Unal (2003), they find intra-market transactions having a more beneficial effect on efficiency than those

geographically expanding a bank's service area. This development is explained by the greater potential to reduce costs associated with branches and personnel. Qualified support for advocating a differentiated approach to examining the effects of mergers on efficiency comes from Knapp et al. (2005). They also detect fewer benefits associated with mergers involving banks with less geographical overlap. The reasons advanced relate to management's engagement in riskier credit transactions and less emphasis on non interest activities. Interestingly, and contrary to Cornett et al. (2004), smaller mergers are deemed to promote larger efficiency gains due to ease in imposing the corporate culture of the acquiror. In the context of the Japanese regional banking sector, Halkos et al. (2016) concur with this assessment. Smaller institutions seem to extract more rewards in technical efficiency from acquisitions of neighboring entities. In contrast, larger banks benefit further from buying distant institutions. Aggarwal et al. (2006) suggest that both size and level of operational proficiency before the merger are determinants of post-transaction efficiency. Experienced and well-managed institutions tend to pay less to acquire other banks. Based on the above, the consolidation experience in Puerto Rico, all within the same geographical area and involving relatively small institutions, should generate at least some moderate improvements in productivity.

Related to the previous consideration of the influence of technology on efficiency, productivity gains emanating from acquisitions frequently depend on the level of innovation adopted by the merging institutions. In a study of the cost and

profit efficiency effects of bank mergers on the U.S. banking industry, Al-Sharkas et al. (2008) discover that these transactions generate a two-fold benefit. First, individual institutions are able to lower expenses due to the employment of the most efficient technology available. Second, mergers may allow the overall banking sector to take advantage of the opportunities created by improved technology. Smaller entities appear to derive less value thus suggesting that size constitutes another contributing factor to performance. The result of the Malmquist TFP index analysis identifies technological advancements rather than increased technological efficiency as the source of productivity growth. On the other hand, scale efficiency has a less than meaningful impact on the latter. For the case of Puerto Rico, these findings support the execution of regulatory initiatives designed to bolster systemic soundness.

The post-merger operational strategies pursued by management influences the productivity gains achieved. The managerial approaches most usually encountered are those that aim to either restrain costs or alternatively to enhance revenue growth. When comparing European and American acquirers, Hagendorff and Keasey (2009) find that the former generally seek to reduce expenses while the latter prefer to increase interest and non-interest activities. Their results indicate that the first strategy is typically successful in improving efficiency whereas the second is not. The reason advanced for this finding avers that post-merger plans emphasizing output objectives tend to be pernicious to cost structures. The transactions which promote the greatest advancement in efficiency

are those involving cross-border mergers and product diversification. These findings contradict earlier research conducted by DeLong (2001). Classifying transactions on the basis of similarity of focus, either geographically or by product, he discovers no value creation in those widening physical footprint or service offerings. There is accord in the view that larger mergers yield more discernible productivity improvements which are not likely to fully surface immediately. The results support the thesis' selection of a relatively extended observation period and both input and output orientations for estimating efficiency scores.

2.2.1.3 Governmental Consolidating Initiatives and Operating Efficiency

Empirical results support the contention that regulatory intervention affects a bank's efficiency by altering management's business strategies[20]. In an examination of the aftermath of a capital infusion scheme implemented following the Great Recession of 2008[21], Duchin and Sosyura (2014) find a discernible increase in risk taking evinced by greater allocations to higher yielding investments. Remarkably, there is no concomitant jump in aggregate credit supply. These developments would suggest that if efficiency is measured as a function of profitability (e.g., net income is a desired output) then, at least in the short term, productivity would appear to improve. If true, the implications would be truly nefarious to systemic stability. The study demonstrates the fallacy of equating efficiency benefits with sector resiliency in all settings. Moreover, it attests to the

[20] As indicated by Peng and Wang (2004), governments deem axiomatic the nexus between systemic stability and market consolidation.

[21] Under the Troubled Asset Relief Program (TARP), the United States Department of the Treasury, injected over $245 billions of capital into more than 130 financial institutions.

need for the regulator to delineate policies which take into account the long-term consequences of government assistance. With respect to the research questions, the study predicts a boost in efficiency scores for banks participating in government-assisted consolidation activity, minimal increase in asset size, and a less resilient banking system.

King and Kong (2016) corroborate the influence that regulatory assistance in the form of TARP exerts on efficiency. However, contrary to Duchin and Sosyura (2104), the operating performance of the banks receiving support deteriorates compared to their competitors. The results are explained by differences in motivation; the management of TARP banks pursues acquisitions to accelerate size expansion at the expense of instituting post-merger productivity initiatives. It can be inferred that the researchers would not consider TARP auspicious to a robust banking sector. The study contributes to the literature by assessing productivity during the periods prior and post government assisted consolidation. With respect to the research questions, the study predicts that banks participating in government-assisted consolidation activity should underperform other financial institutions and alerts researchers to the absence of concurrence regarding TARP's consequences on banks' operations.

Regulatory support in the form of acquisition subsidies also appears to influence bank productivity. Under a scheme which preceded TARP activated between 1980 and 1991, the FDIC facilitated the merger of solvent entities with

failed banks employing purchase and assumption agreements (P&AA).[22] Both Cochran et al. (1995) and Zhang (1997) detect changes in efficiency ascribable to induced consolidation activities. The former posits that productivity gains are solely driven by the magnitude of the support received and not the so often claimed synergies. Interestingly, the size of the acquired target is a determinant factor; efficiency gains are only observed in larger transactions. Examining the same period and form of regulatory aid, Zhang (1997) finds that another condition necessary to obtain improved productivity is for the acquirer to execute repeated transactions; first-time buyers do not report better performance. With respect to the research questions, the study predicts that banks participating in government-assisted consolidation activity should outperform other financial institutions only if they engage in relatively large purchases more than once.

The correlation between regulatory subsidies and efficiency has been observed in more than one banking crisis. A study conducted by Cowan and Salotti (2015) shows that a government program that limited credit losses from a portfolio of loans purchased from a failed institution yielded immediate excess returns to acquiror.[23] Hence, regulatory intervention equates to improved productivity by the contractual transfer of expenses (here, those associated with credit) from a lending institution to the public sector. The effect however should be deemed transitory since the guarantees are issued with a certain expiration date. The

[22] A healthy bank assumes the insured deposits of the failed bank. Insured depositors of the failed bank immediately become depositors of the assuming bank and have access to their insured funds. The assuming bank may also purchase loans and other assets of the failed bank (Source: FDIC).

[23] Under the soi-disant loss share agreements, the FDIC reimbursed 80% of losses on covered assets.

research thus demonstrates the advisability of gauging efficiency over an extended period of time. Another relevant finding is the disadvantaged competitive position experienced by institutions that shun such supportive schemes. With respect to the research questions, the study predicts that banks participating in government-assisted consolidation activity should outperform other financial institutions on account of a temporary improvement in their production function from cost relief.

The correspondence between regulatory measures and efficiency has been detected also outside the United States. Looking at the case of Taiwan, Hsiao et al. (2010) find notable advances in operating performance after the financial reform enacted in 2002. They ascribe the gains to enhanced risk management practices and compliance with mandates requiring lower non-performing loan and higher capital adequacy ratios. In essence, these parameters are deemed to be the determining drivers of overall efficiency. These results are unaffected by exogenous considerations, such as economic growth, or endogenous factors, such as asset size. Considering the same setting and time period, Yu and Luu (2003) observe similar enhancements to productivity which is however exclusively imputed to scale economies obtained from incentivize merger activity. Financial institutions with comparable dimensions perform similarly. In essence, the presence of fewer market participants and not managerial and technical effectiveness constitutes the main driver for enhancing efficiency scores. Examining the case of Norway, a market in which deregulation prompted rapid

consolidation, Berg et al. (1992) coincide in encountering superior performance. They however aver that reduction in idle capacity and not lower competition is the main reason for this development. The convergence in efficiency scores is interpreted as evidence of heightened competition[24]. While analyzing the impact of regulatory reforms imposed on Chinese banks in order to obtain accession to the World Trade Organization, Yao et al. (2007) impute higher efficiency scores to ownership reform and entry of foreign owned firms. Surprisingly, better performance is achieved by operating with less capital and pursuing higher risk, return opportunities. In a similar setting and observation period, and considering different performance benchmarks, Chen et al. (2005) detect progress in cost efficiency levels including its two components - technical and allocative efficiency. As in the case of Puerto Rico, consolidation follows a period of heavy loan losses which left many institutions in precarious positions. These studies suggest that the banks that benefited from regulatory assistance should enjoy higher productivity regardless of business strategies implemented. Moreover, after the oligopoly emerges, their performance levels should converge over time.

Notwithstanding the observed impact on efficiency, regulatory directives remain equivocally successful in ensuring a sound banking system. The frequent upheavals experienced over the past century have provided the FDIC ample opportunities to test the tools available at its disposal. Consequently, the failure to observe progress in avoiding capacious loan impairments is a source of concern.

[24] Cf., Huan et al. (2010) obtain contrary findings when considering data from Eastern European countries. Allocative efficiency suffers from over capitalization and excess funds.

When comparing the credit losses reported in the last two protracted banking crises (i.e., 1986-1992 and 2007-2013), Balla et al. (2015) conclude that reforms instituted in response to earlier downturns fail to preclude repeated adverse performance. The study contributes to the literature by demonstrating that key determinants of operating success (i.e., avoiding receivership) abide regardless of both macroeconomic conditions or regulatory framework. The size of the equity cushion is deemed the only reliable predictor of solvency. With respect to the research questions, the study suggests that the banks exiting the marketplace should be those with limited access to capital (cf., foreign institutions with ample overseas support) and performance related to credit losses should be inure to overall economic conditions.

High concentration levels attained by regulatory support are not often intrinsically sustainable; hence, the attributes associated with such market structures tend to inexorably dissipate over time. Considering the particular case of horizontal mergers,[25] Adams et al. (2009) suggest that in banking systems where the transactions resulted in high concentration levels the number of firms eventually exhibit a relative increase three to five years following these transactions. The results are interpreted as evincing the ability of market forces to mitigate at least some of the anticompetitive effects associated with high concentration. The mechanisms deemed the most efficacious in promoting such development are divestitures, particularly of branches. For the thesis, the study

[25] The sample analyzed consisted of 86 transactions completed between 1989 and 2004 that involved at least one geographic market where both the acquirer and the target operated.

indicates that the pernicious consequences often imputed to highly concentrated markets are both self-correcting and transient.

2.2.1.4 Impact of Foreign Owned Entities on Systemic Efficiency

While conceding that the objectives of foreign banks may differ from those of domestic institutions, some researchers aver that the appropriate framework for examining the operational behavior of these entities is not distinctly unique. Avrikan (2006) outlines the principal motivations for establishing foreign banks and proposes two approaches for measuring their efficiencies. Included in the former are: a) the fear of losing the business relationship when a client sets overseas operations (fear expansion) or engages in trade activities; b) the opportunity to leverage more sophisticated skills in lesser developed markets; c) the pursuit of growth by expanding the client base; and d) the redeployment of underutilized assets. Based on the bank's particular objective, its behavior can be then modeled based on two alternative theoretical frameworks. If management's main aim is to focus on operating efficiency, the production approach to modeling bank behavior would be appropriate. That is, the priority is to minimize the use of resources.[26] In contrast, the intermediation approach is preferable when management seeks revenue and profit maximization.[27] He finds no meaningful

[26] If productivity estimates are to be derived by applying Data Envelopment Analysis, the input orientation would be appropriate.
[27] If productivity estimates are to be derived by applying Data Envelopment Analysis, the output orientation would be appropriate.

variation in operating efficiencies between foreign and domestic owned institutions.

While Avrikan's contributions are irrefutable, his theories have now been superseded in some key aspects. First, other researchers posit that foreign owned commercial banks may pursue institutional objectives not akin to those of domestic banks (e.g., projecting prestige by touting the extent of international presence); and therefore, their examination requires a bespoke framework. Second, more recent studies categorically reject the assertion that financial institutions exclusively behave following the two approaches identified by him (e.g., Lim et al., 2005). That is, a bank acts in a different manner according to the internal activity being performed; thus, the production and intermediation approaches are not mutually exclusive. To account for the existence of various types of management behavior within a single corporate structure, some researchers make use of two-stage models for estimating efficiency (e.g., Lim and Randhawa, 2005)[28]. Moreover, the individual components of efficiency for foreign banks may differ from domestic institutions. For example, Isik et al. (2002) find the latter to excel in allocative efficiency but underperform regarding other operating criteria. The researcher should therefore be cognizant of the need to perform a more nuanced analysis which considers distinguishing characteristics beyond solely ownership.

[28] Applying the two-stage banking model reveals significant variations of efficiency that co-exist within a singular corporate entity. For example, when comparing banks in Singapore and Hong Kong, Lim and Randhawa (2005) estimate differences exceeding 20%.

The literature often remarks on the mutually beneficial symbiotic relationship between foreign and autochthonous banks. In the context of the privatizations implemented in Hungary following the demise of the Soviet Union, Hasan and Marton (2002) find that the introduction of non-indigenous players improved the stability and efficiency of the banking sector. The primary drivers for such development are attributed primarily to capital infusions and cost-control measures. Of interest, the benefits derived from foreign capital emanate regardless of the form of ownership structure implemented. For example, both the establishment of competing participants and joint venture firms contribute positively to the resiliency of the banking sector. Considering the peculiar circumstances of the setting - an economic system transitioning from communism to capitalism – extrapolating these findings to the case of Puerto Rico may be problematic. Moreover, the researchers acknowledge the divergence in experiences between developed and developing countries noted by others (e.g., Claessens et al., 2001). However, the study evinces the advantages derived by acquirers from regulatory backstopping of potential credit losses, a scheme actively applied in the thesis' setting. Nair and Vinod (2019) also posit that having more foreign banks improves the overall efficiency of native institutions by fostering competition. These studies indicate that a banking system populated with financial institutions with diverse ownership composition should be more productive.

In contrast to the previous beliefs, other academics categorize the interrelation between foreign and domestic banks as akin to commensalism. For example, examining the case of the Philippines between 1990 to 2006, Manlagnit (2011) finds a deleterious effect on profitability of local banks imputed to increased competition. The latter prompts significant alterations in business strategies which entail allocating additional resources, and increasing expenses, in order to upgrade production technologies. Domestic institutions appear to be less successful in deriving benefits from technological innovation. The analysis is however limited in scope since no apparent consideration is given to a) the expected negative spillover effects (e.g., most profits obtained by foreign banks are repatriated and not reinvested locally, overall reduced sector employment as expatriates displace local workers), b) the offsetting impact on profits attributable to revenue enhancing initiatives, and c) the importance ascribed to participants who control only 10% of assets and thus lack the authority to influence corporate policy. Despite these shortcomings, Manlagnit does contribute to the literature by recognizing that the consequences of foreign bank entry are ultimately a function of home-country characteristics and quality of governing institutions. Her findings also evince a positive correlation between market share and profitability and a significant negative relationship with overhead cost.

Finally, some researchers fail to detect any meaningful impact on systemic productivity from the participation of foreign banks. Sathye (2001), Assaf et al. (2011), and Figueira et al. (2009) find little difference in performance between

state-owned and privately-owned banks and between foreign and domestically-owned institutions[29]. To the question, do banks with foreign investors perform more efficiently than institutions controlled by local capital?, the empirical results obtained from performance ratios, DEA, and Stochastic Cost Frontier[30] are resoundingly unsupportive. Surprisingly, this view is held while concurrently recognizing regional variations in efficiency levels which are in turn imputed to national idiosyncrasies. The insight here is that these local dissimilarities outweigh ownership considerations. That is, macroeconomic and regulatory regimes are more determinants of productivity than the provenance of capital per se. Generalizing these results is however debatable on account of the rather limited sampling taken (e.g., observations from only two institutions were employed in some countries). Zouari and Tartak (2014) report similar findings. Using regression analysis to examine returns on assets and equity for over fifty Islamic banks scattered in more than fifteen countries, entities with foreign shareholders do not appear to perform better than other financial institutions. The main distinguishing consideration is corporate governance. Observing the same performance measures, Lee (2008) reaches a congruous conclusion in the case of South Korea. As market concentration advances, productivity gains in tandem but the contributions coming from foreign owned entities are deemed insignificant.

[29] Rezvanian et al. (2011) are in the minority arguing that foreign banks are less efficient on account of inherently less competitive cost structures (i.e., higher compensation of expatriates).

[30] In the stochastic econometric frontier approach, a bank is labeled as inefficient if its costs are higher than the costs predicted for an efficient bank producing the same output/input price combination and the difference cannot be explained by statistical noise. The cost frontier is obtained by estimating a cost function with a composite error term, the sum of a two-sided error representing random fluctuations in cost and a one-sided positive error representing inefficiency (Mester, 1996).

Interestingly, this pattern peaks at a given level determined by the nature of corporate governance present in the marketplace. The study is particularly relevant to the thesis on account of the similarity between the market concentration trajectories observed in South Korea and Puerto Rico. The above indicates that the impact of foreign ownership on efficiency may be muted compared to other considerations.

The asymmetrical manner in which technological innovation affects commercial banks with disparate ownership structures has been identified as another contributor to divergence in operating performance. In a study of the banking reforms implemented in China after 1979, Yao et al. (2008) apply DEA and the Malmquist TFP index to estimate efficiency scores and then decompose the sources of productivity growth. For state-owned entities, they find that efficiency improvements are driven mainly by endogenous factors. In contrast, efficiency gains for joint ventures with foreigner partners result from technological progress. These findings have policy implications to the extent that bespoken regulations are necessary to incentivize efficiency advances. Of note, and concurring with Figueira et al. (2009), Yao detects no evidence of outperformance by entities with foreign ownership. Moreover, the correlation between the size of an institution and its profitability is not statistically significant. This may imply that consolidation per se cannot explain productivity gains. The limitation of the study resides in the severe constraints imposed by Chinese authorities on foreign investors. Unlike the case of Puerto Rico, overseas investors are prohibited from holding a majority stake in a

financial institution, a condition that precludes non-native organizations from exerting full management control.

2.2.1.5. Bank Competition and Systemic Stability

The empirical evidence available fails to elucidate the nature of the relationship between the level of competition manifested in a banking system and its inherent stability. This is not surprising given the lack of consensus among theoretical frameworks, competing definitions of these concepts, and alternative manners of measuring them. In a discussion of existing literature, Beck (2008) remarks that under the charter value view of competition excessive competition incentivizes risk taking activities and thus promotes fragility. In contrast, the risk-shifting paradigm postulates that the absence of competition leads banks to charge higher margins to firms which are then prompted to pursue more speculative investment opportunities. Beck's paper posits that competition per se is not detrimental to system stability. However, such a conclusion is issued with an all-important caveat. Namely, the banking sector must be in a market-based financial system with the necessary supporting institutional frameworks. Anginer et al. (2012) examine the special case of lack of competition under a concentrated marketplace. The study contributes to the literature by departing from the usual approach of measuring overall industry strength by aggregating constituents' individual measures of efficiency and instead relies on the extent of correlations between constituents. While acknowledging the importance of the institutional and regulatory environment, the results indicate that more competition heightens

system fragility[31]. Of note, state ownership and limitations on market entries are deemed aggravating factors. Beck et al. (2012) revisit an earlier study to reconcile the two competing theoretical paradigms. They find that consolidation favors resiliency in countries with stricter merger restrictions, better developed stock exchanges, more generous deposit insurance, and more effective systems of credit information sharing. The reverse is plausible under a different regulatory regime. With respect to the research questions, the empirical evidence suggests that systemic risk should ameliorate as the oligopoly coalesces. An offsetting consideration is the moral hazard associated with the emergence of too-large-to-fail institutions and their reliance on regulatory backstopping of customer deposits.

A recent study reveals that the presence of smaller banks in a market dominated by one institution is conducive to economic stability. According to Soldatos (2020), price-taking entities can be of assistance in achieving this commendable objective by becoming transmission conduits of monetary policy (e.g., setting lending rates below the dominant player). The necessary conditions are two-fold. First, market share stability requires that the size of the price-taking commercial banks is the same as under perfect competition. Second, regulators need to prevent the dominant firm from engaging in price wars to monopolize the loan market. The results are relevant to the thesis since the foreign banks operating after the oligopoly is formed are significantly smaller than the three

[31] For a decisively contrarian view, Schaeck et al. (2006) aver that greater competition associated emanating from more diverse markets promotes system stability and extends their survival time.

remaining domestic institutions. Hence, systemic stability could be consonant with a marketplace composed of firms with widely dissimilar asset sizes.

2.2.2 Findings Particular to Concentrated Markets

On account of governing regulatory statutes, oligopolies in the banking sector are seldom observed in the United States. Consequently, empirical literature pertaining to this type of market structure concerns overseas settings, primarily Canada, Japan, and the United Kingdom. Moreover, within each country, researchers tend to examine particular sub-segments separately. For example, in the case of Norway, Berg and Kim (1998) aver that the differences in market dynamics between retail and corporate businesses warrant a bifurcated approach to their investigation. The rationale is two-fold. First, each segment serves customers with an inherently distinct ability to acquire and process relevant information in financial markets. Second, the organizational structure of commercial banks reflects the activities required to produce the services demanded. A retail operation must rely on branches to capture required deposits; an institution serving mostly corporate accounts can depend instead on purchased funds. The study finds that the marginal cost of corporate lending is almost always higher than that of retail lending. The reason ascribed to this result is the greater incentive and competence of institutional clients to search for the best offer among competing lenders. Hence, answering the research questions of this dissertation entails first assessing the relative market power of each financial institution in the

most relevant segments[32]. Higher efficiency scores should be expected for commercial banks more focused on serving corporate customers.

Efficiency in concentrated marketplaces has been found to be not simply a function of size but also of the nature of the participants' organizational form and its production processes. Examining the experience of the United Kingdom, a market dominated by four clearing banks, Drake (2001) finds that productivity tends to improve with the amount of assets controlled by retail banks. However, at a certain threshold level, the correlation turns negative. For building societies with their unique business models, this inflection point is much higher than for other financial institutions. Moreover, the economies of scale associated with the production function of building societies decline at a faster rate than for clearing banks. Given the amalgamation of entities with different dimensions and business strategies, the study suggests that significant variations in efficiency scores could be expected between domestic and foreign participants and among entities with similar asset size in Puerto Rico.

The Canadian banking sector, another highly concentrated system with only five main participants, provides valuable insights on the relationship between efficiency and market power. Examining the period between 1965 and 1989, Shaffer (1993) detects no substantial degradation of competition and performance from the reduction in industry members. That is, abundance of financial institutions is not a sine qua non condition for achieving perfect competition. Such

[32] To that effect, Bikker and Haaf (2002) survey the tools available to calculate the degree of concentration and recommend the method adopted in this thesis.

finding indicates that commercial banks set marginal cost equal to their perceived marginal revenue even in oligopolies. In contrast, Asmild et al. (2004) find that efficiency in an oligopoly is subject to a multiple of exogenous and endogenous factors such as managerial changes, overall economic activity, and regulatory changes. The contradictory results could be explained by the difference in periods observed (1965 to 1989 vs. 1981 to 2000) and methodologies employed (parametric vs non-parametric). The studies indicate the need for exercising restraint in generalizing conclusions and acknowledging the problems associated with not knowing with certainty the constituent parameters of the production function.

Empirical research of the Japanese banking industry also furnishes understanding of operating efficiency in a highly concentrated marketplace. Similar to Drake (2001), Drake and Hall (2003) aver that size and business structure are the main determinants of productivity. Not surprisingly, the magnitude of marginal improvements is inversely related to the starting dimensions of the asset base (i.e., smaller entities experience relatively higher efficiency gains). Notwithstanding these results, the authors also posit that at some asset threshold productivity actually begins to decline; mergers involving large participants may exacerbate diseconomies of scale. Considering a later time period, Barros et al. (2010) reach a contrarian view. In a setting experiencing abiding merger activity, they find increasing inefficiency levels driven primarily by the incremental expenses related to personnel and premises. Deposits appear to have a minimal

impact on productivity. Like Drake and Hall (2003), the study detects differences in efficiency scores between business models (e.g., regional vs. universal institutions). Finally, Halkos et al. (2014) agree with Drake and Hall (2003) that smaller banks benefit more with respect to efficiency obtained from mergers. Furthermore, the geographical distance between the coverage areas of the entities involved in an acquisition appear to stimulate productivity gains. Unlike the case of Puerto Rico, the sample considered by Drake and Hall (2003) did not include incentivized combinations but instead entailed direct capital injections from regulators to all commercial banks, regardless of their financial condition. The experiences of the Japanese bank industry suggest that the efficiency scores of Puerto Rican banks improved during the observation period.

The impact of market power on efficiency has been observed also in developing markets. A wave of deregulation and liberalization swept throughout most of Latin America between 1997 and 2005. As a result, foreign participation in the banking sector expanded while consolidation activity flourished. According to Chortareas et al. (2011), these developments help financial institutions enhance managerial and scale efficiency levels. The proximate cause of higher profitability is not the exertion of greater market power but endogenous improvements in operating performance.[33] Given that these results were observed in a region with so many differing regulatory regimes and macroeconomic conditions, generalization of the

[33] This is a key finding. In a similar vein, researchers should avoid the fallacy that equates concentration to market power. As demonstrated by Claessens and Laeven (2004) and DeGuevara and Maudos (2007), the latter is achievable through size, specialization, and efficiency even in the absence of the former.

findings to adjacent locales, including Puerto Rico, may be appropriate. To conclude, the study suggests that once the oligopoly emerges the surviving banks in the island should report upgraded rentability and productivity.

2.3 Summary and Research Gap

The literature review informs as to the preference for a theoretical framework that views commercial banks as transformation agents. According to the tenets of real resource theory, financial institutions either produce services, as posited by the production approach, or allocate funds between savers and borrowers, as expounded by the intermediation approach. X-efficiency is currently the favored manner of assessing operating performance. The categorical exclusion of qualitative methodologies in the examination of the phenomenon denotes the unquestionable adherence to a positivist worldview. As per the study of oligopolies, the prevalent view avers that the banks operating in a concentrated marketplace behave in a manner akin to that predicted by the Cournot model. However, in order to present a more accurate representation of the characteristics prevalent in the research context, this theoretical framework needs to be modified to allow for the consideration of various endogenous factors (e.g., macroeconomic conditions).

Empirical results yield often contradictory evidence concerning the causal relationship between productivity and conditions present in the setting considered. This hinders formulating a priori answers to the research questions of interest. Notwithstanding the congenial level of uncertainty present, several expectations

can be derived from the literature. There is considerable support for the view that the emergence of an oligopoly generally favors improved operating performance. Surprisingly, this development can be achieved without lessening competition or harming customers' well-being. Moreover, industry concentration per se is not a not sine qua non for market power. Intervening factors include size, regulatory environment, and client base. Research also points to rapid convergence in efficiency scores for members of the oligopoly. With regards to the contributions of foreign institutions to systemic performance, results are mostly positive but not always in accord. Similarly, regulatory intervention supporting consolidation tends to improve industry resiliency and institutional productivity; however, the mechanism that renders these consequences remains nebulous.

In conclusion, the literature review reveals a knowledge gap concerning the subject of operating efficiency in Puerto Rico's banking industry and the concomitant effects stemming from its inexorable transformation into an oligopoly between 2010 and 2020. A similar void is identified regarding the effectiveness of regulatory initiatives embarked on the expectation of attaining a more resilient financial system.

CHAPTER III: RESEARCH CONTEXT

3.1 Historical Synopsis of the Commonwealth of Puerto Rico

Puerto Rico, the last vestige of the once vast Spanish Empire in the Western Hemisphere, is the smallest of the Greater Antilles. Its total surface area slightly exceeds 9,100 square kilometers; population hovers around three million.[34] In the aftermath of the Spanish-American War, the island became a possession of the United States in 1898. Since then, and in contrast to many Caribbean nations, advocates of political independence have enjoyed limited support from the population. The current political status is denominated Commonwealth, under which residents enjoy a hybrid form of citizenship. While individuals born on the island are deemed citizens of the United States, they are not allowed to participate in presidential elections nor appoint a voting representative to the mainland's legislative bodies. In contrast, Puerto Ricans who migrate to the continent do enjoy these privileges in addition to freedom to relocate anywhere in the mainland without prior consent from federal authorities. The organizational structure of the local legislative, executive, and judicial branches closely mirrors those prevalent in the mainland's fifty states. Similarly, federal laws and regulatory statutes take precedence over local enactments. Spanish is the preferred language of verbal

[34] "Central America: Puerto Rico." *The World Factbook,* Central Intelligence Agency, February 14, 2022.

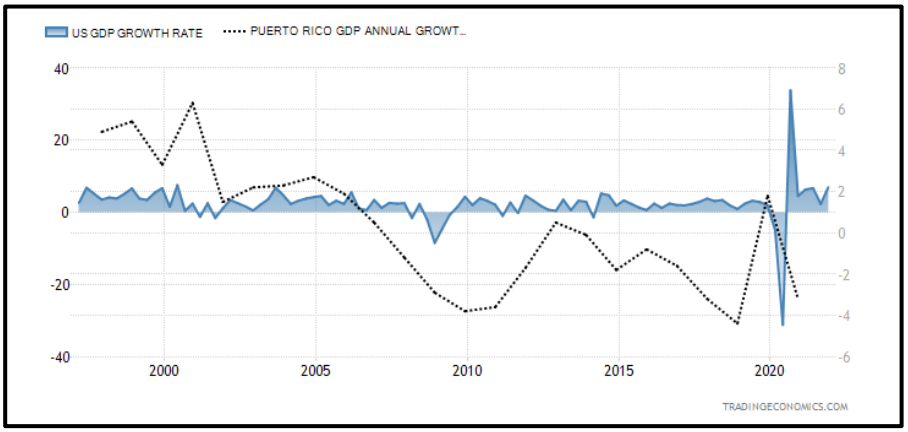
communication; even though, English is widely spoken. The United States dollar is the territory's legal tender.

3.2 Current Condition of the Puerto Rican Economy

According to the World Bank, Puerto Rico is considered a high-income country ($35,100 per capita) with one of the most competitive economies in Latin America (ranked 86th in world in terms of Gross Domestic Product (GDP)). However, its performance lags significantly behind the United States mainland ($74,000 per capita income). As per US Census Bureau, 44% of the population is considered poor while the comparable figure for the continent is 11%. Moreover, as shown in Figure 3-1, this divergence in performance has been growing in recent years. Of note, the end of a period of relative outperformance by the local economy coincides with the complete phaseout in 2006 of a federal tax exemption (Section 936) granted to U.S. companies operating in Puerto Rico.

Figure 3-1: Divergence in Economic Performance

U.S. Mainland vs. Puerto Rico[35]



[35] Source: Tradingeconomics

Noting the significant exodus of U.S. subsidiaries during this period, some economists ascribe the extended decline in the island's well-being to this modification in fiscal incentives coupled with high costs of doing business locally, particularly electricity (Bram et al., 2008) (see Appendix A-4 for GDP growth rate from 2000 to 2020). These prejudicial changes in labor market conditions in turn prompted considerable outmigration; the US Census Bureau reported a 12% decline in population between 2010 and 2020 (see Appendix A-3 for population trends).[36] Another exacerbating development was the bankruptcy of the local government in 2015, following years of fiscal mismanagement during which public debt exceeded GDP, in per capita terms three times higher than the most indebted state in the U.S.[37]

Currently, the principal business sectors are manufacturing, services, tourism, and agriculture; trade with the mainland dominates commercial flows.[38] Their current economic outlook is uncertain due to the ongoing impact of three systemic shocks: the COVID-19 pandemic, Hurricane Maria, and the bankruptcy of the central government. The situation has been somewhat ameliorated by the receipt of significant transfers from the federal government (Marxuach, 2021). However,

[36] U.S. Census Bureau. (2021, August 25). *Puerto Rico Population Declined 11.8% From 2010 to 2020*. Retrieved from https://www.census.gov/library/stories/state-by-state/puerto-rico-population-change-between-census-decade.html

[37] Ibid.

[38] "Central America: Puerto Rico." *The World Factbook,* Central Intelligence Agency, February 14, 2022.

the inherent political vagaries attached to these flows and the imminent budgetary constraints faced by the mainland after recent fiscal largesse suggest that reliance on their continuation is ill-advised. Appendix A depicts selected macroeconomic indicators for Puerto Rico.

3.3 Market Structure Evolution of the Banking System

The recent history of the banking sector in Puerto Rico can be divided into the following three periods (see Appendix B-4 for total assets held by commercial banks from 2012 to 2020):[39]

- Period 1: 1995 to 2005

  Total assets tripled from $33 billion to $105 billion fueled by intense real estate activity. The phaseout of federal tax credits resulted in the disappearance of deposits held by U.S. subsidiaries in local banks; hence, commercial banks had to increase reliance on brokered funds to finance their activities. Consolidation activity commences without regulator support.

- Period 2: 2006 to 2015

  The burst of the real estate bubble caused a sharp increase in the non-performing loans ratio (from 1.74% in 2005 to 13.1% in 2011). Total assets collapsed (from $105 billion in 2005 to $58 billion in 2015) on account of reductions in mortgage activity and lower individual consumption. Consolidation activity accelerates with FDIC assistance.

[39] V2A Consulting (2020). *Documenting the Socioeconomic Contributions of Puerto Rico's Banking Sector*. Retrieved from: https://www.abpr.com/Presentations/ViewPresentation?FN=documenting-the-socioeconomic-contributions-of-prs-banking-sector-12.8.2020.pdf

- Period 3: 2016 to 2020

  Increased consumption and investment levels support gradual recovery in lending and deposit activity. Banks continue to strengthen capital position and asset quality. Consolidation activity ceases.

The banking sector is regulated by an agency of the Department of Treasury of Puerto Rico named the Office of the Commissioner of Financial Institutions of Puerto Rico (OCIF). The entity is responsible for issuing banking licenses, conducting compliance examinations, and promotes financial literacy.[40]

Antitrust policy concerning bank mergers in the United States is guided by both the Department of Justice and the Federal Reserve Bank. These regulators rely heavily on market share and concentration calculations to gauge the potential competitive impacts of a proposed transaction (Adams et al., 2009). Specifically, the governmental agencies calculate the Herfindahl-Hirschman Index("HHI")[41] and then classify markets into three types[42]:

- *Unconcentrated Markets: HHI below 1500*
- *Moderately Concentrated Markets: HHI between 1500 and 2500*
- *Highly Concentrated Markets: HHI above 2500*

[40] Oficina del Comisionado de Instituciones Financieras (February 20, 2022). Retrieved from: https://ocif.pr.gov/SobreNosotros/Pages/Rese%C3%B1a-Hist%C3%B3rica.aspx

[41] The index is calculated by summing the squares of the individual firms' market shares; and, thus gives proportionately greater weight to the larger market shares.

[42] Source: Horizontal Merger Guidelines (August 19, 2010; updated June 25, 2015) issued by the United States Department of Justice and the Federal Trade Commission.

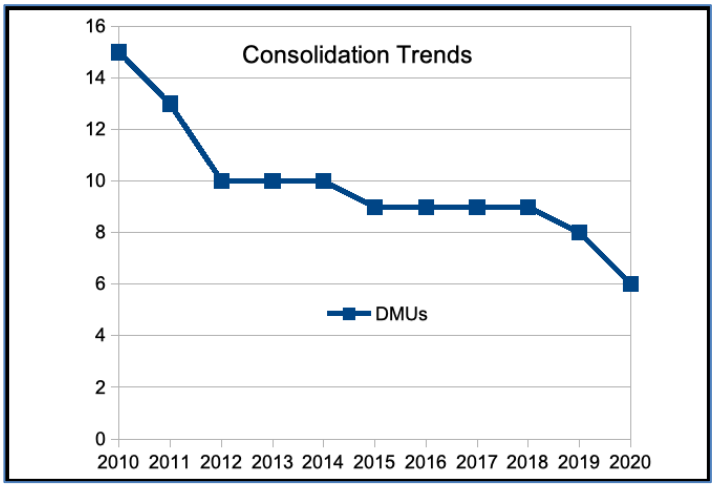
The regulators proceed by categorizing the structural effects of the proposed transaction as follows:

- *Small Change in Concentration: Mergers involving an increase in the HHI of less than 100 points are unlikely to have adverse competitive effects and ordinarily require no further analysis.*
- *Unconcentrated Markets: Mergers resulting in unconcentrated markets are unlikely to have adverse competitive effects and ordinarily require no further analysis.*
- *Moderately Concentrated Markets: Mergers resulting in moderately concentrated markets that involve an increase in the HHI of more than 100 points potentially raise significant competitive concerns and often warrant scrutiny.*
- *Highly Concentrated Markets: Mergers resulting in highly concentrated markets that involve an increase in the HHI of between 100 points and 200 points potentially raise significant competitive concerns and often warrant scrutiny. Mergers resulting in highly concentrated markets that involve an increase in the HHI of more than 200 points will be presumed to be likely to enhance market power. The presumption may be rebutted by persuasive evidence showing that the merger is unlikely to enhance market power.*

As per Adams et al. (2009), mergers falling below the first two thresholds are usually approved. Other transactions may proceed only if mitigating factors are identified and deemed sufficiently strong to overcome concerns regarding potential anticompetitive impact. Of note, the guidelines recognize and consider the salubrious impact on efficiency that can be derived from mergers. For example, higher productivity may lead to new or improved products without immediately and directly affecting prices.

During the time period studied, the banking sector experienced significant consolidating activity. This is denoted in Figure 3-2; from 2005 until 2020, 70% of market participants disappeared.

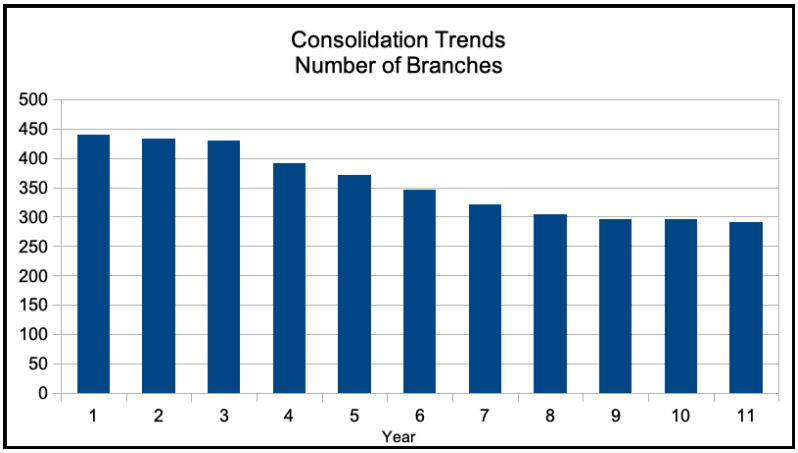
Figure 3-2: Number of Commercial Banks in Puerto Rican Banking System[43]



As shown in Figure 3-3, there was a concomitant reduction in the number of branches in the system.

[43] Oficina del Comisionado de Instituciones Financieras

Figure 3-3: Number of Branches in Puerto Rican Banking System[44]



The decline in banking footprint also coincided with depopulation trends in the island. At the same time, the overall size of the system contracted. Total assets and net loans declined by 10% and 35%, respectively[45]. Appendix B presents selected performance indicators for local commercial banks.

3.4 Market Participants considered in the Study

To calculate the various measures of efficiency, concentration, technological progress, and correlation, data was collected from all commercial banks active in the island between 2010 and 2020. As depicted in Figure 3-2, the sample size comprised fifteen commercial banks at inception, a figure which steadily declined to only six market participants by the end of the observation period.

[44] Ibid.
[45] Source: FDIC Bank Data & Statistics

Table 3-1 describes the evolution of the marketplace, discloses the ownership structure of each participant, and names the incorporation domicile of the ultimate proprietor. The first column contains the name of each bank. The second column presents the ownership structure; entities identified as private are controlled by private shareholders while those named public are managed by governmental entities. The next column presents the domicile of the bank's effective proprietor. For example, Citibank operates a branch in Puerto Rico which is ultimately fully-owned by a corporation domiciled in the mainland; hence, the label applied is "foreign." The final column provides an account of the institution's operating situation at the conclusion of the observation. An extant entity refers to a commercial bank still conducting business in the island as of December 31, 2020.

Table 3-1: Financial Institutions Considered in the Study

Bank	Ownership	Provenance	Status at conclusion of observation period
Banco Popular PR	Private	Autochthonous	extant entity
Firstbank PR	Private	Autochthonous	extant entity
Orientalbank PR	Private	Autochthonous	extant entity
Banco Cooperativo PR	Cooperative	Autochthonous	extant entity
Citibank N.A.	Private	Foreign	extant entity
Banesco	Private	Foreign	extant entity
Banco Santander	Private	Foreign	Merged or acquired without government assistance
Bank of Nova Scotia	Private	Foreign	Merged or acquired without government assistance
Scotiabank	Private	Foreign	Merged or acquired without government assistance
Doral	Private	Autochthonous	Failed and received government assistance
BBVA	Private	Foreign	Merged or acquired without government assistance
DBG Fomento	Public	Autochthonous	Closed
Economic Development	Public	Autochthonous	Closed
RG Premier Bank	Private	Autochthonous	Failed and received government assistance
Eurobank	Private	Autochthonous	Failed and received government assistance

The phrase ”failed and received government assistance” identifies entities which were intervened by the regulator to effect their closure. Their assets were sold to other local banks under schemes that entailed some form of monetary support (e.g., restriction on credit losses). Several public banks were liquidated as part of the local government’s receivership process. Other institutions, primarily foreign

operators, simply sold their franchises on account of the limited opportunities associated with stagnant economic growth and unfavorable demographic trends.

Government assistance refers to the role played by the Federal Deposit Insurance, an agency of the US government, in facilitating the sale of a failed financial institution. Under the terms of a purchase and assumption agreement (P&AA), an acquiring bank purchases certain assets (e.g., loans) and assumes liabilities (e.g., deposits) with limited indemnification. This could include the sharing of losses incurred during a certain period after the transaction closes or full reimbursement up to a specified amount.

Table 3-2 summarizes and provides information about the sample data.

Table 3-2: Summary Statistics of Selected Input and Output Variables

	Input	Input	Input	Output	Output	Output	Output
Statistic	Number of employees	Fixed assets	Interest Expense	Net loans	Deposits	Securities Available for Sale	Net Interest Income
Minimum	9	0	0	7	0	0	33
Maximum	186546	510000	347000	19153000	47834000	20103000	1257000
Mean	4777	74934	52194	4245035	5406438	1265600	239656
Standard Deviation	22655	133129	64949	5119878	7992649	2917202	319977
Skewness	7.24	2.23	1.95	1.61	2.90	4.42	1.91

The divergence in the size of the commercial banks involved is clearly denoted by the standard deviation and skewness. Three of the surviving entities (i.e., Popular,

Orientalbank, and First Bank) offer a wide gamut of banking products to a large customer base. In contrast, the other three remaining participants (i.e., Banesco, Banco Cooperativo, and Citibank) have a limited footprint in terms of both branch network and services provided. For the purpose of this study, Banesco and Citibank are deemed as entities controlled by foreign owners while the other four commercial banks are considered autochthonous.

3.5 Conclusion

The study examined a setting plagued with adverse macroeconomic conditions which in turn prompted a significant restructuring of its banking sector. The extended nature and severity of these circumstances fomented the segmentation of the industry into niche and universal institutions. The larger domestic participants pursued initially acquisitions involving troubled local institutions. As prospects for growth and profits declined, foreign banks exited the island despite exhibiting adequate operating performance. At the closure of the observation period, the number of market participants and branch network had contracted by over 50%.

CHAPTER IV: METHODOLOGY

4.1 Overview of the Research Problem

Puerto Rico has experienced a tumultuous period over the last decade on account of a barrage of natural disasters, prolonged economic downturn, and deteriorating demographic trends. The integrity and cohesion of its society depend more than ever on maintaining a sound economic system and resilient business entities. Of these arguably, commercial banks are of primordial importance. Beyond the detectable provision of employment, these financial institutions are widely recognized as facilitators of ancillary economic activity and efficient allocation of resources. For example, idle funds from individuals in the form of deposits can be channeled into more productive uses by companies with immediate investment needs. Hence, the study of the island's banking sector over this period is of practical necessity to both a government in need of urgent policies to stem economic malaise and regulators seeking to understand the ramifications of recently completed and extensive consolidation activity. The dearth of research in this topic revealed by literature review is the problem the study aims to correct.

The performance of commercial banks is commonly examined by investigating operating efficiencies (Kaffash & Marra, 2017). Such an approach offers several advantages. First, the necessary data required to perform the analysis is readily available on account of the sector's heavy regulatory oversight. Entities are required to report on a frequent basis material which is readily available to the public at no cost. Second, the information is usually compiled following uniform

standards, thus allowing for comparisons between banks. Management is constrained in the manner these figures can be calculated. Third, commercial banks are often subject to regulatory audits and investor scrutiny which provides some assurance as to the accuracy and reliability of the data. Finally, by studying the relative contribution to profitability of specific inputs and outputs, management obtains a better understanding of the actions that can be taken to improve performance.

4.2 Research Framework

Rigor in research requires consonance between the methodology applied and the author's philosophical views and study's aim. Answering the research questions contemplated herein entails finding explanations for a phenomenon (i.e., operational efficiency) and identifying underlying causal relationships. The objective is thus to collect empirical evidence in order to test hypotheses. Consequently, this study is best suited to be informed by the rationalistic inquiry paradigm. Guba and Lincoln (1982) identify the five axioms that constitute this theoretical framework as follows:

- The nature of reality: a single, tangible reality decomposable into independent variables and processes.
- The inquirer-object relationship: the researcher is able to maintain a discrete and inviolable distance between herself and the object of inquiry.
- The nature of the truth statements: knowledge is best encapsulated in generalizations; truth statements have enduring value and are independent of

context.

- Attribution/explanation of action: every action can be explained as a result of a real cause that precedes the effect.
- The role of values in inquiry: the methods employed guarantee inquirer's neutrality and inquiry rigor.

Here, the single reality is the operating performance of a particular banking system. It is deemed to be an observable and measurable phenomenon as reflected in large quantities of numerical data compiled and disclosed by individual market participants. The process of collecting such information is achieved without any interaction between the observation and the researcher. Moreover, data analysis yields a quantifiable and discrete outcome (e.g., Malmquist Total Factor Productivity index) that denotes a causal relationship between dependent and independent variables.

Figure 4-1: Research Framework Diagram[46]

This thesis adopts an ontological objectivism and epistemological positivism philosophy. In terms of nature of existence and being, the world is viewed as one in which objective phenomena exists. Social entities can be studied by themselves

[46] Mackenzie & Knipe (2006)

and independent of social actors. This position contrasts with constructivism which posits that reality is constructed by individual experiences and thus inherently subjective. According to this perspective, organizations are reflections of social actors and are shaped by interactions with them. In terms of acquiring knowledge, positivism avers that reality is both ascertainable and quantifiable. Thus, there is preference for natural sciences methods in research. Observations can be made bereft of individual bias. That is, the research process can be performed objectively and without affecting the observed. Moreover, cause and effect relationships can be ascertained and gauged by analyzing data; thus, quantitative methods are appropriate for testing hypotheses. In comparison, realism postulates that acquiring knowledge entails active interactions with the researched. Hence, there is a predilection for qualitative methods designed to gain in-depth understanding of an ever-morphing phenomenon. Unsurprisingly, the most common instrument for collecting data is conducting interviews.

4.3 Research Purpose and Questions

The purpose of this thesis is to investigate the changes in operational efficiencies in a banking system experiencing significant consolidation activity. Moreover, the study aims to scrutinize individual bank performance, calculate the elasticity of each input and output considered, and assess the effectiveness of regulatory actions designed to bolster the soundness of the financial system.

Specifically, the following research questions are considered:

- Has the emergence of an oligopoly, on account of the initiatives instituted by regulators, benefited the aggregate operating performance of the banking sector in Puerto Rico?
- Has this transformation impacted equally the surviving banking entities?
- Is the effect from the departure of foreign players similar to that associated with the liquidation of autochthonous banks?
- How do individual inputs affect specific performance measures?

4.4 Research Design

On account of the theoretical framework espoused, the research approach hereto adopted is deductive. The topic has been the subject of extensive research and therefore various theories already exist to explain the phenomenon. Of these, the production and intermediation models have been the most widely applied. From these conceptual frameworks, the researcher is called to make use of logical reasoning to devise predictions as to expected outcomes. By comparing these with empirical data, the validity of these theories can then be appraised.

The three components of the research design provide a roadmap for collecting and analyzing the data necessary to address the questions considered. They are:

- *Research Strategy*

  On account of the nature of the information required to answer the research question, the research strategy employed in this thesis is secondary data collection from regulatory filings. Specifically, numerical entries will be extracted from the Reports of Condition and Income Report issued by the Federal Financial

Institutions Examination Council and Puerto Rico Financial Activity Reports published by the Office of the Commissioner of Financial Institutions. The sample of observations is taken from a population that encompasses the commercial banks operating in the island during the period under consideration.

- *Data Analysis Methods*

  The study utilizes quantitative methods (e.g., linear regression) to analyze observations in order to address the research questions considered, an approach consistent with the philosophical view adopted. The objective is to identify causal relationships between variables such as inputs and outputs.

- *Measurement of Efficiency and Market Concentration*

  The thesis relies on linear programming models (e.g., data envelopment analysis) to estimate the operating performance of the commercial banks included in the sample. Such techniques have been applied in similar contexts in over 600 journal articles (Kaffash & Marra, 2017). Moreover, the extent of market concentration is ascertained by calculating ratios derived from key banking benchmarks (e.g., loans and deposits).

4.5 Research Methods

The diverse nature of the research questions examined mandate the application of various research methods. Their selection was guided by the manner in which the subject matter has been most recently examined, capabilities of software packages, and data available. Reliance on multiple approaches also serves indirectly to either corroborate or question the findings yielded by each technique,

a particularly fortuitous development considering the inherent limitations associated with them. As indicated by Peristiani (1997), estimates of efficiency based solely on financial ratios are too inaccurate to be relied on.

4.5.1 Non-Parametric Model to Measure Static Technical Efficiency

The methods for measuring efficiency have been traditionally segregated into parametric and nonparametric (Chortareas et al., 2011). Unfortunately, literature reveals a lack of consensus regarding the preferable approach; thus, explaining the use of both approaches in studies addressing similar questions in identical settings (Rezvanian et al., 2011). For example, when conducting a study of the Japan banking sector, Barros et al. (2011) estimate performance scores based on the Russell directional distance function while Drake et al. (2009) rely on non-parametric analysis. The latter also finds that substantial differences in entities' efficiency scores can be obtained depending on methods applied. Some researchers even combine both approaches in the same study (e.g., Al-Sharkas et al., 2008).

Parametric methods derive an efficient frontier by applying statistical distributions to an assumed production function. Deviations between observed costs and optimal performance represent the sum of random errors and derived inefficiencies. The three main approaches to parametric techniques diverge on account of the formulation employed to estimate the distribution of these residuals. First, Stochastic Frontier Analysis (SFA), the most popular option, specifies a functional form for the cost, profit or production functions; the distributional

assumption on the error terms is usually either asymmetric half-normal or symmetric standard normal distribution. Second, under Distribution Free Approach (DFA), the estimated efficiency of a given bank is the difference between its mean residual and that at the frontier. Hence, efficiency differences are stable over time. Third, the thick frontier approach prescinds from the distributional assumption and simply provides an overall level estimate rather than a point estimate (Yao et al., 2007). The main limitations of parametric methods are the need to specify a production function and assume a particular distribution of errors; ascertaining the validity of these is usually an insurmountable task (Drake et al., 2006). Some researchers posit that parametric methods are preferable in transitional environments due to the likely presence of significant measurement error (Jian et al., 2009).

An illustrative and widely popular example of a parametric model is the representation of the cost function advanced by Aigner et al. (1977) and Meeusen and Broeck (1977). Its mathematical representation is as follows,

$$\boxed{lnC_n = f(lny_{i,n}, lnw_{j,n}) + \varepsilon_n}$$

where, C_n is the total operating cost for the nth bank, $y_{i,n}$ measures the ith output of the nth bank; $w_{j,n}$ is the price of the jth input of the nth bank; and, ε_n, the error term, can be represented as $\varepsilon_n = \mu_n + v_n$ where, μ_n is the random factor and v_n corresponds to the controllable component.

Variations of this specification have been widely applied in the study of operating performance in banks. For example, Huljak, I., Martin, R. and Moccero, D. (2019) use a trans-log cost function for total cost with three inputs and two outputs, while

including both a linear and a quadratic time trend and the bank capital ratio to capture technological progress and risk considerations, respectively. In this framework, banks produce loans and other earning assets (outputs), while employing labor, physical capital and financial funds (inputs).

In contrast, nonparametric techniques prescind from *a priori* specification of the production function. Instead, they derive efficiency scores from a particular data sample extracted from commercial banks operating in the setting under consideration. There are two approaches to this type of method: Free Disposable Hull (FDH) analysis and Data Envelopment Analysis. The former has the disadvantage of producing less precise estimates of average efficiency (Berger & Humphrey, 1997). This study employs the second method on account of its wide acceptance by the research community and availability of software packages necessary for performing calculations. DEA is a mathematical programming procedure which uses observed input/output ratios to estimate efficiency for the production units considered and then create a "best practice" frontier. Essentially, the objective is to create a non-parametric envelopment frontier over the data points such that all observed points lie on or below the production or best practice frontier. Mathematically, Berger & Mester (1997) show that this can be represented as follows,

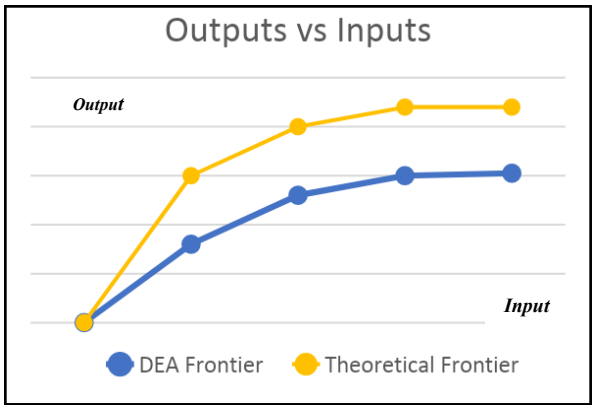
> Assume Y is a matrix of M outputs such as $Y = (y_1, y_2, \ldots, y_m)$, X is a matrix of K inputs such as $X = (x_1, x_2, \ldots, x_m)$, and N is the number of firms. Efficiency is then defined as,
>
> $$\boldsymbol{Efficiency = output/input = u'y_i/v'x_i}$$

where u is an M x 1 matrix of output weights and v is a K x 1 vector of input weights.

The most efficient commercial bank in the sample gets assigned a score 100% while the figures for other firms are based on relative performance. The inverse of the score corresponds to the ratio of actual to optimum output. Hence, DEA helps identify areas in need of improvement by comparing each entity's execution against that of the best performer in the sample.

Figure 4-2 depicts the DEA frontier which is created by connecting the points denoting the performance exhibited by the best performer in the sample given a specific set of inputs and outputs. The theoretical frontier corresponds to the best possible frontier for the population.

Figure 4-2: Theoretical vs. DEA Frontiers



Optimal weights can then be derived by solving the following linear programming problem:

$$\textbf{\textit{Maximize } } (u'y_i/v'x_i)$$

$$\textit{subject to} \quad u'y_j/v'x_j \leq 1, \qquad j = 1,2\ldots, N$$

$$u, v \geq 0.$$

That is, the objective is to maximize the efficiency measure subject to the constraint that the ratio has to be less than or equal to one. To avoid an infinite number of solutions, the mathematical problem is then reformulated by requiring that $v'x_i = 1$. This version which is named the multiplier form can be expressed as,

$$\boxed{\textbf{\textit{Maximize } } (\mu' y_i)}$$

$$\begin{aligned} \textit{subject to} \quad & \upsilon' x_j = 1, \\ & \mu' y_i - \upsilon' x_j \leq 0, \qquad j = 1,2\ldots, N \\ & \upsilon, \mu \geq 0. \end{aligned}$$

The change in notation is on account of the transformation.

The advantage of not having to specify *a priori* the seldom known production function, the possibility of measuring variables in different units, and the ability to gauge any deviations from the efficiency frontier account for DEA's popularity. On the other hand, all deviations from "best practice" frontier are attributed to cost differences on account of X-inefficiencies (i.e., managerial incompetence). Since the presence of random errors is not considered, these estimates tend to exceed those derived using parametric methods. For example, Frantz (2018) finds scores for U.S. banks to average 16% higher using non-parametric estimators instead of linear regression models. For DEA to yield precise estimates of efficiencies, the expected value of random errors over time needs to approach zero, a condition most difficult to corroborate (Berger, 1993). Another consideration pertains to measurement error which could be significant if the number of observations is small in comparison to the number of inputs, outputs, and environmental variables

to be specified (Okeahalam, 2006). The distinction between DEA and the other form of non-parametric method, Free Disposal Hull, resides in the relaxation of the convexity assumption (i.e., the shape of the efficiency frontier). Unfortunately, the software packages available do not rely on the second technique; therefore, an alternative manner of performing the estimates is not possible.

This study makes use of the widely adopted DEA techniques to estimate the efficiencies of the banks that operate in Puerto Rico. The reasoning for this selection hinges on the positive experience obtained by many other researchers in examining the topic (Al-Sharkas et al., 2008) and the availability of the off-the-shelf software. On account of the limited number of banks operating in the selected setting and the large number of observations necessary to render accurate estimates of efficiency required by parametric models, the nonparametric method is preferable. Moreover, and of critical importance, this linear programming approach does not require knowledge of the underlying production function or error distribution (Berger et al., 1997). Therefore, the researcher is not required to select a priori the variables that exhibit a causal relationship. At the same time, this lack of understanding of the state of the underlying production function necessitates consideration of multiple scenarios. For example, following Assaf et al. (2011), researchers are advised to estimate efficiency scores assuming both constant and variable returns to scale. Similarly, disagreement concerning management's ability to control specific aspects of the production process warrants pondering various model specifications. Some researchers posit that

management focuses primarily on minimizing costs (Hsiao et al., 2010); others aver model orientation is driven by idiosyncratic market dynamics (Henriques et al., 2020). That is, model orientation depends on the commercial bank's sway over inputs and outputs.

Alternative Classifications of Efficiency

Sherman and Zhu (2006) aver that overall productivity of a bank depends on four components of efficiency classification. Namely,

1. Technical efficiency: Also known as global efficiency measures the ability of banks to produce actual outputs with fewer inputs, or less resources used indicates higher efficiency;
2. Scale efficiency: Refers to the optimal activity volume level whereby inefficiency may arise if goods or services are produced above or below optimal level that resulted in added fixed cost;
3. Price efficiency: Bank could increase its efficiency if it could purchase the inputs (human capital and material) at lower price without sacrificing the quality;
4. Allocative efficiency: Measure the optimal mix of several inputs in order to produce products or services, such as banks incorporating automatic teller machines (ATM) and Internet banking for capital labor tradeoffs to increase efficiency.

Diacon et al. (2002) advance an alternative view which incorporates three aspects of efficiency. Namely,

- Pure Technical Efficiency: measures the extent to which a firm can

decrease its inputs (in fixed proportion) while still remaining within the variable returns to scale (VRS) frontier. Thus, it is a proxy for a producer's overall success at utilizing its inputs.

- Scale Efficiency: reflects the extent to which a firm projected to the VRS efficiency frontier can further decrease its inputs (again in fixed proportions) while still remaining within the constant returns to scale frontier. Hence, it measures the firm's ability to reduce inputs by moving to a part of the frontier with more beneficial returns to scale characteristics.
- Mix Efficiency: gauges the extent to which a firm projected onto the VRS efficiency frontier can further decrease some inputs without decreasing outputs (or increase output without increasing inputs). Therefore, it measures the extent to which a commercial bank can benefit from a change in its mix of its inputs and outputs.

4.5.1.1 Model Orientation: Input vs. Output

DEA affords researchers the opportunity to examine efficiency measurements under various scenarios. The first decision to be made requires selection of model orientation. That is, the study must answer the question as to which variables are to be deemed endogenous or exogenous. To address such inquiry, the researcher must assess the extent of actual control management exerts over either inputs or outputs. For example, if a commercial bank faces a constrained supply of deposits (an input), then the primary role of its administrators is the

selection of a product portfolio, such as loans and fee services, that maximizes profitability. Cheng (2014) posits that model orientation should also be guided by the objective of the study. For example, if management is concerned with maintaining market share in particularly strategic sectors, an output-oriented model should be adopted. The findings would then be useful in locating the resources (e.g., by acquisitions) necessary to accomplish these goals.

Under the input-orientated measures, the objective is to determine the extent to which input quantities can be proportionally reduced without affecting the output quantities produced. The linear programming expression is as follows,

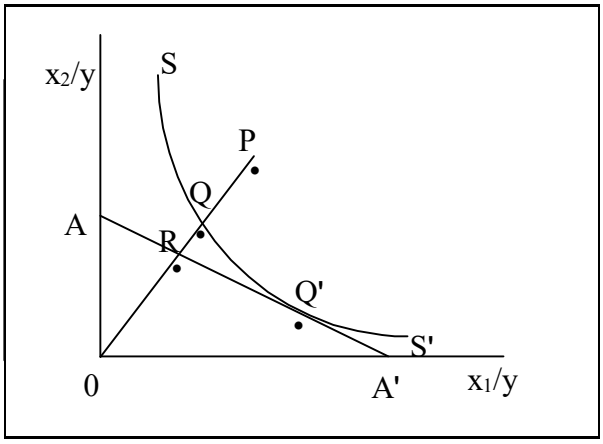
$$\boldsymbol{Max\ \Sigma\ u_r y_{rk} / \Sigma\ v_i y_{ik}}$$

$$\textit{subject to}\ \Sigma\ u_r y_{rj} / \Sigma\ v_i y_{ij}\ \leq 1$$

where, v (input weight) ≥ 0; *u* (output weight) ≥ 0;
$i = 1,2\ldots$, *m(input)*; $r = 1,2\ \ldots$, *q(output)*; $j = 1,2\ \ldots$, *n (production unit)*

Figure 4-3 illustrates the case of a model following input orientation and constant returns to scale. Following the definition advanced by Farrell (1997), technical efficiency refers to the ability of a firm to obtain maximum output from a given set of inputs. Here, two inputs (x_1 and x_2) are combined to produce one single output (y); the axes represent the efficiencies derived from using each input separately.

Figure 4-3: Technical and Allocative Efficiencies
Input Orientation[47]



DEA estimates the production function of the fully efficient firm denoted here by the isoquant SS'. Hence, technical efficiency (TE) can be calculated using the following formula,

$$\boldsymbol{TE = \frac{OQ}{OP}}$$

The line QP represents the amount by which inputs could be curtailed without affecting output (i.e., the technical inefficiency). Farrell (1957) also introduces the concept of allocative efficiency to denominate the ability of a firm to use the inputs in optimal proportions given their respective prices. In the graph, the line AA' represents the input price ratio; therefore, allocative efficiency (AE) can be determined applying the following formula,

$$\boldsymbol{AE = \frac{OR}{OQ}}$$

[47] Coelli (1996)

In contrast to input orientation, output orientation looks to assess the extent to which the amount of output can be proportionately expanded without altering the input quantities. The linear programming expression is as follows,

$$\boldsymbol{Minimize\ \Sigma\ v_i x_{ik}}$$

$$subject\ to\ \Sigma\ u_r y_{rj} - \Sigma\ v_i y_{ij} \leq 0$$

where, v (input weight) ≥ 0; *u* (output weight) ≥ 0;

$i = 1,2\ldots$, *m (input)*; $r = 1,2\ \ldots$, *q (output)*; $j = 1,2\ \ldots$, *n (production unit)*

The graphical representation is shown in Figure 4-4(a) assuming a decreasing returns to scale technology represented by the function f(x)[48]. Again, following Farrell's definition of technical efficiency, the input-oriented measure is given by the ratio AB to AP; the output-oriented score becomes CP/CD. The two are identical (i.e., AB/AP = CP/CD) only in the case the returns to scale are constant as shown in Figure 4-4(b). Fare and Lovell (1978) demonstrate that technical efficiencies for output and input orientations do not coincide when increasing or decreasing returns to scale are present.

[48] Given an input *x*, the business entity can produce output *y*.

Figure 4-4: Technical Efficiency Measures and Returns to Scale[49]

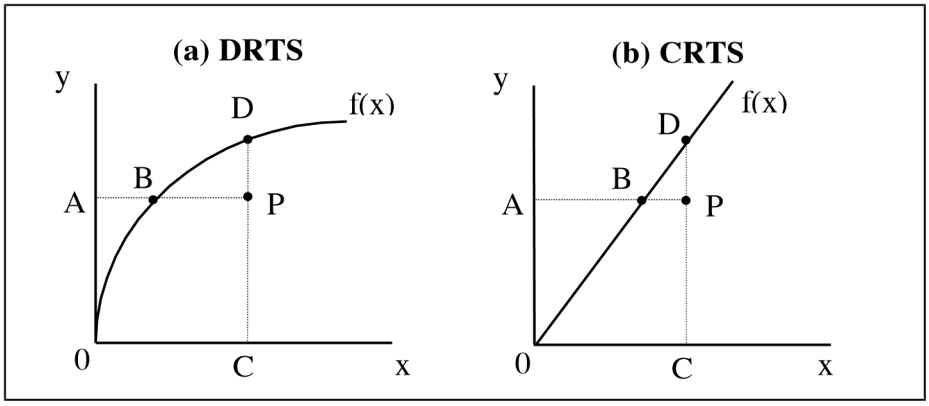


Figure 4-5 depicts the scenario of an output-oriented model that assumes constant returns to scale. Here, one single input (x_1) is consumed to produce two outputs, namely y_1 and y_2; the unit production possibility curve is given by the line ZZ'. Hence, the measure of output-oriented technical efficiency is the ratio,

$$\boxed{TE = \frac{OA}{OB}}$$

Price data could be then used to derive the isorevenue line DD' and thus define the allocative efficiency as,

$$\boxed{\mathbf{AE} = \frac{\mathbf{OB}}{\mathbf{OC}}}$$

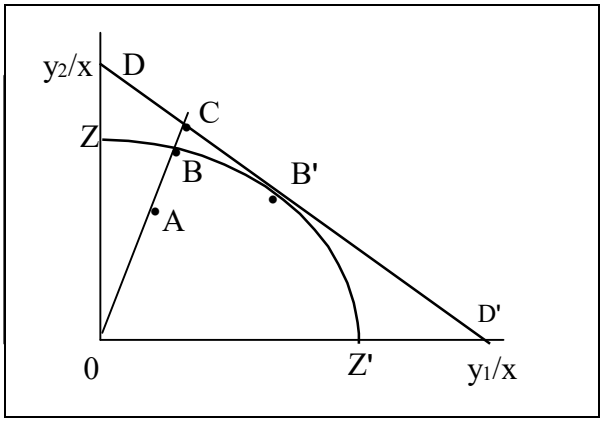
Finally, the overall economic efficiency is defined as the following product,

$$\boxed{EE = \left(\frac{OA}{OC}\right) = \left(\frac{OA}{OB}\right) x \left(\frac{OB}{OC}\right) = TExTA}$$

[49] Coelli (1996)

The range for all these defined terms remains zero to one. Of note, each form of efficiency could move independent of the other. Thus, gains in allocative efficiency could offset losses in technical efficiency thus rendering overall efficiency unchanged.

Figure 4-5: Technical and Allocative Efficiencies
Output Orientation[50]



As indicated by Coelli (1996), the advantage of using radial efficiency scores is that they are unit invariant. That is, changing the units of measurement will not affect the value of the efficiency estimate. This is helpful when analyzing commercial banks due to the wide variance in the magnitudes of input and output variables.

4.5.1.2 Returns to Scale Assumption

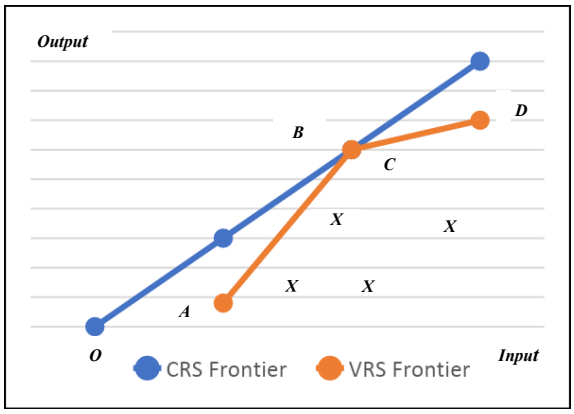
DEA also allows researchers to estimate efficiency scores under various assumptions concerning the scale of production technology. This flexibility is

[50] Coelli (1996)

critical since researchers are divided as to the most appropriate premise to be applied in investigating commercial banks. For example, Drake (2001) finds that smaller banks exhibit increasing returns to scale, whereas larger banks experience the opposite condition. Other investigators postulate that the technology prevalent in production functions follows an inexorable trajectory comprising three well-defined stages: increasing, constant, and decreasing (Cheng, 2014). On account of the uncertainty surrounding the matter, this study considers the two most common types of scale assumptions. The first, constant returns to scale (CRS), presumes that producers are operating at the size and input/output configuration that maximizes profits. One unit increase in input has a proportional, fixed effect on output. Banker et al. (1984) and Al Shamsi et al. (2009) aver that the CRS assumption is appropriate in a market in which all decision-making units are operating at an optimal scale, a condition difficult to ascertain. In contrast, the assumption of variable returns to scale posits that the consequence of modifying inputs and outputs fluctuates.

Figure 4-6 depicts the shapes of the frontier for constant and variable returns to scale.

Figure 4-6: CRS vs VRS Frontiers



The efficient frontier of the constant returns to scale model is the ray OB and the decision-making unit is only efficient at one point (B). In contrast, the efficient frontier of the variable returns to scale model is the ABCD convex curve and a producer could be efficient at four points (A, B, C, D).

4.5.1.3 Inputs and output variable selection

Estimates of efficiency are susceptible to the selection of inputs and outputs variables (Jiang et al., 2009). That is, scores could vary depending on the parameters considered. This condition is explained by the nature of the banks' operating processes. Unlike manufacturing firms that produce identifiable physical goods, financial institutions create many intermediate services with measurable final outputs (Yao et al., 2007). Hence, the researchers frequently select parameters based on the type of assessment to be made. For example, the variables to be used for estimating cost efficiency may be quite distinct from those required to gauge profit efficiencies (e.g., Lim and Randhawa, 2005).

The most frequently applied approaches for measuring service flows involving banks are intermediation and production; these are not deemed substitutes but rather complements. Under the intermediation view, the principal function of a bank is to convert deposits into loans; thus, proxy inputs are commonly income statement items such as income expense and non-interest income (Avrikan, 2009). In contrast, under the production approach, banks are regarded as production units. They utilize labor and physical capital to execute transactions and provide document processing services for customers (Freixas and Rochet,1997). As noted by Okeahalam (2006), the two positions are not mutually exclusive on account of a bank's dual role of both producer of services and intermediary in transferring funds between lenders and borrowers. Consequently, input selection is driven by the type of assessment to be made, namely either cost or profit efficiencies (e.g., Lim and Randhawa, 2005). On account of the dissertation' objective to explore overall efficiency applying frontier analysis, the conceptual framework to be adopted is the intermediation approach advocated by real resource theory. Other considerations supporting this selection are the availability of data and practices widely followed by other researchers (Hsia et al., 2010, Avrikan, 2009, Kwan, 2006). Two model specifications are tested to gauge sensitivity to model orientation (i.e., input vs. and output) and the assumption regarding the returns to scale prevalent at the efficiency frontier (constant vs. variable). Robustness is tested by considering alternative inputs sourced from

macroeconomic data (e.g., unemployment rate, inflation, and GDP growth rate) and conducting traditional ratio analysis.

The number of decision-making units to be considered has an impact on the precision obtained from DEA analysis. If the figure considered is sparse, the scores may fail to distinguish minute differences in efficiency between entities. To overcome this situation, Cooper et al. (2007) proposes that the sum of entities analyzed at any given time (n) shall be no less than (a) the product of the numbers of inputs (m) or outputs (q) or (b) three times the sum of the variables. Namely,

$$n \geq \max\{m \times q,\ 3 \times (m+q)\}$$

Cheng (2014) avers that this guiding principle is often unattainable (i.e., the universe of production units is fixed) and therefore improvements in degree of distinction mandate constraining the use of inputs or outputs. In this study, the data available at inception of the observation period allows for compliance with Cooper's recommendation. However, as consolidation activity progressed and the number of participants declined, it is not possible to satisfy either strand of his test. Hence, robustness tests are applied to corroborate the results.

4.5.2 Malmquist TFP Index to Identify Contributors to Total Production Efficiency

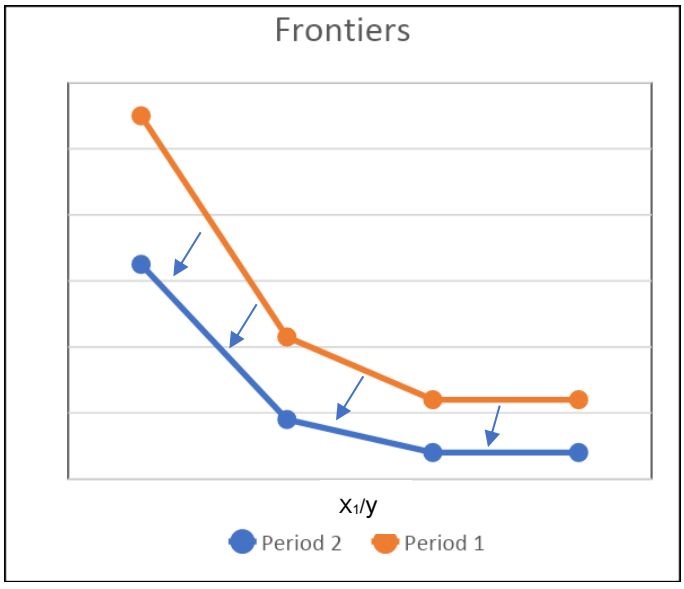
Following Berg et al. (1992), inter-temporal productivity growth is assessed by calculating the Malmquist TFP index for each bank in the system. This selection is on account of its ability to distinguish between contribution attributable to efficiency improvement by each entity and systemic technological progress. The index

measures the change in total factor productivity experienced between two dates by recognizing two sources of variation in relative performance. Mathematically, Berg et al. (1992) represent this as follows,

$$M_k = (\Delta OTE_k) \; x \; (\Delta T_k)$$

The left side of the equation (M_k) is the Malmquist TFP index. The right side measures the movement to the best practice frontier for the firm under consideration (ΔOTE_k) and the technological change between two dates, or shift in the curve itself, (ΔT_k). If $M_k > 1$, the bank is deemed to be gaining in comparative efficiency over time. Figure 4-7 graphically represents the respective frontiers for two periods assuming two inputs (x_1, x_2), one output (y) and an input-oriented model.

Figure 4-7: Malmquist Total Factor Productivity Index
Intertemporal Frontier Shift



The shift in the curves represents the change in a bank's efficient frontiers over time driven by the two factors identified in the equation above.

As per Fare et al (1994), the mathematical formulation of the Malmquist productivity change index can be construed as the product of the "catch-up" and "frontier-shift" terms. The former stands for an improvement or deterioration in a given bank's efficiency from one period to another; the latter represents movements in the efficient frontiers (i.e., systemic technological progress). The mathematical formulations are as follows.

- The change in how far observed production is from maximum potential production between years t+1 and t is called efficiency change.

$$\boxed{\textit{Efficiency change} = d^{t+1}(x_{t+1},y_{t+1})/d^{t}(x_t,y_t)}$$

- Similarly, the shift in technology between the periods is denominated technological change.

$$\boxed{\textit{Technological change} = [(d^{t}(x_{t+1},y_{t+1})/d^{t+1}(x_{t+1},y_{t+1})) \times (d^{t}(x_t,y_t)/d^{t+1}(x_t,y_t))]^{1/2}}$$

- Their combination is then known as the Malmquist productivity index.

$$m\ (y_{t+1},x_{t+1},y_t,x_t) = d^{t+1}(x_{t+1},y_{t+1})/d^{t}(x_t,y_t) \times [(d^{t}(x_{t+1},y_{t+1})/d^{t+1}(x_{t+1},y_{t+1})) \times (d^{t}(x_t,y_t)/d^{t+1}(x_t,y_t))]^{1/2}$$

The above stands for the productivity of the production point (x_{t+1}, y_{t+1}) relative to the production point (x_t,y_t). The equation indicates that the index is derived from the geometric mean of two Malmquist TFP indexes; one of which employs the technology available at time *t* and the other at time *t+1*. Values higher than unity

denote positive growth in efficiency for both the index and its components. Of note, changes in the latter do not necessarily follow the same trajectory (i.e., innovation may stall between two periods while individual bank performance may improve in relation to its peers). Given the excess of inputs available after the exit of market participants, the study assumes that management's priority is enhancing product production and thus an output-oriented index is constructed.

4.5.3 Parametric Model to Assess Impact of Specific Parameters

The analysis is further complemented by examining the impact on efficiency of specific endogenous and exogenous variables. Having derived the estimates of technical efficiency employing the DEA technique, various specifications of a parametric model test the statistical significance of the contribution afforded by the inputs and outputs selected. This is followed by an exercise that considers the difference in performance between commercial banks predominantly based in Puerto Rico and those controlled by foreign entities. Finally, a model specification incorporates the effects of various macroeconomic conditions (i.e., GDP growth rate, prevalent interest rates (10-year United States Treasury Note), and unemployment rate.

As per Ouenniche and Carrales (2018), the model specification for the regression model is represented by:

$$\boxed{Y_i = \beta_0 + \beta_1 X_{i1} + \ldots + \beta_p X_{ip} + \varepsilon_i}$$

where,
Y_i *is the dependent variable specified as some measure of efficiency (i.e., output/input) determined herein by DEA analysis;*

X_{ip} *is the explanatory or environmental variable hypothesized to affect performance;*
β_i *is the regression coefficient intended to measure the nature and magnitude of the relation of* Y_i *and* X_i*;*
β_o *is the intercept; and,* ε_i *is the unobserved error term.*

Following Coelli et al. (1998), determinants of efficiency are identified using a censored regression model (i.e., Tobit); the circumscribed range of the dependent variable (i.e., zero to one) justifies this decision (i.e., the definition of efficiency limits its numerical range).

4.5.4 Time Horizon for Observations

The time span under consideration comprises the years between 2010 to 2020 which corresponds to the emergence of an oligopoly and regulator-assisted consolidation. The selection of a longitudinal rather than cross-sectional approach is explained by the need to address limitations in DEA. First, all deviations from the best practice frontier are entirely ascribed to cost difference owing to X-inefficiencies without any consideration for random errors. For the assumption that the expected value of the latter approaches zero over time to be valid, the number of observations considered needs to be increased as much as possible. Second, a model with such limited quantity of decision-making units is likely to yield numerous relatively efficient units and thus decrease discriminatory power (Asmild et al., 2004). Third, as noted already, measurement error could be significant if the number of observations is small in comparison to the number of inputs, outputs, and environmental variables to be specified. In order to improve the ability to differentiate the performance among banks, Al Shamsi et al. (2009) posit that the

sample size should exceed the product of inputs and outputs. Alternatively, Nunamaker (1985) avers that the observation tally should be at least three times larger than the sum of inputs and outputs. During the period under consideration, the number of banks declined from fifteen to six; therefore, the application of the cross-sectional approach is likely to be problematic. To overcome this limitation, this study examines sequential productivity changes with the assistance of the Malmquist TFP index, a technique that greatly expands the number of observations considered.

4.6 Instrumentation

The instrument selected in this study is guided by the theoretical paradigm adopted, namely positivism. The researcher holds that postulations concerning bank performance can be proven by mathematical methods. Thus, analyzing figures corresponding to observations taken from a population sample is the most suitable form to examine the interaction of different variables. The objective of this exercise is to establish a cause-and-effect relationship between efficiency and selected inputs and outputs. This process of collecting and analyzing data is assumed to entail minimum intrusion by the researcher, be conducted free of bias, and yield results that are reliable, replicable, and applicable in other settings.

4.7 Data Collection Procedures

Foreign banks do not publish segregated reports for their operations on the island. Conversely, the larger local banks maintain a presence on the mainland. Hence, data that appears in SEC filings is not appropriate for the study. Therefore, the

figures pertained to individual entities employed here were obtained exclusively from reports published by the Office of the Commissioner of Financial Institutions. Data pertaining to the exogenous variables were extracted from public documents published by the Department of the Treasury and other instrumentalities of the United States government.

4.8 Data Analysis Software

A plethora of software packages are available to perform DEA analysis, calculate the concentration index, and run Tobit regressions (Daraio et al., 2018). The following options were considered:

- DEA-Solver
- DEA Excel
- Frontier Version 4.1
- Stata
- LP Solver
- Efficiency Measurement System
- Win4Deap
- MaxDEA
- DEAP 2.1
- Gretl

On account of flexibility, range of options, and acceptance by researchers, the last three options were employed in this study.

4.9 Research Design Limitations

The research design aims to identify a relationship between various variables and operating efficiencies which presupposes its existence under the theoretical

framework adopted. Confirmation of the latter is an unattainable task.

Furthermore, the study assumes the accuracy of the data reported; the researcher is precluded from confirming its validity. Similarly, the soundness of DEA analysis rests on several assumptions which remain untested (e.g., the behavior of error terms). Reliance is also placed on the correctness of the estimates yielded by the various software packages used. Finally, the availability of data circumscribes the analysis that can be performed. For example, items from the income statement were scarce and not available for the entire observation period.

4.10 Conclusion

This chapter discusses the theoretical paradigm that informs the study, the selection of quantitative methods adopted in consonance with such ontological and epistemological tenets, and the data analysis procedure to be implemented. Moreover, it introduces the setting and time period examined, names the source of materials, and identifies potential design limitations.

The next chapter presents the results of the application of various quantitative methodologies to ascertain the operating efficiencies of the commercial banks active in Puerto Rico between the years 2010 and 2020.

CHAPTER V: FINDINGS

5.1 Introduction

This chapter presents the results obtained from applying various quantitative methods which will in turn constitute the basis for answering the research questions considered by the thesis. First, non-parametric techniques estimate operating efficiencies for individual participants and the entire banking system. Second, the Malmquist Total Factor Productivity Index decomposes the various contributors to productivity growth. Third, a parametric model examines the impact of individual input and output variables, ownership structure, and macroeconomic conditions. Finally, the extent of market consolidation is determined by calculating various *k* concentration indexes.

5.2 Non-Parametric Model: DEA Results

In order to gain a more comprehensive understanding of the changes in relative performance experienced in the market place observed from 2010 until 2020, a frontier-based linear programming-based optimization technique (i.e., Data Envelopment Analysis)[51] was used to derive operating efficiencies under different return to scale assumptions and orientation approaches. That is, model specifications considered the existence of both constant and variable returns to scale in the production process and alternative management's strategic objectives (i.e., minimize expenses or maximize revenues).

[51] As noted by Cook et al. (2013), DEA is a tool for benchmarking in operations management; the efficient decision-making units are those deemed to have reached the best-practice frontier (cf., production frontier).

5.2.1 Single-Year Estimates

To gauge operating efficiencies on an annual basis, observations for each decision-making unit (DMU) were used under the various scenarios listed above.

5.2.1.1 Constant Return to Scale

The estimates were first calculated using a model that assumes constant return to scale of production technology. That is, an increase in an input such as labor generates a proportional increment in an output such as interest income. In this scenario, the premise is that all decision-making units (e.g., commercial banks) are at the optimal production scale stage.[52] In other words, each firm is operating at the size which derives the maximum benefit. The graphical representation of the efficiency frontier is thus a straight line formed by the highest score in the sample. Hence, such assumption implies that the results for input and output orientations are equivalent. This model formulation is named CCR after the initials of its creators Charnes, Cooper and Rhodes (Charnes et al., 1978).

Table 5-1 presents the outcomes following the output approach assuming constant return to scale. In considering these figures, the reader must remember that efficiency is a relative, dynamic benchmark determined by the score of each bank. The estimate derived is thus a measure of a relative and not absolute efficiency index. Consequently, an entity that exhibits the same operating performance year after year may still, in comparison to other market participants, record a different efficiency score for each measuring period. For example, if a

[52] Stage efficiency (SE) is defined as the ratio of aggregate efficiency and technical efficiency.

new, more productive financial institution enters the banking sector during the second period, the scores of other decision-making units already present would appear diminished. Essentially, the inclusion of a more efficient bank serves to shift the best practice frontier; thus, the gap between the new curve and efficiency scores of extant entities widens.

Table 5-1: CCR Output Model Results

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of Banks	15	13	10	10	10	9	9	9	9	8	6
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Minimum	0.448	0.432	0.411	0.332	0.596	0.645	0.754	0.279	0.746	0.942	0.824
Standard Deviation	0.211	0.219	0.214	0.204	0.127	0.135	0.108	0.242	0.098	0.021	0.071
Inefficient Banks	8	7	7	6	2	4	4	3	3	1	2
% Inefficiency	53%	54%	70%	60%	20%	44%	44%	33%	33%	13%	33%
Efficient Banks	7	6	3	4	8	5	5	6	6	7	4
% Efficiency	47%	46%	30%	40%	80%	56%	56%	67%	67%	88%	67%
Mean	0.783	0.784	0.813	0.877	0.952	0.894	0.917	0.872	0.948	0.993	0.963
Annual Change		0.17%	3.66%	7.83%	8.59%	-6.08%	2.51%	-4.82%	8.73%	4.67%	-3.01%
Mean Survivors	0.782	0.829	0.871	0.943	1.000	0.931	0.919	0.929	0.923	0.990	0.963
Mean Foreign	0.864	0.833	0.820	0.940	0.985	0.893	0.947	0.856	1.000	1.000	1.000

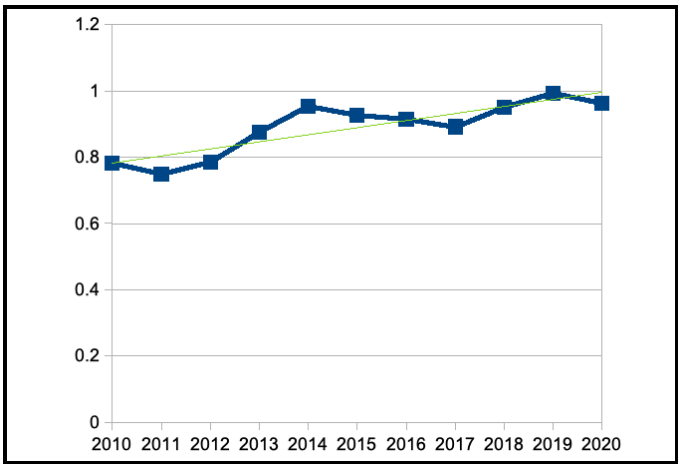
From the above, the following inductions can be drawn:

- The long-term trend of systemic efficiency is upward; even though its progression is not unilinear (e.g., a decline in the mean is recorded in 2015). From 2010 until 2020, overall productivity gains approach 23%. This is a remarkable development

considering the adverse underlying economic conditions prevalent in the setting. Namely, the local government filed for the largest municipal bankruptcy in the history of the United States, population losses accelerated, and GDP contracted. The aforementioned natural disasters that began in 2017 and the concomitant disruptions caused appear to explain the temporary setback recorded that year. The subsequent recovery reflects the generous aid received from the federal government in the form of both direct disbursements to individuals (e.g., food stamps, tax refunds) and indirect support to local governmental agencies (e.g., soft loans to finance infrastructure repair).

- Consolidation activity did not necessarily coincide with reported gains in systemic performance. For example, in 2015, the exit of one commercial bank occurred while overall efficiency declined by 6%. Moreover, the rate of change in efficiency was sometimes negative despite the steady reduction in market participants. This could be explained by lagging effects and the dissimilar businesses in which existing entities participated (e.g., larger financial institutions were absorbed by the surviving banks following a prolonged schedule). Figure 5-1 depicts the actual pattern observed superimposed on the derived long-term improving trend.

Figure 5-1: Charnes – Cooper - Rhodes Average Efficiency for Puerto Rican Banking System



- The range in efficiency estimates narrows by over 50% over the observation period (i.e., from 0.55 to 0.18); such contraction does not however follow a uniform trajectory. The sharp divergence in 2017 coincides with the disruptions caused by Hurricane Maria. Consistent with the results obtained by Halkos et al. (2014), differentiation in performance declines as the oligopoly gradually coalesces. Moreover, the effect is inversely related to geographical distance. That is, in-market consolidation has a more pronounced impact perhaps driven by greater cost savings opportunities (e.g., branch closures). At first hand, this could also attest to the presence of collusion in pricing or services rendered. However, as discussed below, examination of individual bank's performance indicates that only the two largest players benefitted in relative terms, thus, the impact was not uniform.

- Mirroring the above, the standard deviation, a measure of variability in performance, shows a dramatic contraction. From a relatively high 0.21 in 2010, it declines to 0.07 in 2020. This reflects the emergence of institutions with more similar marketing strategies and product platforms. Higher predictability in results is also consistent with oligopolistic behavior as competition in prices and services offered wanes.
- The mean efficiency for surviving entities also shows an improving trend (from 0.78 in 2010 to 0.96 in 2020); even though; the progression is far from steady. The score recorded at the conclusion of the period is high on account its proximity to the best practice frontier. An inflection point is observed in 2015 which coincides with the start of the crisis associated with the local government loan default. Once again, a smaller number of market participants does not necessarily translate into relative outperformance.
- For most years, foreign banks perform better than both the overall system and surviving entities. This could be attributed to superior business practices, more talented management or access to vaster resources. Of note, there is no inflection point observed in 2015 denoting the difference in business model adopted by foreign entities. Instead, a plateau is reached in 2018 when the scores for all banks reach the efficiency frontier, an accomplishment achieved ahead of domestic institutions.
- The percentage of efficient banks surges from 47% to 67% during the observation period. This pattern provides further evidence of the emergence of a more resilient

banking sector if assessed by systemic efficiency. Notably, the score of the worst performer in 2020 (i.e., 0.824) outclasses all but one of the participants observed in 2010. An intermediate apex of 80% is observed in 2015, an anomaly perhaps created by temporary disruptions caused by acquisition activities.

5.2.1.2 Variable Return to Scale

The efficiency estimates were then calculated assuming variable return to scale in which the technical efficiency that is obtained eliminates the effect of scale (so-called "pure technical efficiency"). In contrast to constant return to scale, banks are not assumed to be operating at an optimal level of scale. The addition of one more unit of input does no longer translate into a proportional change in output. As interpreted by Assaf et al. (2010), technological improvements and changes in regulations do not affect decision-making units in the same manner. This method for estimating efficiencies is christened BCC after the initials of its creators, Banker, Charnes, and Cooper (Banker et al., 1984). The efficiency frontier now becomes a convex curve delineated by the highest scores in the sample. This in turn implies that the frontier of an output-oriented model is not the same as that of an input-oriented model. As the former approach is favored by researchers studying banks' behavior, only those are presented here.[53] In essence, management views output maximization as the primary organizational objective. Table 5-2 presents the outcomes following the output approach with variable return to scale.

[53] Estimates following both input and output orientations were calculated; the differences observed were circumscribed to 5%.

Table 5-2: BCC Output Model Results

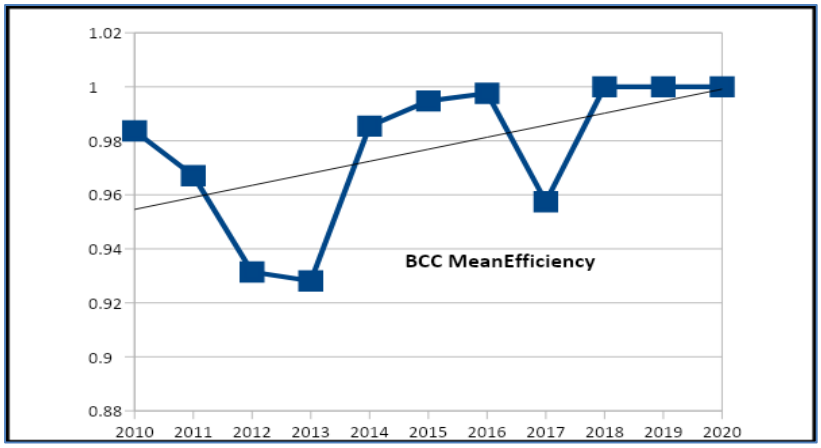
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of Banks	15	13	10	10	10	9	9	9	9	8	6
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Minimum	0.847	0.829	0.607	0.505	0.854	0.970	0.978	0.617	1.000	1.000	1.000
Standard Deviation	0.041	0.066	0.147	0.165	0.046	0.011	0.007	0.128	0.000	0.000	0.000
Inefficient Banks	3	3	2	2	1	2	1	1	0	0	0
% Inefficiency	20%	23%	20%	20%	10%	22%	11%	11%	0%	0%	0%
Efficient Banks	12	10	8	8	9	7	8	8	9	8	6
% Efficiency	80%	77%	80%	80%	90%	78%	89%	89%	100%	100%	100%
Mean	0.984	0.967	0.931	0.928	0.985	0.995	0.998	0.957	1.000	1.000	1.000
Annual Change		-1.68%	-3.72%	-0.32%	6.18%	0.95%	0.29%	-4.03%	4.44%	0.00%	0.00%
Mean Survivors	0.743	0.794	0.814	0.940	1.000	0.959	0.919	0.929	0.927	0.990	1.000
Mean Foreign	0.759	0.829	0.829	0.939	0.986	0.917	0.944	0.891	1.000	1.000	1.000

The results indicate the following:

- The means of efficiency are significantly higher from the beginning until the end of the observation period. Similar to the CCR model, the exit of market participants does not necessarily translate immediately into improvements in systemic performance. Moreover, there is also a noticeable gain in variability which is incongruent with the mature nature of technology in this business sector. Unlike the CCR model, a deteriorating pattern extending over several years is identifiable at the beginning of the observation period. Individual bank estimates ascribe this development to specific poor performers who were eventually acquired or

liquidated (e.g., Doral). Hence, the BBC model appears to provide better early indications of potential consolidation activity. The results show that the eventual surviving banks outperform their competitors (e.g., in 2018, 0.927 vs. 1.000). The trendline superimposed on the curve shown on Figure 5-2 denotes an ascending pattern.

Figure 5-2: Barnes – Charnes - Cooper Average Efficiency for Puerto Rican Banking Sector



- The range of means tends to trend lower even though the pattern is not unilinear. There is also an inflection point reached in 2013 when consolidation activity accelerated. Once the poor performers exited the marketplace, more predictability emerges with the sole exception observed in 2017.
- Standard deviation follows a declining pattern after 2011 until reaching nil in 2018. At that time, all banks are deemed to be operating at optimal levels.
- Surviving banks gain in performance in a fairly even manner. Notably, most of them are shown to be the most efficient entities from the beginning of the measuring period. In contrast, the poor performers at inception eventually exit the

marketplace within a four-year window. Unlike the CCR model, foreign banks no longer appear to be better performers than the surviving entities.

- The percentage of efficient banks begins at the relatively high level of 80% and eventually reaches 100%. While this corroborates the findings of the CCR model as to overall improvement in performance, the task of discerning relative efficiencies is significantly exacerbated. That is, the distribution of results is not sufficiently broad to distinguish salient characteristics of surviving entities.

5.2.1.3 Correlation Analysis

In order to elucidate the relation between the input and output variables, correlation statistics were derived. As shown in Table 5-3, the strength of linear relationship is quite positive and strong between these observations.

Table 5-3: Correlation of Input and Output Variables

Correlations	Net loans	Deposits	Securities Available for Sale	Net Interest Income	Number of employees	Fixed assets	Interest Expense	Non-interest Expense
Net loans	1.0000							
Deposits	0.9542	1.0000						
Securities Available for Sale	0.8588	0.9718	1.0000					
Net Interest Income	0.9939	0.9719	0.8896	1.0000				
Number of employees	0.9901	0.9641	0.8765	0.9987	1.0000			
Fixed assets	0.9688	0.9925	0.9445	0.9864	0.9819	1.0000		
Interest Expense	0.9702	0.9308	0.8372	0.9699	0.9722	0.9325	1.0000	
Non-interest Expense	0.9897	0.9776	0.9018	0.9994	0.9982	0.9907	0.9673	1.0000

These results are to be expected between inputs and outputs. More deposits support expanded lending activities. These in turn generate higher net interest income and incur additional net interest expense. Incremental staff is needed to deliver further services and manage an enlarged branch network. Securities for sale is the less correlated variable. Considering that these banks are not extensively engaged in trading and investment banking activities, this is not surprising. On the other hand, the relationship between number of employees and various output variables is telling; the highest correlation (i.e., 0.9939) pertains to net interest income to personnel. This result should have been expected between interest income and interest expense to loans. On the other hand, labor and non-interest expenses are the most linearly related variables which are foreseeable. The weak correlation between deposits and interest expense can be explained by the low yields earned by the former on account of excess liquidity in the system. As the balance sheets grow and efficiencies improve, these collinearities should be expected to decline. For example, as consolidation allows for closure of branches in close proximity and elimination of duplicate back-office systems, banks would be able to manage more assets per employee.

Data Envelopment Analysis posits that efficiency estimates depend on the interrelationships between inputs and outputs (Bastani et al., 2021; Xia and Chen, 2017). For the mathematical approach to be reliable, correlation between output and input variables is necessary. However, input and output variables must be independent of each other. While this condition is seldom achieved, available DEA

models nevertheless assume that these variables are independent at all times (Pedraja-Chaparro et al., 1999). The analysis performed hereto reveals the presence of three forms of correlation between variables: a) between outputs on inputs; b) between outputs; and c) between inputs. The lack of stochastically independent outputs and inputs results in the diminishment of the discriminatory power of the estimator. Bastani et al. (2021) advances several approaches designed to ameliorate the distortion introduced by this condition, including the use of the Centralized Data Envelopment Analysis (CDEA) model.

5.2.2 Malmquist TFP Index Analysis

The DEA analysis performed hitherto has measured efficiency at a specific point in time and thus is static in nature. Performance is however affected by variations in technology, regulation, economic conditions or the competitive situation (Asmild et al., 2014). Since the aim of the thesis is indeed to evaluate these changes in operating performance over ten years, panel data is now incorporated into the study. This allows for tracking variances in productivity and then decomposing the specific contribution of technical change and technical efficiency to the process. The methodology applied to accomplish the task is the widely used Malmquist Total Productivity Index. Progress derives from the combination of change in technical efficiency at the level of the evaluated decision-making unit and the change of production technology. The latter corresponds to the shifts of the production frontier in the DEA analysis. A value over one denotes positive growth. The availability of panel data for the observation period between 2010 and 2020

allows for the examination of the productivity change of the six surviving commercial banks. The results for the reduced sample of annual means are depicted in Table 5-4.

Table 5-4: Malmquist TFP Index Summary of Annual Means

Year	Effch	techch	Pech	Sech	tfpch
2011	0.998	1.177	1.000	0.998	1.175
2012	0.853	0.944	1.000	0.853	0.805
2013	1.175	1.559	1.000	1.175	1.833
2014	1.000	1.035	1.000	1.000	1.035
2015	0.914	1.366	1.000	0.914	1.249
2016	0.958	1.025	1.000	0.958	0.982
2017	1.049	0.997	1.000	1.049	1.046
2018	1.044	0.900	1.000	1.044	0.939
2019	1.043	0.989	1.000	1.043	1.031
2020	0.961	1.702	1.000	0.961	1.635
Mean	0.996	1.143	1.000	0.996	1.138

Note: effch = efficiency; techch = technical progress; pech = pure efficiency; sech = scale efficiency; tfpch = total productivity growth

During the period of observation, the mean growth in total productivity was 13.8%. Annual changes were however not always positive and magnitudes fluctuated widely. Overall, the six surviving banks experienced total productivity growth in seven out of ten years. Often, improvements were followed by setbacks as performance oscillated around an ascending trend line. The greatest improvement was recorded in the early years of consolidation, most notably in 2013. As also indicated by DEA analysis, fewer participants did not necessarily translate into immediate superior performance. The absence of panel data for all banks present in the marketplace precluded a complete assessment of the sector's overall

strength. However, it could be inferred that surviving entities outperformed exiting banks. With respect to the contributors to this development, the key driver was technology change. In 70% of the years, it outpaced endogenous efficiency gains. This is not surprising as performance benefitted from the introduction of automated teller machines, allowing for fewer direct customer interaction, and consolidation in back-office operations and branch network. [54]

Figure 5-3: Technical and Technology Change Efficiencies for Banking System

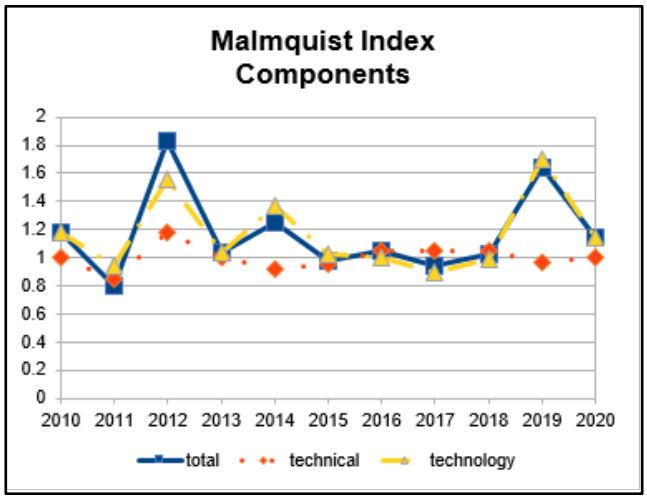


Figure 5-3 illustrates the trends of total factor productivity change and its components during the observation period. Two sharp increases appear as bookends to rather subdued oscillations in the middle years. The variations in total productivity change are driven primarily by technological change as technical efficiency remains muted. As the surviving entities capture larger market shares

[54] Pre-tax return on equity increased from 2.6% on average in the 2011-15 period to 14.6% in 2018 and 19.2% in 2019. Source: Office of the Commissioner of Financial Institutions

and grow complaisant, there appears to be less incentive to internally innovate. This is perhaps evidence of collusive behavior identifiable with the emergence of an oligopoly. At the same time, considering that technology in the banking sector is readably available from third-party vendors, exhibits commodity characteristics, and becomes easier to acquire on account of more extensive resources, its effects on efficiency should be expected to be more pronounced.

Table 5-5: Malmquist TFP Index Summary of Firm Means

Firm	effch	techch	pech	Sech	Tfpch
Banco Popular	1.000	1.210	1.000	1.000	1.210
Firstbank	0.995	1.071	1.000	0.995	1.066
Oriental	0.981	0.957	1.000	0.981	0.939
Cooperativo	1.000	1.152	1.000	1.000	1.152
Citibank	1.000	1.264	1.000	1.000	1.264
Banesco	1.000	1.233	1.000	1.000	1.233
Mean	0.996	1.143	1.000	0.996	1.138

Note: effch = efficiency; techch = technical progress; pech = pure efficiency; sech = scale efficiency; tfpch = total productivity growth

Table 5-5 depicts the results for each of the six surviving entities. The only laggard in the population sample is Orientalbank (i.e., down 6.1%) while the other five banks report improved performance (mean gain 13.8%). The market leader in terms of assets, Popular, records a 21% gain while foreign banks, Citibank (26.4%) and Banesco (23.3%), clearly outperform other entities. This is a rather surprising outcome on account of the similarity in operations of the three largest financial institutions (Popular, Firstbank, and Orientalbank), the scale advantages usually afforded by larger operations, and the support received from regulators to

incentivize acquisitions.[55] Notably, the decline in efficiency in the sector (0.4%) is entirely attributable to two local banks while all the foreign banks report no change. With respect to taking advantage of technology innovation, scores for all banks except for one (Orientalbank) evince success. Once again, foreign banks outperform local entities with respect to this contributor to total productivity growth.

Figure 5-4: Technical and Technology Change Efficiencies for Individual Banks

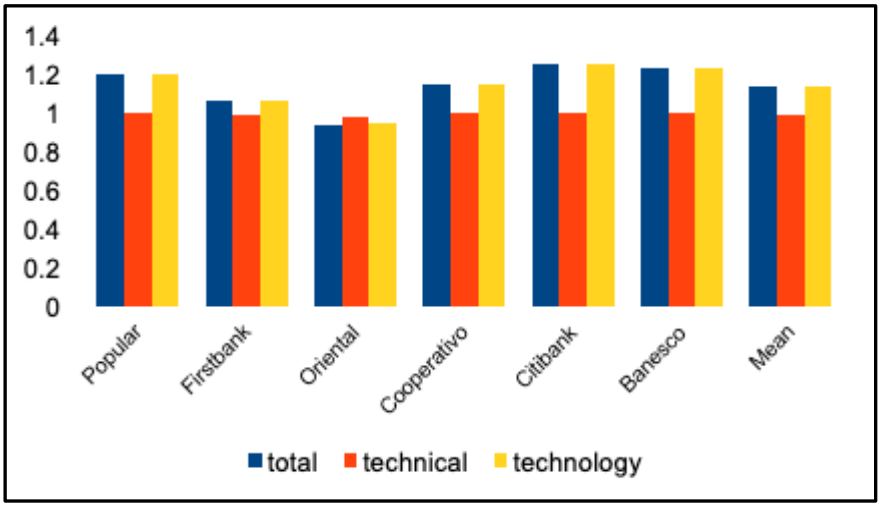


Figure 5-4 compares the variations in total production change and its components for each of the surviving commercial banks. Technological improvements are the main drivers of efficiency improvement while technical efficiency remains muted. Clearly, Firstbank and Orientalbank have not been able to match the performance of its four other competitors. Thus, this suggests that gains in efficiency are not always concomitant with consolidation activity. Al-Sharkas et al. (2008) posits that bank mergers produce such improvement only if the acquirer implements the most

[55] These included the sale of deposits priced below par and loan stopgap schemes that limited potential losses.

efficient technology available. The results of Table 5-5 indicate that Firstbank and Orientalbank failed in this regard.

5.3 Parametric Model: Tobit Regression Results

A regression model is used to assess the elasticity of the operating efficiencies derived from DEA analysis with respect to inputs and outputs, ownership control, and macroeconomic conditions. A Tobit model is required because the dependent variable is censored (i.e., efficiency by definition is circumscribed within a range of 0 to 1).

5.3.1 Base Specification

The mathematical representation of the base specification is as follows,

$$\boxed{\boldsymbol{EFF_i = \alpha_o + \alpha_1 * input_i + \alpha_2 * output_i + \cdots + \varepsilon_i}}$$

The results of the base specification are presented in Table 5-6.

Table 5-6: Tobit Model: Base Specification

Dependent variable: Efficiency
Standard errors based on Hessian

	Coefficient	*Std. Error*	*Z*	*p-value*	
const	0.920757	0.0259199	35.52	<0.0001	***
Net Loans	5.64251e-09	2.61868e-08	0.2155	0.8294	
Deposits	−2.67846e-08	2.00568e-08	−1.335	0.1817	
Securities Available for Sale	4.41295e-08	2.68640e-08	1.643	0.1004	
Net Interest Income	1.44019e-07	2.70829e-07	0.5318	0.5949	
Number of Employees	−5.70939e-07	1.31486e-06	−0.4342	0.6641	
Fixed Assets	1.00069e-06	5.20117e-07	1.924	0.0544	*
Interest Expense	−1.84868e-06	5.33018e-07	−3.468	0.0005	***

Chi-square (7)	30.33547	p-value	0.000082
Log-likelihood	40.15994	Akaike criterion	− 62.31988
Schwarz criterion	−38.18070	Hannan-Quinn	−52.53232

sigma = 0.166828 (0.0113512)
Left-censored observations: 0
Right-censored observations: 0
Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square (2) = 79.0804 **w**ith p-value = 6.72849e-18

The coefficients of three outputs (i.e., net loans, securities for sale, and net interest income) are positive which is the expected relation. Higher outputs should translate into higher efficiency. Unexpectedly, the sign of the coefficient corresponding to deposits is negative. This appears to indicate that amassing a larger pool of funds *per se* without its useful redeployment is detrimental to underlying profitability (i.e., interest paid to depositors outpaces earnings). With respect to inputs, the signs of the coefficients corresponding to number of employees, a proxy for labor costs, and interest expense are negative as expected. More inputs translate into lower profitability. In contradistinction, the

coefficient for fixed assets, a proxy for premises, is positive. This could be interpreted as signaling that those commercial banks gain from a wider coverage area. The difference in magnitude of the coefficients can be explained by the discrepancy in units (e.g., the figures for deposits and loans are much larger than those for number of employees and premises). Reflecting the high efficiencies observed, the coefficient of the constant is high at 0.92; the range of samples is thus quite circumscribed on account of the limit imposed on the dependent variable (i.e.,1.0). Of note, unlike Ordinary Least Square regression coefficients, the linear effect is on the uncensored latent variable and not the observed outcome. Hence, adding one employee translates into a decline of $5.7 * e^{-7}$ in operating performance. The standard errors, which measure variability, are large compared to the estimated coefficients. This is to be expected on account of the idiosyncrasies of market participants. That is, foreign entities provide a limited set of services to a niche segment while domestic banks offer more products to a larger population. The latter also manage assets and liabilities of much larger magnitudes.

Statistically significance is denoted by the p-value. The estimate for the coefficient for interest expense is the most significant at 0.0005. Therefore, there is strong evidence to reject the null hypothesis (i.e., the coefficient is zero). To a lesser degree, a similar conclusion can be drawn for the estimate of the coefficient for fixed assets. The larger values ascribed to the other variables simply evince the lack of evidence to reject but not support the null hypothesis. There are no

censored observations on either limit of range. Concerning the assumption that errors are normally distributed, a condition required for reliance on the estimates yielded by the model, a chi-squared of over 79 alerts to its possible violation. Non-normality affects detrimentally the discriminatory power of the estimator. Thus, caution is warranted in ascribing precision to the results.

Table 5-7: Base Specification: 95% Confidence Interval

Variable	Coefficient	95% confidence interval
Const	0.920757	(0.869955, 0.971559)
Net Loans	5.64251e-009	(-4.56828e-008, 5.69678e-008)
Deposits	-2.67846e-008	(-6.60953e-008, 1.25260e-008)
Securities Available for Sale	4.41295e-008	(-8.52290e-009, 9.67820e-008)
Net Interest Income	1.44019e-007	(-3.86795e-007, 6.74834e-007)
Number of Employees	-5.70939e-007	(-3.14802e-006, 2.00615e-006)
Fixed Assets	1.00069e-006	(-1.87163e-008, 2.02010e-006)
Interest Expense	-1.84868e-006	(-2.89338e-006, -8.03986e-007)

Table 5-7 presents the confidence intervals for the estimates of the coefficients. The range excludes nil only for interest expense; therefore, this is the sole statistically significant result. If management intends to be more effective, its goal should then be to minimize this income statement item.

Figure 5-5: Regression Residuals Plot for Base Specification

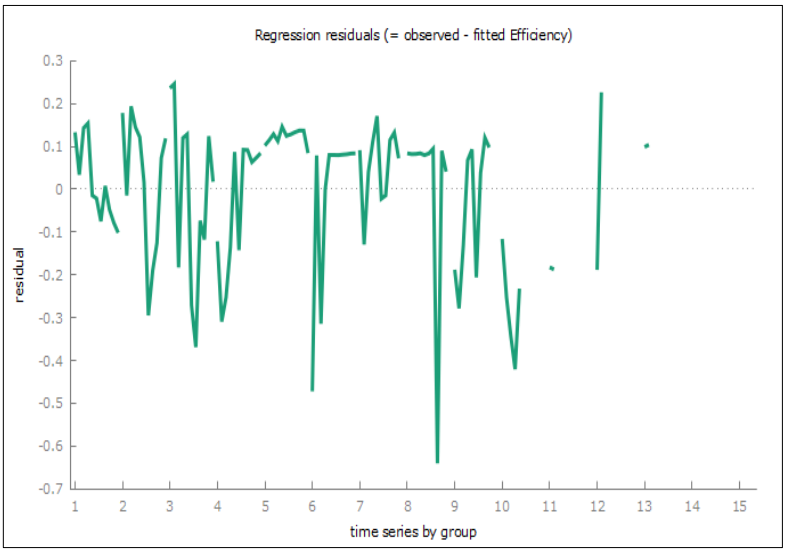


Figure 5-5 presents the regression residuals over the observation period. It clearly depicts an oscillation pattern with numbers mostly below nil. This evinces the potential presence of heteroscedasticity (i.e., the variance of the error is not constant), a development to be expected for two reasons. First, the data set includes very small and large values due to the dissimilar size of the balance sheets of market participants. Second, the dependent variable changes significantly in relative terms from the beginning to the end of the observation period for the second and largest banks. Heteroscedasticity affects the standard errors of the coefficient with a potentially detrimental impact on accuracy. Here, the condition is treated by reporting robust standard errors, a common technique to address this condition.

Figure 5-6: Quantile-Quantile Plot for Base Specification

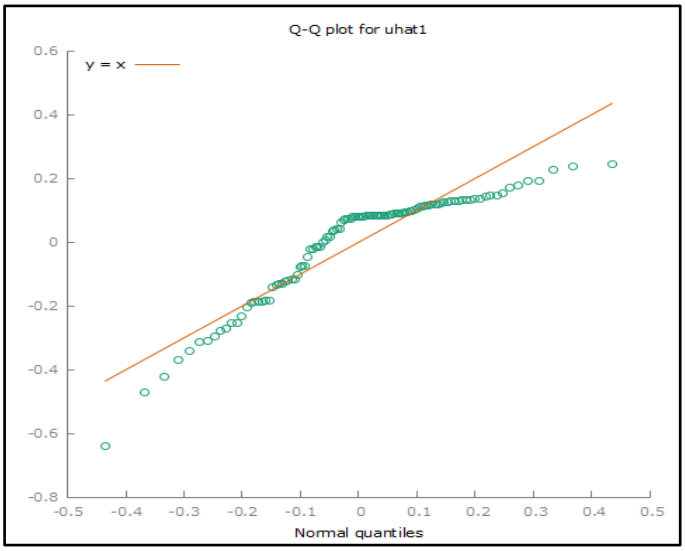


Figure 5-6 corresponds to the Q-Q plot, or quantile (points in a distribution that relate to the rank order of values in that distribution) plot. The graph compares the theoretical quantiles of a distribution with the sample quantiles of the data set. The purpose is to determine if two sets of data come from the same distribution. Here, the horizontal axis represents the theoretical normal distribution while the vertical axis stands for the sample distribution. The points tend to cluster close to a 45-degree line, but the fit is far from optimal. This deviation from the curve indicates imprecision in the estimator. An inverted S-curve usually implies a distribution with

short tails. The presence of outliers on the extremes also do not benefit the accuracy of the estimator.

Figure 5-7: Box Chart of Residuals for Individual Banks
(group denotes each individual bank)

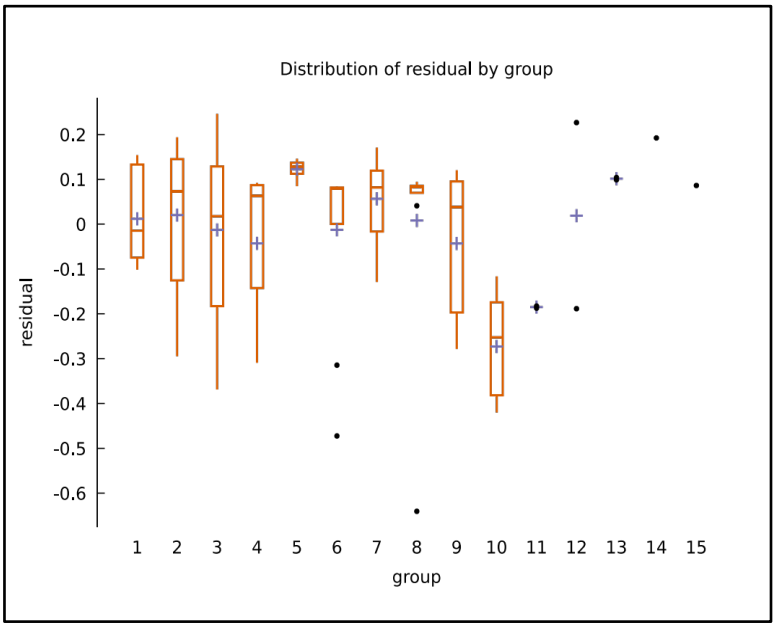


Figure 5-7 displays the distribution of residuals for each bank in the form of boxplots. There are no variations for the last banks on account of observations only considered for one year; they exited the marketplace at inception of the observation period. For the remainder, there is a notable discrepancy between means and medians for the larger banks which is to be expected on account of larger balance sheets, extensive involvement in consolidation activity, and

divergence in marketing strategies. The surviving foreign banks (i.e., group 5 and 6) cover niche sectors (e.g., private banking) where results tend to be more predictable and deployment of resources more circumscribed. The next groups correspond to both local and foreign entities that exited the marketplace during the observation period. The distributions of residuals are comparable to the first three survivors; this is to be expected as they competed in similar markets. Of note, there are several outliers in these groups which can be ascribed to disruptions from underperformance and abrupt closure of footprint in the island (i.e., timing of acquisitions do not coincide with reporting period). Overall, there is evidence of skewness, a condition that negatively affects the precision of the estimator. The ranges are also more pronounced in the earlier years and then narrow in tandem with progress in consolidation activity. As performance becomes more uniform, a characteristic of oligopolies, this is to be expected. The figure also identifies several outliers in years six thru eight. As market leaders emerge and expand market share, their operating efficiencies should bifurcate from institutions facing financial distress. For example, a commercial bank with liquidity concerns is unlikely to be able to invest in the technology required to keep up with its competitors.

Figure 5-8: 95% Confidence Ellipse: Labor and Net Loans

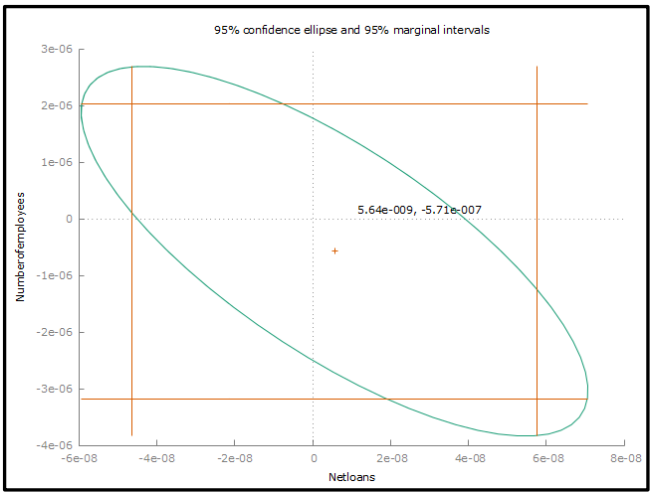


Figure 5-8 depicts the correlation between number of employees, a proxy for labor expense, and net loans, an output. The variable axes have been standardized (by dividing the variables by their respective standard deviations), thus the ratio of the two axis lengths reflects the magnitude of the correlation between the two variables. A ratio of one appears graphically as a circular confidence contour indicating that the variables are uncorrelated. Divergences from unity denote larger positive or negative correlation between the variables. Here, the diagonal shape of the curve indicates that there is a muted interrelationship between the parameters. In other words, having more employees allows commercial banks to extend loan production in a disproportionate manner.

Figure 5-9: 95% Confidence Ellipse: Labor and Interest Expense

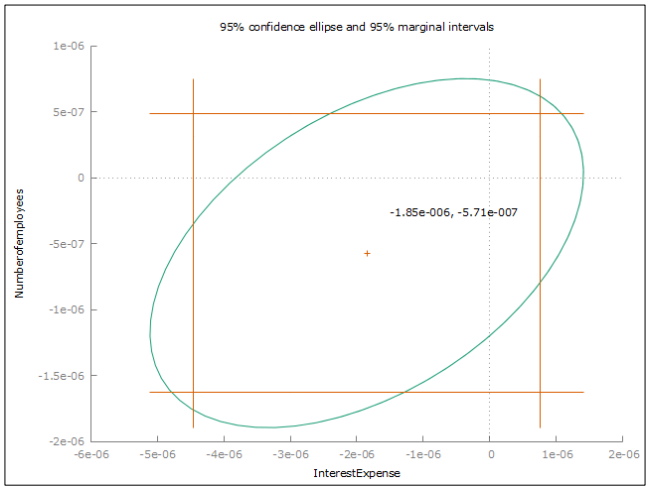


Figure 5-9 depicts the correlation between the number of employees, a proxy for labor expense, and interest expense, the sole statistically significant coefficient estimate. The shape of the curve is rounder thus denoting less correlation between the variables. Still, there is some form of relationship between the two inputs. This result is reasonable; more staff is required to support a larger loan portfolio which in turn accrues more interest expense.

5.3.2 Base Specification with Indicator Variables

The base specification is then modified to include an indicator variable to distinguish between domestically incorporated entities and those controlled by foreign capital. The objective is to assess if the difference in ownership structure affects operating performance. The mathematical representation of the altered base specification is as follows,

$$\boldsymbol{EFF_i = \alpha_0 + \alpha_1 * input_i + \alpha_2 * output_i + \alpha_3 * ownership_i + \varepsilon_i}$$

The results of the base specification with indicator variable[56] are presented in Table 5-8.

Table 5-8: Tobit Model: Indicator Variable

Dependent variable: Efficiency
Standard errors based on Hessian

	Coefficient	*Std. Error*	*Z*	*p-value*	
const	0.883200	0.0354121	24.94	<0.0001	***
Net Loans	5.71565e-09	2.59049e-08	0.2206	0.8254	
Deposits	−2.72521e-08	1.98432e-08	−1.373	0.1696	
Securities Available for Sale	4.32146e-08	2.65813e-08	1.626	0.1040	
Net Interest Income	1.17848e-07	2.68452e-07	0.4390	0.6607	
Number of Employees	−5.24055e-07	1.30106e-06	−0.4028	0.6871	
Fixed Assets	1.16821e-06	5.25922e-07	2.221	0.0263	**
Interest Expense	−1.74096e-06	5.31911e-07	−3.273	0.0011	***
Domestic Ownership	0.0584994	0.0380446	1.538	0.1241	

Chi-square (8)	33.36397	p-value	0.000053
Log-likelihood	41.32937	Akaike criterion	−62.65875
Schwarz criterion	−35.83743	Hannan-Quinn	−51.78368

sigma = 0.165032 (0.011229)
Left-censored observations: 0
Right-censored observations: 0
Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square (2) = 68.7043 with p-value = 1.20517e-15

The introduction of a categorical variable affects the results of the model in several key aspects. First, foreign ownership is deemed beneficial to operating efficiency perhaps due to technical support and managerial expertise; however, the estimated coefficient is not statistically significant. The results are consistent with

[56] The value of the indicator variable is binary with 1 assigned to institutions controlled by foreign capital.

the findings of De Haas & van Lelyveld (2006) and Lensink et al. (2008) which ascribe the difference in performance to the quality of management, availability of resources, and institutional experience. Second, the sole previously significant coefficient – interest expense - retains this designation, but the evidence against the null hypothesis (i.e., coefficient is zero) drops sharply (from 0.0005 to 0.0011). Third, the estimate of the coefficient for fixed assets is now more statistically significant by moving to under the 5% threshold (from 0.0544 to 0.0263). The explanation for this change is the smaller footprint of foreign banks which are bereft of extensive branch networks. Fourth, the introduction of the categorical parameter does not vary the signs of the coefficients nor impact severely their magnitude. Finally, the test statistic for normality (i.e., chi-square) declines (from 79.1 to 68.7) so the evidence against the null hypothesis remains strong. The comparison is now between more homogenous groups.

Table 5-9: Base Specification with Indicator Variable: 95% Confidence Interval

Variable	Coefficient	95% confidence interval
const	0.883200	(0.813794, 0.952607)
Net Loans	5.71565e-009	(-4.50570e-008, 5.64882e-008)
Deposits	-2.72521e-008	(-6.61440e-008, 1.16398e-008)
Securities Available for Sale	4.32146e-008	(-8.88382e-009, 9.53131e-008)
Net Interest Income	1.17848e-007	(-4.08308e-007, 6.44005e-007)
Number of Employees	-5.24055e-007	(-3.07409e-006, 2.02598e-006)
Fixed Assets	1.16821e-006	(1.37418e-007, 2.19900e-006)
Interest Expense	-1.74096e-006	(-2.78349e-006, -6.98435e-007)
Domestic Ownership	0.0584994	(-0.0160666, 0.133065)

Table 5-9 presents the confidence intervals for the estimates of the coefficients for the new model specification. Once more, the range excludes nil for interest expense, but now, the same condition applies to fixed assets. Hence, there are two statistically significant coefficients; and therefore, the distinction between foreign and local banks affects the findings. Management should consider both input variables when aiming for better performance. As previously indicated, the sign for fixed assets is positive; therefore, expanding its branch network could be advantageous to an institution to a certain extent.

5.3.3 Base Specification with Exogenous Variables

The base specification is then modified to include exogenous variables to account for prevalent macroeconomic conditions. Specifically, these are GDP growth rate, a broad proxy of extant economic activity, unemployment rate, and the yield of the 10-year Treasury Note, a proxy of interest rates. The objective is to assess if they are relevant in determining operating efficiency. The mathematical representation of the modified base specification is as follows,

$$\boldsymbol{EFF_i = \alpha_0 + \alpha_1 * input_i + \alpha_2 * output_i + \alpha_3 * exogenous_i + \varepsilon_i}$$

The results of the base specification with exogenous variables are presented in Table 5-10.

Table 5-10: Tobit Model: Exogenous Variables

Dependent variable: Efficiency
Standard errors based on Hessian

	Coefficient	*Std. Error*	*Z*	*p-value*	
const	0.994373	0.0983585	10.11	<0.0001	***
Net Loans	1.81909e-08	2.72710e-08	0.6670	0.5047	
Deposits	−2.74664e-08	2.07272e-08	−1.325	0.1851	
Securities Available for Sale	4.47686e-08	2.70722e-08	1.654	0.0982	*
Net Interest Income	−5.18782e-08	2.96896e-07	−0.1747	0.8613	
Number of Employees	−9.64879e-07	1.33108e-06	−0.7249	0.4685	
Fixed Assets	9.99345e-07	5.18080e-07	1.929	0.0537	*
Interest Expense	−1.80770e-06	5.38358e-07	−3.358	0.0008	***
GDP Growth Rate	0.00452440	0.0108450	0.4172	0.6765	
Unemployment Rate	−0.0135119	0.00865368	−1.561	0.1184	
10-Year Yield	0.0439682	0.0433146	1.015	0.3101	

Chi-square (10)	33.49463	p-value	0.000225
Log-likelihood	41.37926	Akaike criterion	−58.75852
Schwarz criterion	−26.57295	Hannan-Quinn	−45.70844

sigma = 0.164955 (0.0112238)
Left-censored observations: 0
Right-censored observations: 0
Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square (2) = 71.0285 with p-value = 3.77007e-16

The introduction of exogenous variables changes the results of the base specification in several key aspects. First, growth in GDP and interest rates improve performance. The former stands as a proxy for demand of loans and the latter as an opportunity to expand net interest margin. Higher unemployment is perhaps inimical on account of restricted consumer finances and lower levels of economic activity. However, none of these estimates are statistically significant. Second, the sole previously significant coefficient – interest expense - retains this

designation, but the evidence against the null hypothesis (i.e., coefficient is zero) drops slightly (from 0.0005 to 0.0008). Third, the estimate of the coefficient for fixed assets is scarcely affected (from 0.0544 to 0.0537). Fourth, the signs of all the coefficients remain unaltered, but the impact on the magnitude is far from uniform. Notably, net loans are a more important contributor to efficiency once the level of interest rates is taken into account (i.e., the profitability associated with the former gains as the margin expands in a rising rate scenario). Fifth, the estimate of the coefficient for securities available for sale is now under the 10% confidence threshold. A plausible explanation for this development is the commingled effect of interest rates (i.e., interest earned on these assets vs. carrying cost). Finally, the test statistic for normality (i.e., chi-square) declines (from 79.1 to 71.0) so the evidence against the null hypothesis remains strong.

Table 5-11: Base Specification with Exogenous Variables 95% Confidence Interval

Variable	Coefficient	95% confidence interval
const	0.994373	(0.801594, 1.18715)
Net Loans	1.81909e-008	(-3.52592e-008, 7.16411e-008)
Deposits	-2.74664e-008	(-6.80910e-008, 1.31582e-008)
Securities Available for Sale	4.47686e-008	(-8.29193e-009, 9.78291e-008)
Net Interest Income	-5.18782e-008	(-6.33784e-007, 5.30028e-007)
Number of Employees	-9.64879e-007	(-3.57374e-006, 1.64399e-006)
Fixed Assets	9.99345e-007	(-1.60733e-008, 2.01476e-006)
Interest Expense	-1.80770e-006	(-2.86287e-006, -7.52541e-007)
GDP Growth Rate	0.00452440	(-0.0167315, 0.0257803)
Unemployment Rate	-0.0135119	(-0.0304728, 0.00344900)
10-Year Yield	0.0439682	(-0.0409269, 0.128863)

Table 5-11 depicts the confidence intervals for the estimates of the coefficients for the final model specification. Removal of the categorical variable produces a reversion to results similar to those yielded by the original model. Namely, the range excludes nil only for interest expense; thus, it is the sole statistically significant variable. The range for the estimate of the coefficient for fixed assets barely includes zero. Therefore, the effect of introducing exogenous variables is not statistically meaningful. Despite the detrimental macroeconomic conditions prevalent in the island during the observation period, the surviving banks thrived. This would indicate that the favorable impact of consolidation activities was able to overcome the headwinds contributed by other exogenous factors.

5.4 Concentration Index

To study the impact of consolidation on the market structure and the performance of banks, researchers rely on several measures of concentration. As per Bikker and Haaf (2002), when data is limited and simplicity is desired, the often convenient approach adopted is the *k* bank concentration ratio. It takes the following form:

$$\boldsymbol{CR_k = \sum_{i-1}^{k} S_i}$$

k is the number of banks and *S* is the ratio of determinant parameters (e.g., branches) for a particular entity and total for the marketplace. Values range from zero to unity (i.e., $0 < CR_k < 1$). A score at the lower end of the scale evinces no concentration and similar market shares for all participants. In contrast, higher

figures attest to the existence of a monopoly. The concentration index provides a static assessment of the level of market share concentration at a particular time period.

Ratios were calculated on the basis of two key variables associated with performance, namely loans and deposits. This selection conformed with the approach followed in conducting the previous DEA analysis. Also, these parameters are often used by regulators to measure market share. On account of their leading market positions, indices were determined for the three largest banks: Banco Popular, Firstbank, and Orientalbank. These entities were all managed domestically and retained a private ownership structure. The results appear on Tables 5-12 and 5-13 below.

Table 5-12 *k* Concentration Index - Loans

CR1	29%	30%	38%	40%	42%	46%	47%	50%	51%	52%	55%
CR2	43%	45%	55%	57%	60%	65%	66%	69%	70%	71%	80%
CR3	45%	48%	66%	71%	72%	77%	78%	82%	82%	90%	98%

The emergence of an oligopoly is clearly discernible from the results pertaining to loans. The three largest surviving entities almost doubled their market shares in one decade (i.e., from 45% to 98%), thus, essentially exerting commanding control over the entire lending business. The three remaining banks, two of which are administered by foreign institutions, are relegated to niche players, primarily in the areas of private and corporate banking. Hence, consolidation was an activity of the exclusive purview of domestic banks, a reversal of the prior decade's experience.

Of note, the near parity between loans and deposits observed at inception gradually morphs into a capacious cushion of excess liquidity. This reflects mediocre investment opportunities on account of deteriorating macroeconomic conditions and the public sector's default. An aging of the population could also be a contributing factor as wealth accumulation is favored over consumption. Unlike the trend observed for efficiencies, the upward trend is uninterrupted. The effects of consolidation are immediate and irreversible.

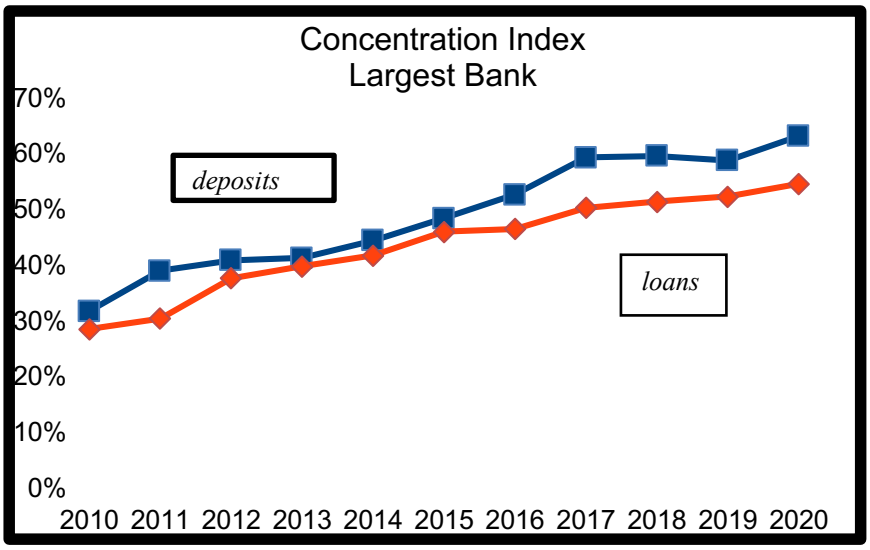
Table 5-13 *k* Concentration Index - Deposits

CR1	32%	39%	41%	41%	44%	48%	53%	59%	60%	46%	63%
CR2	48%	54%	57%	57%	61%	65%	67%	72%	72%	61%	80%
CR3	52%	58%	68%	68%	71%	75%	77%	82%	81%	77%	90%

A similar development is observed concerning deposits. The dominant position of the largest bank (i.e., 63%) is even more pronounced despite the smaller share held by the oligopoly (i.e., 98% vs. 90%). The situation involving surplus funds is even more pronounced for the smaller players which attest to the absence of redeployment opportunities. With the exception of 2019, an expansion in market share is achieved every year. At the end of the observation period, there is clear evidence of the emergence of an oligopoly composed of just three domestic financial institutions. Of note, all surviving entities benefited from the deposit insurance protection and acquisition assistance afforded by the FDIC. Therefore, the divergence in deposit growth cannot be ascribed solely to differences in perceived credit profiles or ownership structure. Customers did not favor foreign

banks despite the more desirable credit ratings associated with them. Another observation is the difference in growth rates in market share; Popular Bank, the dominant institution, gained 97% while the entire oligopoly added 73%. The difference could be explained by the competitive advantages associated with owning a larger branch network and longer operating presence in the marketplace. Finally, the advances reported by all three entities indicate that concentration benefits all surviving banks, although in an uneven manner.

Figure 5-10: *k* Bank Concentration Ratios for Loans and Deposits



Closer examination of the trends in concentration ratio reveals the growing dominant position exercised by the largest bank, Popular Bank. Figure 5-10 depicts the hegemonic market share gains achieved during the observation period. Accounting for under a third of the system's deposits and loans in 2010, it held majority stakes in both sectors at the end of the decade. While Casu and Girardone (2006) find that the degree of concentration is not an accurate

barometer for the level of competition extant in the marketplace, the emergence of such high concentrated levels should be a source of concern to regulators on account of potential undesirable outcomes on societal well-being. As noted by Atleberg and Kim (1998), financial institutions in oligopolies benefit from substantial market power, particularly in retail banking. They attribute this competitive advantage to the lack of resources available to smaller customers for finding the most attractive product offerings and informational asymmetries in the supply side of the market. Similarly, Schleifer (2004) contends that the absence of competition can foment unethical behavior while Gertner et al. (1988) posit that it could also preclude the entrance of other participants deterred by the limited flow of information. The prevention of this objectionable behavior (e.g., price fixing, limited product offerings, and unresponsive customer service) would require heightened monitoring by regulators.

5.5 Summary of Findings

In this chapter, parametric and non-parametric models were constructed and results were obtained to examine the performance of the commercial banks conducting business in Puerto Rico from 2010 until 2020. Specifically, DEA techniques were applied to estimate the operating efficiencies of these financial institutions. Both input and output orientations were considered along with assumptions for constant and variable rates to scale. The Malmquist TFP index was then derived in order to decompose the total productivity growth into its main components: technical efficiency and technology change. Several specifications of

the Tobit model were subsequently considered to measure the contributions to efficiency of individual input and output variables, ownership, and macroeconomic conditions. As an additional analysis tool, the concentration index for the banking system observed was calculated over the time period under consideration. The purpose was to measure the degree of consolidation on account of an emerging oligopolistic market place. In the next chapter, these results are discussed and then applied to address the research questions which are the subject of this study.

CHAPTER VI: DISCUSSION

6.1 Discussion of Results

This chapter addresses the four research questions which together constitute the subject matter of the thesis. The approach adopted entails a three-step process. Namely, the results obtained from various quantitative methods are applied to formulate responses, triangulation is then introduced to corroborate explanations advanced, and finally, conformity with empirical literature is assessed.

6.2 Research Question One

Has the emergence of an oligopoly, on account of the initiatives instituted by regulators, benefited the aggregate operating performance of the banking sector in Puerto Rico?

- Empirical Results

The findings from the DEA models and Malmquist TFP indices indicate that overall systemic productivity gained during a period of market consolidation. Hence, the empirical evidence evinces an affirmative answer. Following Berger & Humphrey (1997), estimates of median or median efficiency for an industry may be a more consistently reliable guide for policy and research purposes than are rankings of firms by their efficiency value, especially between nonparametric and parametric approaches. The corresponding figures presented in Tables 5-1 and 5-2 indicate that efficiency followed an ascendant trajectory over the observation period under different assumptions for returns to scale. Similarly, the Malmquist TFP indices

depicted in Table 5-4 show a 14% improvement in productivity between 2010 and 2020.

- Triangulation

As per Heale and Forbes (2013), triangulation in research is the use of multiple approaches to address a singular inquiry. Essentially, relying on more than one independent and rigorous measure is expected to increase confidence in the findings. Moreover, the combination of various results should provide a more comprehensive response to the research question than either approach could do alone.

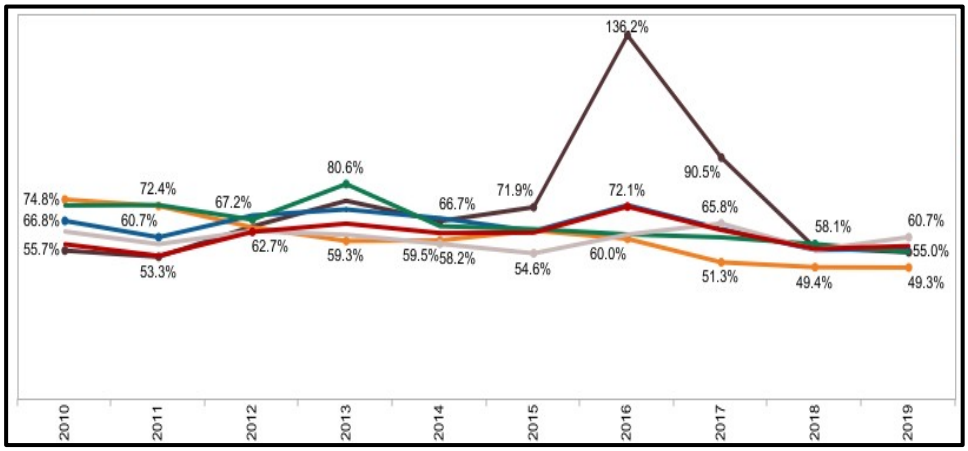
On account of their ease of computation and simplicity, financial ratios are widely employed by regulators and investment professionals to assess the performance of financial institutions (Fraser et al., 2009). They also provide an indication of the general trajectory of productivity parameters over time. However, the inherent limitations of the technique do not favor its use as a primary research tool. Among other considerations, Faelo (2015) highlights the possibility of managerial manipulation of the data, inconsistent reporting standards, and inability to identify outliers.[57]

Figure 6-1 depicts the efficiency ratios for commercial banks that operated in Puerto Rico throughout 2010 and 2020. There are several inferences to be drawn. First, systemic productivity gained as the ratio declined 18% from 66.8% to 55%;

[57] Their presence could skew the distribution of observations and thus obviate the normality assumption required to derive unbiased estimators under ordinary least squares regression.

hence, they confirm the findings of the DEA model, although the magnitudes of the improvement do not coincide. Second, the range of the figures narrowed by 40% which also mirrors the non-parametric technique's results; the emergence of the oligopoly tends to circumscribe divergence in operating performance. Third, the worst performing entities exited the marketplace by the end of the observation period. A Darwinian effect frequently associated with the capitalist economic model would appear to be present.

Figure 6-1: Efficiency Ratio for Five Largest Puerto Rican Banks[58]
(industry average in blue)



- Empirical Literature

The results obtained are mostly in accord with the findings of previous studies. Higher efficiency has been detected by other researchers in cases involving

[58] The bank efficiency ratio is calculated by dividing a bank's operating expenses by its total income and is therefore also referred to as a bank's "Cost to Income Ratio". Source: Office of the Commissioner of Financial Institutions and V2A Consulting.

extensive consolidation (Cornett and Tehranian, 1991) and oligopolistic sector structures (Drake, 2001). The presence of technological progress detected by the Malmquist TFP index is another contributing element as per Al-Sharkas et al. (2008). The similarity in size of the participants involved in the mergers that occurred during the observation period and the absence of transactions outside the island obviate the need to address the impact of these elements on efficiency.

6.3 Research Question Two

Has this transformation impacted equally the surviving banking entities?

- Empirical Results

The outcomes attained support the conclusion that performance gains were not distributed evenly among market participants. The mean efficiency scores depicted in Tables 5-1 and Table 5-2 evince a wide range in individual productivities, although the distribution steadily contracts. Moreover, the estimated efficiencies of surviving and foreign banks tend to exceed the systemic mean. Thus, this implies that participants that eventually exited the market did not benefit from consolidation. Consonantly, the Malmquist TFP indices for individual entities portrayed in Table 5-5 elucidate the extent of these divergences. All commercial banks report higher efficacy thus lending probative value to the answer submitted to the first research question. However, the range from 9.4% to 26.4% extends rather widely considering a systemic mean of 13.8%. The foreign-owned entities clearly outpace their competitors, even the sector's largest participant. It could then be inferred that business strategy, provenance of management, and access

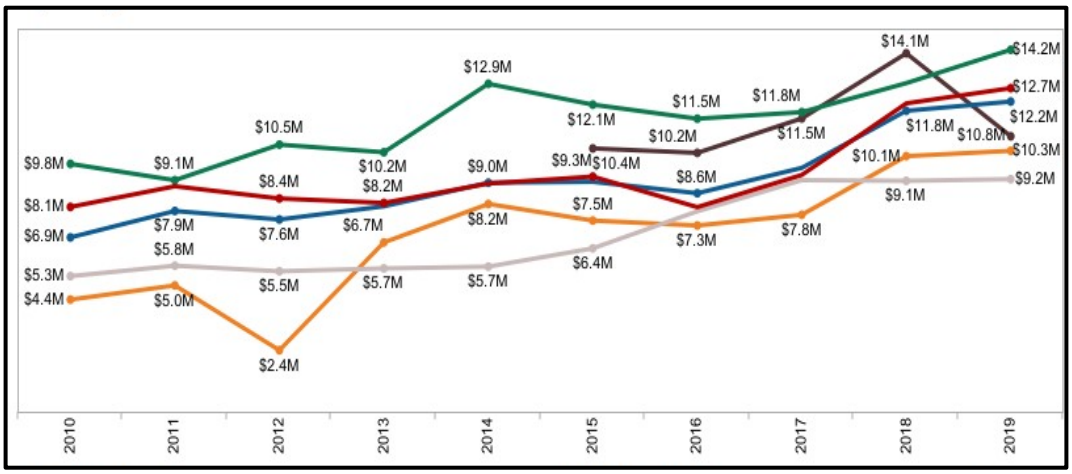
to global resources may be more determinant of success than extent of local physical presence or size. Figure 5-4 attests again to the divergence in operating results. The graph ascribes the origin of these disparities to differences in ability to integrate available technology.

- Triangulation

In an attempt to compare the effectiveness of commercial banks with dissimilar market footprints, Figure 6-2 provides the ratios of operating income to branches. These figures not only corroborate the assertions posted above but also supply a more comprehensive understanding of extant market dynamics. The productivity leaders, as gauged by this financial ratio, retain their relative positions throughout the entire observation period. However, while Popular registers a 56% improvement with a 14% drop in branches, First Bank records a still respectable 45% jump with a corresponding 16% decline in footprint. The standout development pertains to Oriental Bank, the clear market laggard in 2010. A 23% expansion in its branch network translates into a considerable 134% leap in this profitability benchmark. These figures support the contention that the emergence of an oligopoly does not affect each decision-making unit in a similar manner. In addition, they show that the management of participants adopted dissimilar business strategies (i.e., contraction vs. expansion of premises) despite facing similar market conditions. Unlike DEA, the graph indicates that the surviving entities are not necessarily the best performers (e.g., Scotiabank's productivity outclasses Oriental in each measuring period). Of note, the relative ranking

remains fairly stable notwithstanding the turmoil experienced over the observation period.

Figure 6-2: Operating Income/Branches Ratio for Five Largest Puerto Rican Banks[59]
(industry average in blue)



- Empirical Literature

The results concur with the widely held opinion of previous researchers that consolidation and the presence of an oligopoly have asymmetrical consequences on efficiency. As noted by Hasan and Marton (2002) and Yao et al. (2008), foreign-owned institutions usually perform differently from domestic banks regardless of underlying economic model or market conditions. Since there are two entities controlled by overseas interests, a divergence in operating effectiveness should be expected according to this view. Similarly, Cowan and

[59] Source: Office of the Commissioner of Financial Institutions and V2A Consulting.

Salotti (2015) posit that acquirers derive more gains in efficiency. Since not all banks participated in mergers, a divergence in operating effectiveness should be expected according to this view. Likewise, the variations in technological prowess revealed by the Malmquist TFP index have been found to prompt bifurcation in efficiency scores (Al-Sharkas, 2008). Finally, the clearly distinct business strategies pursued (i.e., multi-service vs. niche players) also support a negative answer to the research question (Drake, 2001; Berg and Kim, 1998).

6.4 Research Question Three

Is the effect from the departure of foreign players similar to that associated with the liquidation of autochthonous banks?

- Empirical Results

The efficiency scores obtained for the eleven periods considered do not provide convincing and consistent evidence regarding this matter. Table 6-1 summarizes the estimates yielded by DEA. Most participant exits take place in the earlier years of the observation period; in every case, the departing entity is domiciled locally. Under the assumption of constant returns to scale, immediate gains in mean efficiency are reported. The opposite effect is observed assuming variables return to scale. Even if the impact on productivity requires an extended time lag for full absorption (e.g., twelve months), the results do not appear to change. In 2015, when the last domestic institution exited the market, the results obtained under each return to scale supposition reversed. That is, a gain is shown under BCC while a decline is reported under CCR. All foreign institutions egress in the last two

years of the observation period. Under CCR, an initial improvement in 2019 is reversed the following year. Under BCC, mean efficiency is unaffected. The inconsistency is a source of concern that should preclude drawing generalizations from these results. While DEA and Malmquist TFP indices generally rank foreign banks as more productive, no such conclusion can be inferred from the trajectory of mean systemic efficiency. Consideration should also be given to the nature of the entities themselves. In contrast to the foreign domiciled banks that left the island, those remaining pursue business strategies quite distinct to domestic institutions.

Table 6-1: Historical Trajectory of Market Participants Exiting Banking System

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bank Exits	0	2	3	0	0	1	0	0	0	1	2
Domestic Exits	0	2	3	0	0	1	0	0	0	0	0
Foreign Exits	0	0	0	0	0	0	0	0	0	1	2
Mean Efficiency - CCR	0.783	0.784	0.813	0.877	0.952	0.894	0.917	0.872	0.948	0.993	0.963
Change		0.17%	3.66%	7.83%	8.59%	-6.08%	2.51%	-4.82%	8.73%	4.67%	-3.01%
Mean Efficiency - BCC	0.984	0.967	0.931	0.928	0.985	0.995	0.998	0.957	1.000	1.000	1.000
Change		-1.68%	-3.72%	-0.32%	6.18%	0.95%	0.29%	-4.03%	4.44%	0.00%	0.00%

In consonant, the Tobit regression specification incorporating a categorical variable to account for foreign ownership finds no statistically significant impact on efficiency. As shown in Table 5-8, the p-value of the estimated coefficient is 0.1241 which exceeds the usual 5% threshold; there is not sufficient evidence to reject the null hypothesis of a nil coefficient. Given this threshold tolerance for type

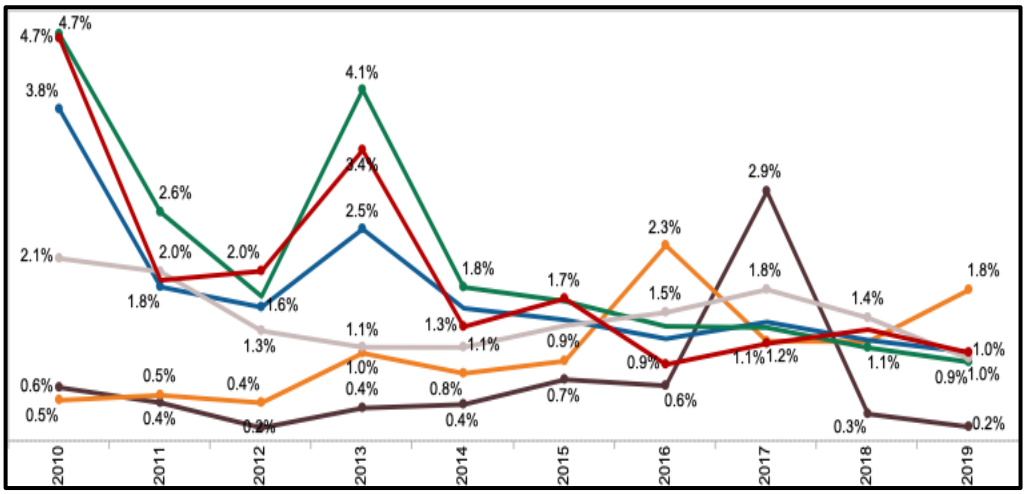
I error[60], the results obtained are best categorized as random in nature. Hence, no answer to the research question can be provided bereft of statistical uncertainty.

- Triangulation

Figure 6-3 presents the loss ratios for three domestic and two foreign commercial banks between 2010 and 2020. The initial period of retrenchment of local institutions (i.e., 2010 to 2013) sees a significant impact on performance of the former but not the latter. The sharp decline in credit losses could be related to different lending practices, business sectors served, and incentives provided by the regulator to incentivize acquisitions of poor performers. At the conclusion of the observation period, corresponding to the departure of the two largest foreign entities, there is a notable bifurcation between the trajectory of Popular and First Bank and that of Oriental, the domestic banks. This indicates that less competition from foreign institutions did not benefit each decision-making unit in the manner. Of note, entities not domiciled in the island post consistently lower relative credit losses even just prior to egression. Moreover, as shown in Figure 6-2 above, the apparent outperformance in this area is not replicated in other productivity measures. That is, domestic banks exhibit better branch effectiveness despite poorer credit practices. Hence, there is no consistent evidence to connect ownership structure of exiting market participants with efficiency changes in the remaining institutions.

[60] Type I error refers to erroneously rejecting the *null* hypothesis (i.e., the coefficients are nil) when it is in fact true.

Figure 6-3: Loss Ratio for Five Largest Puerto Rican Banks[61]
(industry average in blue)



- Empirical Literature

  As noted in Chapter II, there is disagreement in the literature as to the impact of ownership provenance on efficiency. Moreover, during the observation period, not all entities controlled by foreigners exited the marketplace. Finally, the consequences of disparate size and business practices cannot be properly isolated given the limited sampling available. Hence, guidance from previous studies is of limited applicability in the case under consideration. There are prior findings that either concur or differ from the results obtained. Of note, in accord

[61] The loss ratio is calculated by dividing a bank's charge-offs by the balance of outstanding loans; it measures management's effectiveness in extending credit to customers. Source: Office of the Commissioner of Financial Institutions and V2A Consulting.

with Soldatos (2020), the presence of small banks, regardless of ownership, enhances systemic stability and better productivity.

6.5 Research Question Four

How do individual inputs affect specific performance measures?

- Empirical Results

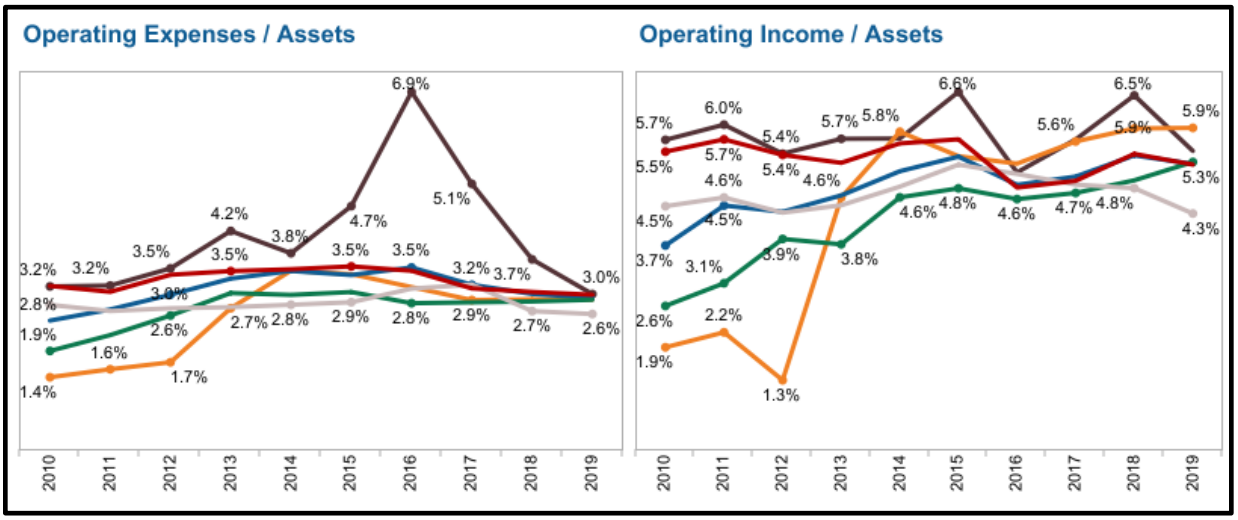
The results obtained from the Tobit model point to an equivocal response to the final research question. All three model specifications yield no statistical significance between the outputs (i.e., net loans, deposits, securities available for sale, and net interest income) and efficiency. With respect to inputs, there is a clear correlation between interest expense and productivity in the scenarios considered. Fixed assets, a proxy for premises, exhibits a less statistically significant relationship that fluctuates according to general macroeconomic conditions and ownership structure. Surprisingly, the number of employees, a stand-in for labor costs, does not affect effectiveness in any of the cases examined. A more extensive branch network should be expected to be concomitant with higher staffing levels. The apparent incongruous results could be explained by the rapid reduction of employment observed during a period of extensive market consolidation; labor is simply not a limiting constraint to growth under these conditions. To conclude, the empirical results provide evidence that each input has idiosyncratic effects on efficiency; thus, precluding drawing generalizations as to the relationship between independent and dependent variables.

- Triangulation

Figure 6-4 presents financial ratios in which assets are the denominators. The objective is to facilitate comparisons between commercial banks with significant dissimilarities in terms of size. Consistent with the pattern observed in the previous graph, performance improves while uniformity advances. Profitability, as measured by operating/assets, rises by 43% in a marketplace that behaves in an increasingly more predictive manner. Surprisingly, while the latter development also applies to the ratio of operating expenses to assets, the trajectory of expense control exhibits a much more muted behavior; the systemic mean of the quotient jumps by nearly 12%. This suggests that management may be able to exert greater influence over outputs than inputs; the anomaly observed in 2016 pertains to extraordinary credit losses.

Similar to the results obtained from the base specification of the Tobit model, there is no evidence to evince an irrefutable linkage among outputs, inputs, and profitability. While Orientalbank is the institution experiencing the largest gain in both output and rentability, the biggest market participant in terms of assets (i.e., Popular) is not the most effective with respect to this performance measure. When examining the relationship with respect to an input, an analogous inference can be drawn.

Figure 6-4: Asset Ratios for Five Largest Puerto Rican Banks[62]
(industry average in blue)



As shown in Figure 6-3, the financial institutions with the broadest physical network are indeed the most profitable as gauged by the operating income to branch proportion. However, they lag in overall efficiency, as assessed by the operating income to assets benchmark, despite following similar business strategies. Thus, triangulation seems to underscore the lack of clear causation between the input and output variables considered and the efficiency scores provided by the empirical results.

- Empirical Literature

  According to the literature, there is no consensus as to the key determinants of efficiency. The main candidates often mentioned are technological

[62] Source: Office of the Commissioner of Financial Institutions and V2A Consulting (February 20, 2022). Retrieved from: http://prbankindicators.v-2-a.com/Productivity/TimeSeries/ProductivityTS_IncomeAssets.php

implementation, organizational structure, regulatory regime, and the country's development progress. Incorporating these factors into econometric models constitutes an abiding difficult task. Nevertheless, the findings do concur with some of the results of the studies mentioned in Chapter II: there is a more significant contribution to efficiency from premises than deposits is observed (Barros et al., 2010); net loans are not deemed to be statistically correlated with productivity (Drake, 2001; Sathye, 2001); and, macroeconomic conditions do not appear to explain the efficiency scores estimated (Rezvarian et al., 2011). Like Hagendorff and Keasey (2009), banks that implement cost-cutting rather than revenue-enhancing measures are more successful in advancing productivity and profitability.

6.6 Conclusion

While the immanent shortfalls of the various quantitative methods employed mandate caution in attributing excise preciseness to the estimates obtained, the empirical evidence exhibits reassuring consistency regarding some of the conclusions advanced. Namely, consolidation does yield systemic resilience, as gauged by various performance benchmarks, desired by the regulators. In addition, the emergence of an oligopoly impacts individual participants differently, foreign ownership may abet productivity, and inputs do not contribute equally to efficiency.

CHAPTER VI: SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

7.1 Summary

Faced with hellacious macroeconomic challenges over a prolonged period, the banking sector in Puerto Rico was by 2010 in a dire condition. To stem systemic collapse, the mainland regulator and other federal agencies actively intervened by providing capital and facilitating the acquisition of entities in distress. These actions in turn resulted in a significant realignment of the industry. Namely, a marketplace characterized by a diversity of numerous participants was replaced by an oligopoly which slowly coalesced over the past decade.

The thesis applied parametric and non-parametric methods to estimate the technical efficiency of the commercial banks that operated in Puerto Rico between 2010 and 2020. Ratio analysis was conducted to derive the benefits ascribed to triangulation. The findings produced empirical evidence that enabled the study to answer the four questions which guided the research endeavor. The responses generally conformed with the opinions held by other investigators to the effect that industry consolidation serves to enhance both systemic and individual performance, at least on a short-term basis. The individual factors driving such developments were however difficult to identify; and consequently, they remained a subject matter warranting further research.

7.2 Implications

The inferences of the research performed and results derived are as follows:

- The operating performance of commercial banks is significantly impacted

by the trajectory of industry consolidation, but the effects are neither immediate nor uniform. This in turn implies that management's ability to select and integrate assets remains a critical consideration. The conclusion is supported by a) the apparent consistent divergence in performance between entities incorporated locally and those controlled by foreign agents and b) the difference in absorption of technological progress.

- Technological change serves as a primary driver of operating performance even during periods of adverse macroeconomic conditions. The thesis thus suggests that management's success in its adoption is of paramount importance in reaching profitability objectives. Moreover, the failure to acquire or fully implement the technology required to compete effectively, perhaps due to liquidity constraints, could result in protracted underachieving or eventual demise.
- Interest expense has a statistically more significant effect on technical efficiency than the other input and output variables considered, general economic circumstances, and ownership structure. Hence, the thesis proposes that this is another area that warrants considerable managerial attention. To a lesser extent, the size of a commercial bank's footprint is also a statistically significant contributor to operating performance.
- The outcomes of the DEA analysis fail to identify a strong correlation between the size of a financial institution and its productivity. Instead, the type of business model adopted provides disparate fillips to effectiveness

and consequently promote bifurcation in performance. The inherently circumscribed extension of the Puerto Rican banking sector does not allow for a more nuanced investigation of geographical factors that could contribute to efficiency.

- The thesis hypothesizes that the emergence of an oligopoly does not preclude coexistence with niche participants. Moreover, by adopting narrower business strategies, the latter are able to compete effectively against much larger financial institutions.

To conclude, for both practitioners and policymakers, the thesis supports the contention that consolidation is a viable option to address pressing fragility in a banking marketplace. The effectiveness of such a course of action appears to be determined by both endogenous and exogenous circumstances. The former pertains to factors related to managerial competence and strategic outlook, while technology progress dominates the latter.

7.3 Recommendations for Future Research

The time period studied coincided with the emergence of an oligopoly, a development with fundamental implications on market dynamics. By measuring efficiency in future years, and assuming no entry of other players, researchers could be able ascertain if the efficiency trends observed abide. In case of a relapse, regulators may have to consider implementing new policy initiatives designed to curb the pernicious effects ascribed to limited competition (e.g., incentivizing formation of new banks or return of foreign participants). By

measuring efficiency during the decade prior to the period considered in the thesis, researchers could be able to confirm if the trends observed preceded the rapid consolidation encouraged by regulators. In case of confirmation, the effectiveness of the regulatory initiatives herein ascribed may need to be revisited. Namely, there may be other exogenous or endogenous factors, other than the emergence of an oligopoly, that drive operating performance.

Balanced panel data is required to derive the Malmquist TFP index for the entire banking sector over a given observation period. The exit of many participants between 2010 and 2020 limited the analysis to surviving banks. Hence, the estimates of total factor productivity and its constituent components presented here yield an incomplete picture of market performance. Further research incorporating other measuring techniques is needed to address this shortfall and therefore provide a more comprehensive and accurate estimate of technological change and its impact on profitability.

Similarly, the lack of data on input prices prevented deriving estimates of allocative efficiency which are necessary to calculate the overall efficiency of financial institutions. Subsequent studies incorporating such information could yield more insight into the modus operandi of these enterprises and hence more robust conclusions than those that could be drawn here.

The Tobit regression model considered a very limited set of exogenous and indicator variables. Further research could examine the elasticity of efficiency with respect to other macroeconomic parameters (e.g., wages, labor participation).

Similarly, the model specifications could also incorporate time-invariant variables (e.g., geographic location) or consider efficiency for specific business units (e.g., custodian services). Given the significant difference in the size of the assets held by the largest banks and their business lines, other researchers may consider examining them separately.

Estimates of efficiency were obtained exclusively from non-parametric linear programming techniques. To validate them, other investigators could rely on other estimating methods such as the stochastic frontier approach.[63] Subsequently, the results obtained could then be used to run the Tobit regression model to ascertain the contributions of various factors to operating performance.

Correlation analysis indicates that inputs or outputs of the decision-making units are not statistically independent of each other at all times. This condition diminishes the discriminatory power of the estimator. Further research may consider employing techniques designed to address such situations. For example, Bastani et al. (2021) advocates prescinding of some strongly correlated variables in applying the nonparametric approach; the decision is guided by use of the Centralized Data Envelopment Analysis model in which all units are simultaneously projected on the efficient frontier rather than using a separate model for each unit.

The theoretical framework that guides this thesis is banking theory, in other words, financial institutions act as intermediaries and not as production units. This

[63] Berger and Humphrey (1997) identify five types of approaches. Until the advent of DEA, parametric frontiers, particularly derived using the stochastic frontier approach, were the most favored by researchers.

in turn affects the selection of input and output variables considered. Other studies may adopt an alternative theoretical framework (e.g., resource dependency theory) which would in turn necessitate consideration of other parameters.

7.4 Limitations of the Study

The study relies on the DEA modeling technique to estimate efficiency of commercial banks. There are however several limitations associated with this approach. First, observations with extreme values cannot be accommodated; therefore, negative inputs or outputs are automatically rejected (e.g., earnings losses). During the period under consideration, the severe downturn in the price of real estate properties translated into numerous loan defaults which had a concomitant negative impact on profits. The exclusion of one of the most widely used measures of operating performance (e.g., net income) required its substitution with less desirable alternatives. Hence, the analysis performed had to rely on parameters that measured operating performance in a more indirect manner. As macroeconomic conditions improve and profitability turns positive for a reasonable period, further studies will be able to consider variables that this thesis was not able to include. Moreover, the DEA methodology assumes there are no statistical errors in the model, a premise which cannot be readily ascertained. Thus, the estimates derived from the computations may contain an element of statistical bias. For example, measurement distortions introduced by inaccuracies associated with accounting rules cannot be detected. The problem is compounded considering the idiosyncrasies of the estimating technique; an error

in one of the decision-making units on the efficient frontier modifies the efficiency score for all other units compared to this unit. In addition, the selection and number of variables tested were guided by those employed in studies deemed most relevant. As the list is far from exhaustive, different results could result from an alternative use of inputs and outputs. A similar observation applies to the period from which observations were drawn. Ten years was considered to be ample to discern an incontrovertible pattern while simultaneously capturing data during the period of most active consolidation. As noted in Chapter IV, the scores estimated pertain to technical efficiency; the unavailability of price data precludes deriving allocative efficiency. Finally, as common to other estimating techniques, accuracy is highly dependent on the number of observations available, with generally a preference for a greater figure. On account of the idiosyncrasies of the marketplace observed and the unavoidable requirement to exclude negative variables, the sample size is limited. This partially explains the tendency of technical efficiency to approach one. Further studies may attend to overcome this issue by resorting to bootstrapping, a statistical resampling technique designed to increase the number of observations while affecting the sample size. Of note, despite the well-known constraints inherent in the DEA approach, it remains one of the most popular estimating techniques in the field. This could be explained by the even more severe limitations associated with other methodologies. Still, further studies may challenge the results obtained here by applying a different estimating technique such as stochastic frontier analysis.

7.5 Conclusion

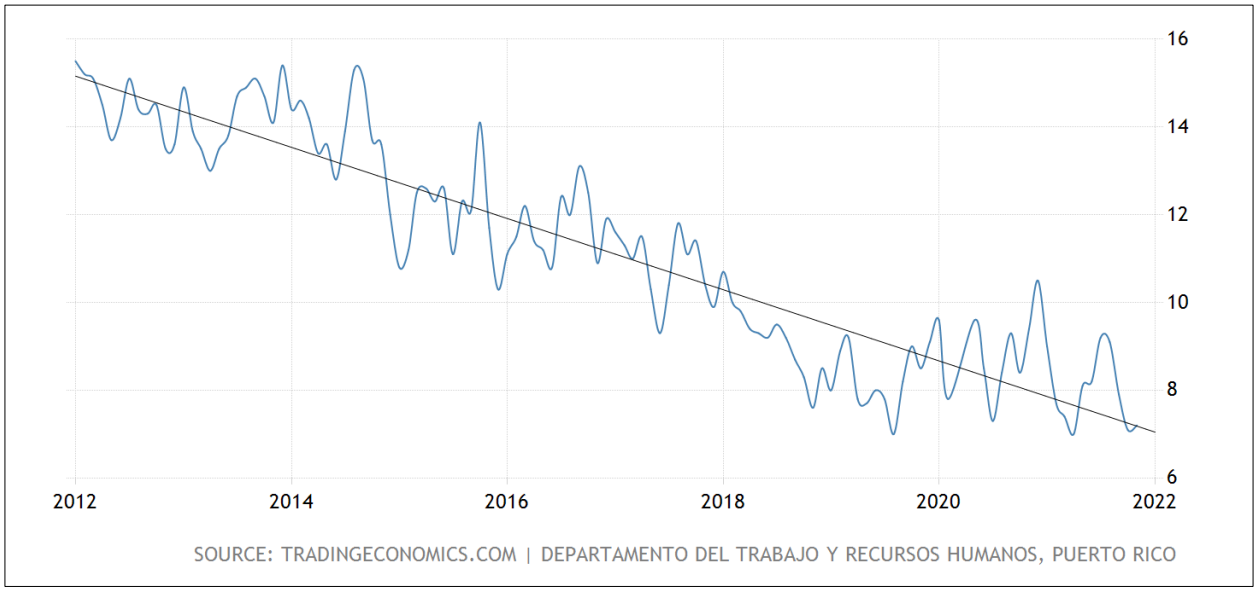
Despite the limitations noted above, this study contributes to the understanding of both the market dynamics of the banking sector in Puerto Rico and the concomitant effects associated with severe consolidation activity. With respect to the former, the thesis serves to address a knowledge gap identified by a review of extant literature which revealed the absence of research concerning operating efficiency in the setting examined. Moreover, the study is one of the few that examines the performance of a banking sector during the emergence of an oligopoly within a clearly discernible time period. In contrast, other researchers had to contend with such market structure as a fait accompli (e.g., Asmild et al., 2004).

Having played such a critical role in fostering consolidating activities which were deemed necessary to avoid systemic collapse, the regulators must now shift their attention to prevent abuses often associated with oligopolies. This would entail assuming a more vigilant role in terms of monitoring and enforcing compliance with statutes designed to prevent anti-competitive behavior. Fortunately, the current strength of the banking system amply allows for its participants to defray the costs that could be imposed by additional regulatory policies deemed necessary to achieve this objective.

APPENDIX A

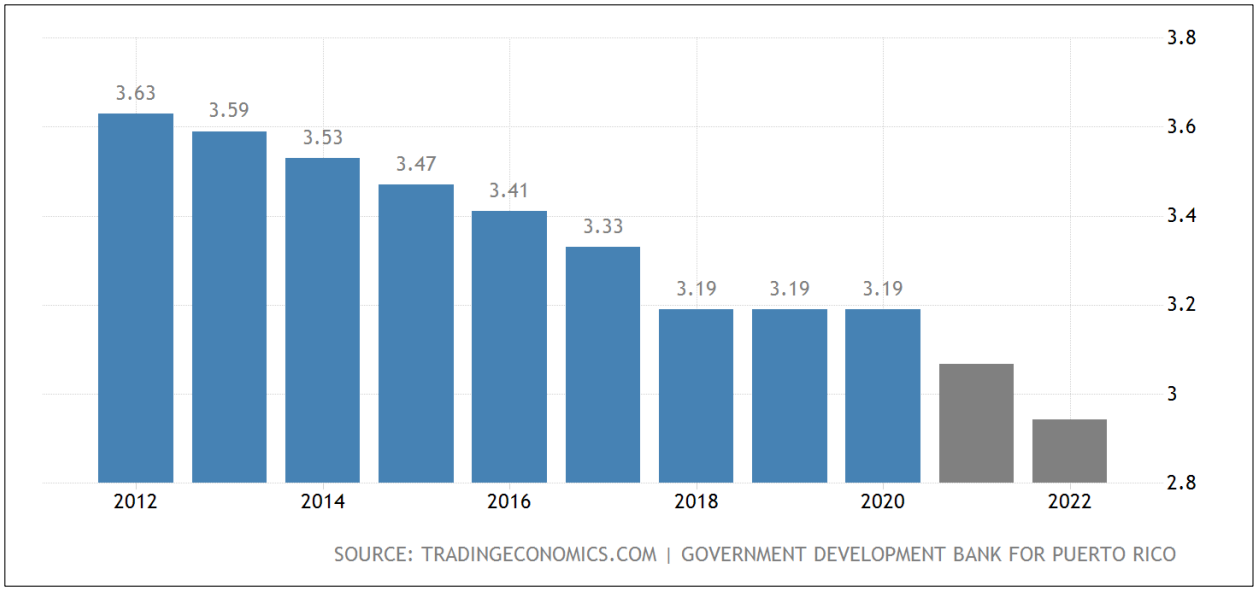
MACROECONOMIC INDICATORS

A-1 Unemployment Rate

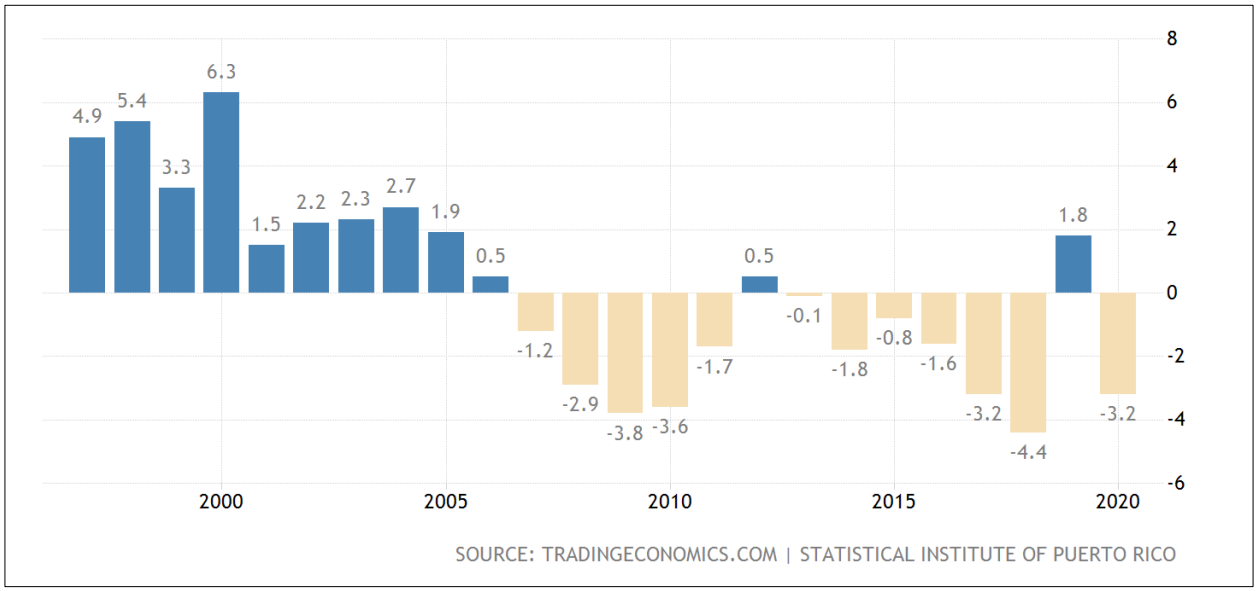


A-2 Labor Participation Rate

A-3 Total Population
(in millions)



A-4 GDP Growth Rate



APPENDIX B

STATE BANKING PERFORMANCE INDICATORS

B-1 Balance Sheet and Income Statement Highlights

(dollar figures in millions)	All Institutions	Assets less than $100 million	Assets greater than $100 million	All Institutions	Assets less than $100 million	Assets greater than $100 million	All Institutions	Assets less than $100 million	Assets greater than $100 million
Number of institutions reporting	7		7	5		5	3		3
Total employees (full-time equivalent)	14,453		14,453	12,958		12,958	12,627		12,627
AGGREGATE CONDITION AND INCOME DATA									
Net income (year-to-date)	-642		-642	370		370	676		676
Total assets	77,786		77,786	57,323		57,323	83,764		83,764
Earning assets	67,998		67,998	51,429		51,429	79,127		79,127
Total loans & leases	52,713		52,713	39,996		39,996	39,937		39,937
Other real estate owned	543		543	532		532	192		192
Total deposits	49,994		49,994	44,273		44,273	73,165		73,165
Equity capital	7,103		7,103	8,281		8,281	7,784		7,784
PERFORMANCE RATIOS (YTD, %)									
Yield on earning assets	5.58		5.58	5.47		5.47	4.12		4.12
Cost of funding earning assets	1.96		1.96	0.61		0.61	0.36		0.36
Net interest margin	3.62		3.62	4.85		4.85	3.76		3.76
Noninterest income to avg. earning assets	0.91		0.91	1.29		1.29	0.84		0.84
Noninterest expense to avg. earning assets	2.97		2.97	3.87		3.87	2.79		2.79
Net charge-offs to loans & leases	3.54		3.54	1.44		1.44	0.83		0.83
Credit-loss provision to net charge-offs	89.83		89.83	117.04		117.04	148.77		148.77
Net operating income to average assets	-0.84		-0.84	0.67		0.67	0.89		0.89
Retained earnings to average equity	-9.50		-9.50	3.46		3.46	0.25		0.25
Pre tax return on assets	-0.68		-0.68	0.80		0.80	1.09		1.09
Return on assets	-0.83		-0.83	0.63		0.63	0.91		0.91
Return on equity	-9.45		-9.45	4.52		4.52	8.97		8.97
Percent of unprofitable institutions	28.57		28.57	20.00		20.00			
Percent of institutions with earning gains	28.57		28.57	40.00		40.00	33.33		33.33
Net loans and leases to assets	65.86		65.86	67.52		67.52	46.09		46.09

(dollar figures in millions)	All Institutions	Assets less than $100 million	Assets greater than $100 million	All Institutions	Assets less than $100 million	Assets greater than $100 million	All Institutions	Assets less than $100 million	Assets greater than $100 million
Number of institutions reporting	7		7	5		5	3		3
CONDITION RATIOS (%)									
Net loans and leases to assets	65.86		65.86	67.52		67.52	46.09		46.09
Noncurrent loans a	21.56		21.56	37.28		37.28	54.76		54.76
Noncurrent loans & leases to total loans & leas	13.02		13.02	8.68		8.68	6.06		6.06
Nonperforming assets to assets	9.61		9.61	6.98		6.98	3.12		3.12
Core deposits to total liabilities	58.19		58.19	75.96		75.96	86.87		86.87
Equity capital to total assets	9.13		9.13	14.45		14.45	9.29		9.29
Leverage (Core capital) ratio	7.70		7.70	13.16		13.16	8.61		8.61
Total capital\risk-weighted assets-NA 2020	14.52		14.52	19.89		19.89			
Gross 1-4 family mortgages to gross assets	22.08		22.08	25.51		25.51	15.10		15.10
Gross real estate assets to gross assets	60.61		60.61	54.07		54.07	41.32		41.32

Source: Call Report and Thrift Financial Report
Prepared by the FDIC-Division of Insurance and Research

B-2 Economic Indicators and Banking Trends
Source: FDIC

Third Quarter 2021

ECONOMIC INDICATORS (NOT SEASONALLY ADJUSTED, UNLESS NOTED)

Employment Growth Rates (% change from year ago, unless noted)	Q3-21	Q2-21	Q3-20	2020	2019
Total Nonfarm (share of trailing four quarter employment in parentheses)	4.2%	9.4%	-5.8%	-5.5%	2.0%
Manufacturing (9%)	5.2%	10.4%	-1.1%	-1.2%	4.4%
Other (non-manufacturing) Goods-Producing (3%)	12.1%	28.7%	-1.2%	-2.3%	3.1%
Private Service-Providing (64%)	5.6%	12.1%	-7.9%	-7.4%	3.3%
Government (23%)	-0.8%	0.2%	-2.4%	-2.2%	-2.7%
Unemployment Rate (% of labor force, seasonally adjusted)	8.3%	8.2%	8.4%	0.0%	8.3%

Other Indicators (% change of 4-qtr moving total, unless noted)	Q3-21	Q2-21	Q3-20	2020	2019
Single-Family Home Permits					
Multifamily Building Permits					
Home Price Index (change from year ago)					
Nonbusiness Bankruptcy Filings per 1000 people (quarterly annualized level)					

BANKING TRENDS

General Information	Q3-21	Q2-21	Q3-20	2020	2019
Institutions (#)	4	4	4	4	5
Total Assets (in millions)	95,489	94,053	84,171	84,054	69,779
New Institutions (# < 3 years)	0	0	0	0	0
Subchapter S Institutions (#)	0	0	0	0	0

Asset Quality	Q3-21	Q2-21	Q3-20	2020	2019
Past-Due and Nonaccrual Loans / Total Loans (median %)	4.41	4.71	5.73	5.87	5.53
Noncurrent Loans / Total Loans (median %)	3.06	3.43	4.27	4.05	4.39
Loan and Lease Allowance / Total Loans (median %)	2.69	2.89	3.32	3.14	1.72
Loan and Lease Allowance / Noncurrent Loans (median multiple)	0.91	0.86	0.63	0.84	0.40
Net Loan Losses / Total Loans (median %, year-to-date annualized)	0.27	0.22	0.67	0.64	1.06

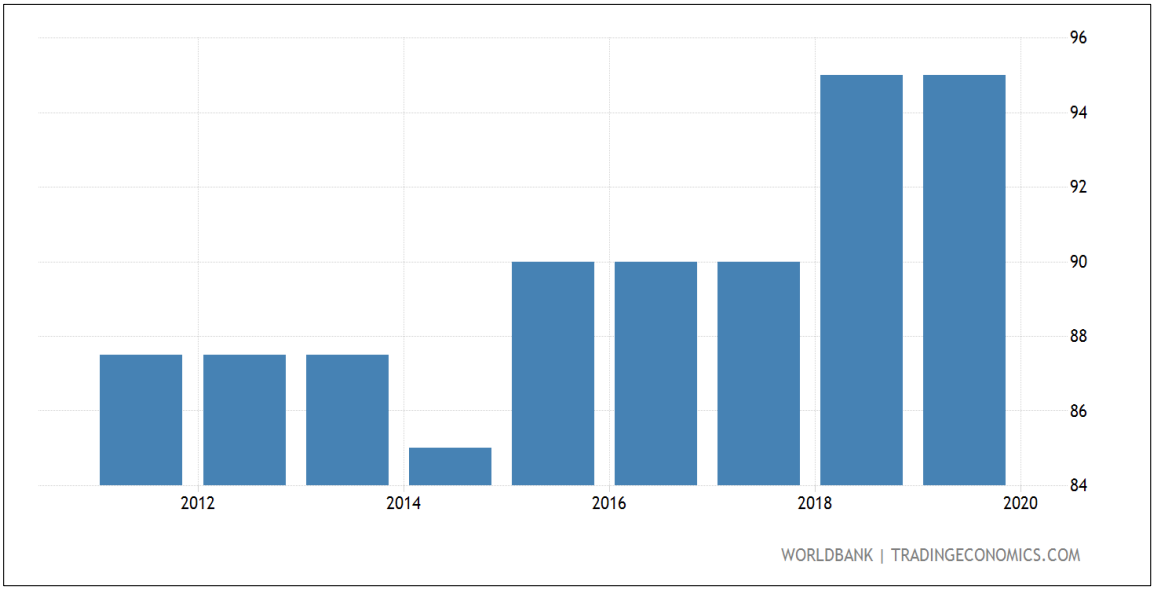
Capital / Earnings (year-to-date annualized, unless noted)	Q3-21	Q2-21	Q3-20	2020	2019
Tier 1 Leverage (median %, end of period)	8.85	8.49	9.21	9.71	9.62
Return on Assets (median %)	1.42	1.40	0.85	0.90	1.40
Pretax Return on Assets (median %)	2.08	1.91	1.03	1.09	1.82
Net Interest Margin (median %)	3.75	3.68	3.98	3.99	4.36
Yield on Earning Assets (median %)	3.93	3.87	4.37	4.35	4.95
Cost of Funding Earning Assets (median %)	0.24	0.25	0.46	0.42	0.73
Provisions to Avg. Assets (median %)	-0.16	-0.14	0.81	0.69	0.32
Noninterest Income to Avg. Assets (median %)	0.73	0.72	0.68	0.71	0.63
Overhead to Avg. Assets (median %)	2.33	2.41	2.56	2.58	2.98

Liquidity/Sensitivity	Q3-21	Q2-21	Q3-20	2020	2019
Net Loans to Assets (median %)	46.11	44.44	52.05	52.67	46.91
Noncore Funding to Assets (median %)	5.27	5.76	8.05	7.24	7.59
Long-term Assets to Assets (median %, call filers)	41.34	40.97	36.24	38.03	42.07
Brokered Deposits (number of institutions)	3	3	4	4	4
Brokered Deposits to Assets (median % for those above)	0.35	0.35	1.97	1.43	1.54

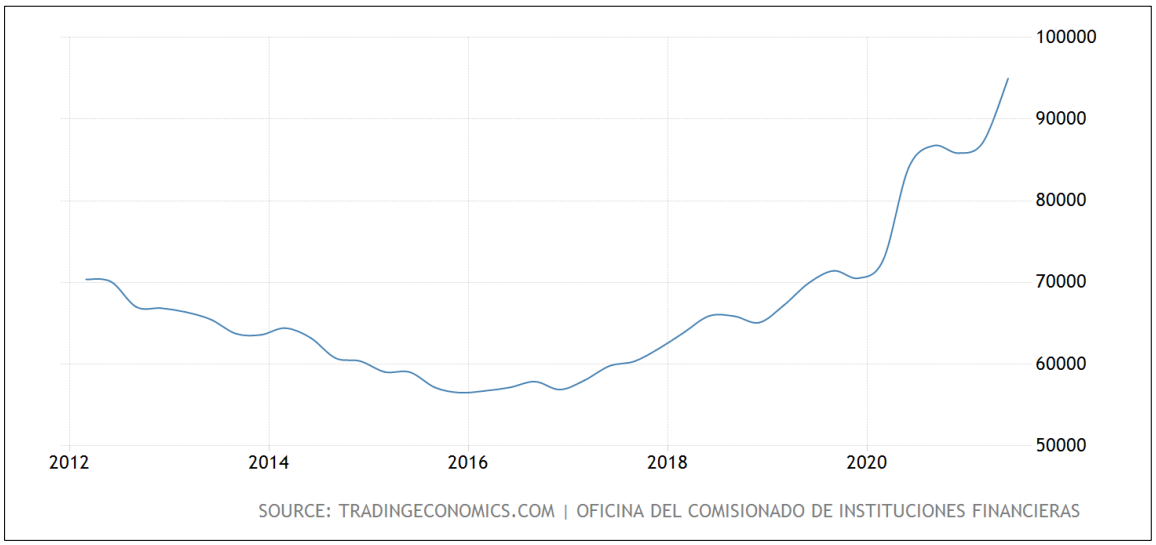
Loan Concentrations (median % of Tier 1 Capital plus the Reserve for Loan and Lease Losses)	Q3-21	Q2-21	Q3-20	2020	2019
Commercial and Industrial	70	81	88	86	50
Commercial Real Estate	113	114	116	115	106
Construction & Development	7	7	9	10	5
Multifamily Residential Real Estate	4	4	4	4	4
Nonresidential Real Estate	101	103	103	102	100
Residential Real Estate	160	162	166	159	141
Consumer	107	107	103	101	81
Agriculture	0	1	0	1	0

B-3 Getting Credit – Distance to Frontier

Distance to the frontier denotes the distance of each economy to the "frontier," which represents the highest performance observed on the getting credit indicator across all economies included in Doing Business.



B-4 Total Assets held by Commercial Banks



REFERENCES

Adams, R., Johnson, R., & Pilloff, S. (2009) Market Structure after Horizontal Mergers: Evidence from the Banking Industry. *Review of industrial organization*, 35(3), 217–231.

Aggarwal, R., Akhigbe, A., & McNulty, J. E. (2006) Are Differences in Acquiring Bank Profit Efficiency Priced in Financial Markets? *Journal of financial services research,* 30(3), 265–286.

Aigner, D., Lovell, C. A. K., and Schmidt, P. (1977), Formulation and Estimation of Stochastic Frontier Production Function Models, *Journal of Econometrics*, 6, 21-37.

Al Shamsi, F.S., Aly. H.Y. & El-Bassiouni, M.Y. (2009) Measuring and explaining the efficiencies of the United Arab Emirates banking system. *Applied Economics*, 41(27), 3505-3519.

Al Sharkas, A. A, Hassan, M. K., & Lawrence, S. (2008) The Impact of Mergers and Acquisitions on the Efficiency of the US Banking Industry: Further Evidence, *Journal of business finance & accounting*, 35(12), 50–70.

Aly, H.Y., Grabowski, R., Pasurka, C., & Rangan, N. (1990) Technical, Scale, and Allocative Efficiencies in U.S. Banking: An Empirical Investigation. *The review of economics and statistics*, 72(2), 211–218.

Anginer, D., Demirgüç-Kunt, A., & Zhu, M. (2013). How does bank competition affect systemic stability?. *Journal of Financial Intermediation, Forthcoming*.

Asaftei, G. (2008) The contribution of product mix versus efficiency and technical change in US banking, *Journal of banking & finance,* 32(11), 2336–2345.

Asmild, M., Paradi, J.C., Aggarwall, V., & Schaffnit, C. (2004) Combining DEA window analysis with the Malmquist index approach in a study of the Canadian banking industry. *Journal of Productivity Analysis,* 21, 67-89.

Assaf, A.G., Barros, C. P., & Matousek, R. (2011) Technical efficiency in Saudi banks. *Expert systems with applications,* 38(5), 5781–5786.

Avkiran, N. K. (2006) Developing foreign bank efficiency models for DEA grounded in finance theory. *Socio-economic planning sciences*, 40(4), 275–296.

Avkiran, N. K. (2009) Opening the black box of efficiency analysis: An illustration with UAE banks, *Omega*, 37(4), 930–941.

Avkiran, N. K. (2014) An illustration of dynamic network DEA in commercial banking including robustness tests, *Omega*, 55(C), 141-150.

Balla, E., Prescott, E.S. & Walter, J.R. (2015) Did the Financial Reforms of the Early 1990s Fail? A Comparison of Bank Failures and FDIC Losses in the 1986-92 and 2007-12 Periods. *Working Paper 15-5, Federal Reserve Bank of Richmond.*

Banker, R. D. (1996) Hypothesis tests using data envelopment analysis. *Journal of productivity analysis*, 7(2-3), 139–159.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management science*, 30(9), 1078–1092.

Barnum, D. T. & Gleason, J. M. (2006) Biases in technical efficiency scores caused by intra-input aggregation: mathematical analysis and a DEA application using simulated data. *Applied economics*, 38(14), 1593–1603.

Barros, C. P., Managi, S., & Matousek, R. (2012) The technical efficiency of the Japanese banks: non-radial directional performance measurement with undesirable output, *Omega*, 40(1), 1–8.

Bastani, M., Ketabi, S., Maddahi, R., & Ahari, R. M. (2021). Data Envelopment Analysis in the Presence of Correlated Evaluation Variables. *Jordan Journal of Mechanical & Industrial Engineering*, *15*(3).

Beck, T. (2008). Bank competition and financial stability: friends or foes?. *World Bank policy research working paper*, (4656).

Beck, T., De Jonghe, O., & Schepens, G. (2013). Bank competition and stability: Cross-country heterogeneity. *Journal of financial Intermediation*, *22*(2), 218-244.

Berg, S.A., Førsund, F.R., & Jansen, E.S. (1992) Malmquist Indices of Productivity Growth during the Deregulation of Norwegian Banking, 1980-89. *The Scandinavian journal of economics*, 94(SUP), S211–S228.

Berg, S. A. & and Kim, M. (1998) Banks as Multioutput Oligopolies: An Empirical Evaluation of the Retail and Corporate Banking Markets. *Journal of money, credit and banking*, 30(2), 135–153.

Berger, A.N. (1993) “Distribution-Free" Estimates of Efficiency in the U.S. Banking Industry and Tests of the Standard Distributional Assumptions. *Journal of Productivity Analysis*, 4(3), 261-292.

Berger, A. N. (1995) The Profit-Structure Relationship in Banking -Tests of Market-Power and Efficient-Structure Hypotheses. *Journal of money, credit and banking*, 27(2), 404–431.

Berger, A. N. & DeYoung, R. (1997) Problem loans and cost efficiency in commercial banks. *Journal of banking & finance*, 21(6), 849–870.

Berger, A. N., & DeYoung, R. (2006). Technological progress and the geographic expansion of the banking industry. *Journal of Money, Credit and Banking*, 1483-1513.

Berger, A.N. & Hanna, T.H. (1998) The Efficiency Cost of Market Power in the Banking Industry: A Test of the "Quiet Life" and Related Hypotheses. *The review of economics and statistics*, 80(3), 454–465.

Berger, A. N., Hasan, I., & Klapper, L. F. (2004) Further Evidence on the Link between Finance and Growth: An International Analysis of Community Banking and Economic Performance. *Journal of financial services research*, 25(2), 169–202.

Berger, A. N., Hanweck, G. A., & Humphrey, D. B. (1987). Competitive viability in banking: Scale, scope, and product mix economies. *Journal of monetary economics*, *20*(3), 501-520.

Berger, A. N. & Humphrey, D. B. (1997) Efficiency of financial institutions: International survey and directions for future research. *European journal of operational research*, 98(2), 175–212.

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

Bikker, J.A. and Haaf, K., 2002. Measures of competition and concentration in the

banking industry: a review of the literature. *Economic & Financial Modelling*, *9*(2), 53-98.

Biondi, Y. (2018). Banking, money and credit: A systemic perspective. *Accounting, Economics, and Law: A Convivium*, *8*(2).

Bram, J., Martinez, F. E., & Steindel, C. (2008). Trends and developments in the economy of Puerto Rico. *Current Issues in Economics and Finance*, *14*(2).

Bryman, A. (2016). *Social research methods*. Oxford university press.

Burki, A.A. & Niazi, G.S.K. (2010) Impact of financial reforms on efficiency of state-owned, private and foreign banks in Pakistan. *Applied Economics*, 42(24), 3147-3160.

Carbone, T.A. (2000) Measuring efficiency of semiconductor manufacturing operations using data envelopment analysis (DEA). In *IEEE/SEMI advanced semiconductor manufacturing conference*, 56-62.

Carpenter, S., & Demiralp, S. (2012). Money, reserves, and the transmission of monetary policy: Does the money multiplier exist?. *Journal of macroeconomics*, *34*(1), 59-75.

Casu, B., & Girardone, C. (2006). Bank competition, concentration and efficiency in the single European market. *The Manchester School*, *74*(4), 441-468.

Caves, D., Christensen, L., & Diewert, E. (1982) Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers. *Economic Journal, Royal Economic Society,* vol. 92(365), 73-86.

Cetorelli, N., & Peretto, P. F. (2000). Oligopoly banking and capital accumulation. *Available at SSRN 254343*.

Charnes, A., Clark, C.T., Cooper, W.W., & Golany, B. (1985) A development study of data envelopment analysis in measuring the efficiency of maintenance units in the US air forces. *Annals of Operations Research,* 2, 95-112.

Charnes, A., Cooper, W.W., & Rhodes, E. (1978) Measuring the efficiency of decision making units. *European Journal of Operational Research,* 2*,* 429-444.

Chen, X., Skully, M., & Brown, K. (2005) Banking efficiency in China: Application of DEA

to pre- and post-deregulation eras: 1993–2000. *China economic review*, 16(3), 229–245.

Cheng, G. (2014) *Data Envelopment Analysis: Methods and MaxDEA Software*, Intellectual Property Publishing House Co. Ltd. Beijing

Chortareas, G. E, Garza-Garcia, J. G., & Girardone, C. (2011) Banking Sector Performance in Latin America: Market Power versus Efficiency. *Review of development economics*, 15(2), 307–325.

Chortareas, G. E, Girardone, C., & Ventouri, A. (2009) Efficiency and productivity of Greek banks in the EMU era. *Applied financial economics*, 19(16), 1317–1328.

Chronopoulos, D. K., Girardone, C., Girardone, Claudia, & Nankervis, J. C. (2013) How Do Stock Markets in the US and Europe Price Efficiency Gains from Bank M&As? *Journal of financial services research*, 43(3), 243–263.

Claessens, S., Demirgue-Kunt, A, Register, C.A., Hudgins, S.C. (2001). How does the foreign entry affect domestic banking markets? *Journal of Banking and Finance*, 25, 891-911.

Claessens, S., & Laeven, L. (2004). What drives bank competition? Some international evidence. *Journal of money, credit and banking*, 563-583.

Clark, J.A. & Siems, T.F. (2002) X-Efficiency in Banking: Looking beyond the Balance Sheet. *Journal of money, credit and banking*, 34(4), 987–1013.

Coelli, T.J. (1996) A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program, CEPA Working Paper 96/08, The University of New England. Armidale.

Coelli, T. Rao, D.S., & Battese, G.E. (1998) *An Introduction to Efficiency and Productivity Analysis*, Kluwer, Norwell, M.A.

Cook, W., Tone, K., & Zhu, J. (2014) Data envelopment analysis: Prior to choosing a model. *OMEGA,* 4, 1-4.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software*. New York: Springer.

Cornett, M. M. & Tehranian, H. (1992) Changes in corporate performance associated

with bank acquisitions. *Journal of financial economics*, 31(2), 211–234.

Cornett, M.M., McNutt, J.J., & Tehranian, H. (2006) Performance Changes around Bank Mergers: Revenue Enhancements versus Cost Reductions, *Journal of money, credit and banking*, 38(4), 1013–1050.

Cowan, A.R. & Salotti, V. (2015) The resolution of failed banks during the crisis: Acquirer performance and FDIC guarantees, 2008-2013. *Journal of Banking and Finance*, 54, 222-238.

Daraio, C., Kerstens, K., Nepomucenon, T. & Sickles, R. (2018) Productivity and Efficiency Analysis Software: An Exploratory Bibliographical Survey of Options, *Journal of Economic Surveys*, 00(0), 1-16.

DeAngelo, H. & Stulz, R. (2015) Liquid-claim production, risk management, and bank capital structure: Why high leverage is optimal for banks. J*ournal of Financial Economics*,116 (2), 219-236.

DeGuevara, J. F. & Maudos, J. (2007) Explanatory factors of market power in the banking system. *The Manchester school*, 75(3), 275–296.

De Haas, R. & van Lelyved, I. (2006) Foreign banks and credit stability in Central and Eastern Europe: A panel data analysis. *Journal of Banking & Finance*, 30, 1927-1952.

DeLong, G. L. (2001) Stockholder gains from focusing versus diversifying bank mergers. *Journal of financial economics*, 59(2), 221–252.

DeYoung, R., Lang, W. W., & Nolle, D. L. (2007). How the Internet affects output and performance at community banks. *Journal of Banking & Finance*, *31*(4), 1033-1060.

Diacon, S. R., Starkey, K., & O'Brien, C. (2002) Size and efficiency in European long-term insurance companies: An international comparison. *The Geneva Papers on Risk and Insurance. Issues and Practice*, *27*(3), 444-466.

Diamond, D. (1984) Financial intermediation and delegated monitoring. *The Review of Economic Studies*, 51, 393-41.

Drake, L. (2001) Efficiency and productivity change in UK banking. *Applied financial economics*, 11(5), 557–571.

Drake, L. & Hall, M. J. B. (2003) Efficiency in Japanese banking: An empirical analysis. *Journal of banking & finance*, 27(5), 891–917.

Drake, L., Hall, M. J.B., & Simper, R. (2006) The impact of macroeconomic and regulatory factors on bank efficiency: A non-parametric analysis of Hong Kong's banking system. *Journal of banking & finance*, 30(5), 1443–1466.

Drake, L., Hall, M. J.B., & Simper, R. (2009). Bank modelling methodologies: A comparative non-parametric analysis of efficiency in the Japanese banking sector. *Journal of International Financial Markets, Institutions and Money*, 19(1), 1-15.

Duchin, R. & Sosyura, D. (2014) Safer ratios, riskier portfolios: Banks' response to government aid. *Journal of financial economics,* 113(1), 1–28.

Dyson, R., Allen, R., Camanho, A., Podinovski, V., Sarrico, C., & Shale, E. (2001) Pitfalls and protocols in DEA. *European Journal of Operational Research,* 132(2), 245-259.

Ensslin, L., Dutra, A., Ensslin, S. R., Chaves, L. C., & Dezem, V. (2015). Research process for selecting a theoretical framework and bibliometric analysis of a theme: Illustration for the management of customer service in a bank. *Modern Economy*, *6*(06), 782.

Faello, J. (2015). Understanding the limitations of financial ratios. *Academy of accounting and financial studies journal*, *19*(3), 75.

Fare, R, Grosskopf, S., Norris, M. & Zhang, Z. (1994) Productivity Growth, Technical Progress, and Efficiency Changes in Industrialised Countries. *American Economic Review*, 84, 66-83.

Fare, R. & Lovell, C. (1978) Measuring the Technical Efficiency of Production. *Journal of Economic Theory*, 19, 150-162.

Farrell, M.J. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, A CXX (3), 253-290.

Figueira, C., Nellis, J., & Parker, D. (2009) The effects of ownership on bank efficiency in Latin America. *Applied economics*, 41(18), 2353–2368.

Frantz, R. (2018) Harvey Leibenstein, and an anomaly called X-Efficiency. *Journal of Behavioral Economics for Policy*, 2(1), 25-31.

Fraser, N.M., Jewkes, E.M., Bernhardt, I., Tajima, M. (2009) Global Engineering Economics: Financial Decision Making for Engineers, *Pearson*, 4th Ed.

Freixas, X. & Rochet, J.C. (1997) “Microeconomics of Banking”, The MIT Press, Cambridge.

Freimanis, K., & Senfelde, M. (2019). Credit Creation Theory and Financial Intermediation Theory: Different Insights on Banks‟ Operations. In *International Scientific Conference: Contemporary Issues in Business, Management and Economics Engineering* (pp. 324-331).

Gertner, R., Gibbons, R. & Scharfstein, D. (1988) Simultaneous signaling to the capita and product markets, *The RAND Journal of Economics*, 19 (2), 173-190.

Girardone, C., Molyneux, P., & Gardener, E. P. M. (2004) Analysing the determinants of bank efficiency: the case of Italian banks. *Applied economics*, 36(3), 215–227.

Goetz, M.R. (2018) Competition and bank stability, *Journal of Financial Intermediation*, 35, 57-69.

Gropp, R., Gruendl, C., & and Guettler, A. (2014) The Impact of Public Guarantees on Bank Risk-Taking: Evidence from a Natural Experiment. *Review of Finance*, 18(2), 457–488.

Guba, E.G. & Lincoln, Y.S. (1982). Epistemological and Methodological Base of Naturalistic Inquiry. *ECTJ, 30(4)*, 233-252.

Hagendorff, J. & and Keasey, K. (2009) Post-merger strategy and performance: evidence from the US and European banking industries. *Accounting and finance (Parkville)*, 49(4), 725–751.

Halkos, G. E., Matousek, R., Matousek, & Tzeremes, N. G. (2016) Pre-evaluating technical efficiency gains from possible mergers and acquisitions: evidence from Japanese regional banks, *Review of quantitative finance and accounting*, 46(1), 47–77.

Hart J. & Apilado, V. (2002) Inexperienced banks and interstate mergers. *Journal of Economic Business*, 54(3), 313-330.

Hasan, I. & Marton, K. (2003) Development and efficiency of the banking sector transitional economy: Hungarian experience. *Journal of banking & finance*, 27(12), 2249–2271.

Heale, R., & Forbes, D. (2013). Understanding triangulation in research. *Evidence-based nursing*, *16*(4), 98. https://doi.org/10.1136/eb-2013-101494

Henriques, I., Sobreiro, V., Kimura, H., & Mariano, E. (2020) Two-stage DEA in banks: Terminological controversies and future directions, *Expert Systems with Applications,* 161.

Houston, J. F., Christopher, M., & Ryngaert, M. D. (2001) Where do merger gains come from? Bank mergers from the perspective of insiders and outsiders. *Journal of financial economics*, 60(2-3), 285–331.

Hsiao, H-C., Chang, H., Cianci, A., & Huang, L-H. (2010) First Financial Restructuring and operating efficiency: Evidence from Taiwanese commercial banks. *Journal of banking & finance*, 34(7), 1461–1471.

Huang, T-H., Shen, C-H., Chen, K-C., & Tseng, S-J. (2011) Measuring technical and allocative efficiencies for banks in the transition countries using the Fourier flexible cost function. *Journal of productivity analysis*, 35(2), 143–157.

Huljak, I., Martin, R. & Moccero, D. (2019) The Cost-Efficiency and Productivity Growth of Euro Area Banks. *ECB Working Paper*, No. 2305,

Isik, I. & Hassan, M. K. (2002) Technical, scale and allocative efficiencies of Turkish banking industry. *Journal of banking & finance*, 26(4), 719–766.

Jiang, C., Yao, S., & Zhang, Z. (2009) The effects of governance changes on bank efficiency in China: A stochastic distance function approach. *China economic review*, 20(4), 717–731.

Jiang, L., Levine, R. & Lin, C. (2016) Competition and Bank Opacity. *The Review of financial studies*, 29(7), 1911–1942.

Joffe, M. & Martinez, J. (2016) Origins of the Puerto Rico Fiscal Crisis. *Mercatus Research, Mercatus Center at George Mason University*, Arlington, VA.

Kaffash, S. & Marra, M. (2017) Data envelopment analysis in financial services: a citation network analysis of banks, insurance companies and money market funds. *Annals of Operations Research*, 253(1), 307-344

Khezrimotlagh, D., Zhu, J., Cook, W.D., & Toloo, M. (2019) Data envelopment analysis and big data. *European Journal of Operational Research*, 274, 1047-1054.

Klein, M. (1971) “A theory of the banking firm”, Journal of Money, Credit, and Banking. 3: 205-218.

Knapp, M., Gart, A., and Becher, D. (2005) Post-Merger Performance of Bank Holding Companies, 1987-1998. *The Financial Review*, 40, 549-574.

King R. G., & Levine, R. (1993). Finance and Growth: Schumpeter Might Be Right. *The Quarterly Journal of Economics*, 108(3), 717-737.

King, T. & Kong, R. (2016). Are all bank acquisitions equal? The Impact of Bank Mergers and Acquisitions around 2007 and 2009 Financial Crisis: Evidence from TARP. *Journal of Accounting & Marketing*, 5:3

Kopecky, K.J. and Van Hoose, D.D. (2012) Imperfect Competition in Bank Retail Markets, Deposit and Loan Rate Dynamics, and Incomplete Pass Through. *Journal of Money, Credit and Banking*, 44, 1185-1205. https://doi.org/10.1111/j.1538-4616.2012.00527.x (accessed January 23, 2022)

Kwan, S. H. (2006) The X-efficiency of commercial banks in Hong Kong. *Journal of banking & finance*, 30(4), 1127–1147.

Lee, S. (2008). *Ownership structure and financial performance: Evidence from panel data of South Korea* (No. 2008-17). Working paper.

Leibenstein, H. (1966) Allocative Efficiency vs. "X-Efficiency”. *The American Economic Review*, 56(3), 392–415.

Lensink, R., Meesters, A., & Naaborg, I. (2008) Bank efficiency and foreign ownership: Do good institutions matter? Journal of Banking and Finance, 32, 834-844.

Lim, G. H. & Randhawa, D. S. (2005) Competition, liberalization and efficiency: evidence from a two-stage banking model on banks in Hong Kong and Singapore. *Managerial finance*, 31(1), 52–77.

Lin, T. & Chiu, S. (2013) Using independent component analysis and network DEA to improve bank performance evaluation. *Economic Modelling*, 32, 608-616.

Mackenzie, N., & Knipe, S. (2006) Research dilemmas: Paradigms, methods and methodology. *Issues in Educational Research, 16*, 193-205.

Manlagñit, M. C. (2011) The economic effects of foreign bank presence: Evidence from the Philippines. *Journal of international money and finance*, 30(6), 1180–1194.

Marxuach, S. (2021) The Threefold Challenge to the Puerto Rican Economy, *Center for the New Economy*, Washington.

McGee, J. (2015). Economies of scope. *Wiley Encyclopedia of Management*, 1-2.

Meeusen, W., and L. van den Broeck (1977), Efficiency Estimation from Cobb-Douglas Production Function with Composed Error, *International Economic Review*, 18, 435-444.

Mester, L. J. (1996). A study of bank efficiency taking into account risk-preferences. *Journal of banking & finance*, *20*(6), 1025-1045.

Mishkin, F. (2007). *The economics of money, banking, and financial markets*. Pearson education.

Mishkin, F. & Eakins, S. (2012). Financial Markets and Institutions (7th ed.). USA: Pearson Education Limited.

Monti, M. (1972). *Deposit, credit and interest rate determination under alternative bank objective function*. North-Holland/American Elsevier.

Nair, A. S. & Vinod, R. (2019) Determinants of the allocative, cost and scope efficiencies of Indian banks. *Applied economics*, 51(5), 509–527.

Nunamaker, T. R. (1985) Using Data Envelopment Analysis to Measure the Efficiency of Non-Profit Organizations: A Critical Evaluation. *Managerial and decision economics*, 6(1), 50–58.

Okeahalam, C. C. (2006) Production Efficiency in the South African Banking Sector: A Stochastic Analysis. *International review of applied economics*, 20(1), 103–123.

Othman, F. M., Mohd-zamil, N. A., Rasid, S. Z. A. , Vakilbashi, A. & Mokhber, M. (2016) Data Envelopment Analysis: A Tool of Measuring Efficiency in Banking Sector, *International Journal of Economics and Financial Issues* , 6 (3) , 911-916.

Ouenniche, J., Carrales, S. (2018) Assessing efficiency profiles of UK commercial banks: a DEA analysis with regression-based feedback. *Ann Oper Res,* 266, 551–587.

Paradi, J., Vela, S. & Zhu, H. (2010) Adjusting for cultural differences, a new DEA model applied to a merged bank. *J Prod Anal*, 33**,** 109–123

Paradi, J. & Zhu, H. (2013) A survey on bank branch efficiency and performance research with data envelopment analysis. *OMEGA,* 41, 61-79.

Pedraja-Chaparro, F., Salinas-Jiménez, J. and Smith, P. (1999) On the quality of the data envelopment analysis model. *Journal of the Operational Research Society*, 50(6), 1999, 636– 644.

Penas, M. F. & Unal, H. (2004) Gains in bank mergers: Evidence from the bond markets. *Journal of financial economics*, 74(1), 149–179.

Peng, Y. & Wang, K. (2004) Cost efficiency and the effect of mergers on the Taiwanese banking industry. *The Service Industries Journal*, 24(4), 21-39.

Peristiani, S. (1997) Do Mergers Improve the X-Efficiency and Scale Efficiency of U.S. Banks? Evidence from the 1980s. *Journal of money, credit and banking*, 29(3), 326– 337.

Ray, S.C. & Desli, E. (1997) Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Comment. *The American economic review*, 87(5), 1033– 1039.

Rezvanian, R., Ariss, R. T., & Mehdian, S. M. (2011) Cost efficiency, technological progress and productivity growth of Chinese banking pre- and post-WTO accession. *Applied financial economics*, 21(7), 437–454.

Rezvanian, R. & Mehdian, S. (2002) An examination of cost structure and production performance of commercial banks in Singapore. *Journal of banking & finance*, 26(1), 79–98.

Rhoades, S.A. (1993) Efficiency effects of horizontal (in-market) bank mergers, *Journal of Banking & Finance*, 17, 411-422.

Ross, A., & Droge, C. (2002) An integrated benchmarking approach to distribution center performance using DEA modeling. *Journal of Operations Management,*

20, 19-32.

Sathye, M. (2001) X-efficiency in Australian banking: An empirical investigation. *Journal of banking & finance*, 25(3), 613–630.

Schaeck, K., Čihák, M., & Wolfe, S. (2006). Are more competitive banking systems more stable?. *IMF Working Papers*, *2006*(143).

Schleifer, A. (2004) Does competition destroy ethical behavior? *American Economic Review*, 94, 414-418.

Schumpeter, J. A. (2016). Bank credit and the "creation" of deposits. *Accounting, Economics and Law: A Convivium*, *6*(2), 151-159.

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

De Servigny, A., Renault, O., & de Servigny, A. (2004). Measuring and managing credit risk.

Shaffer, S. (1993). A Test of Competition in Canadian Banking. *Journal of money, credit and banking*, 25(1), 49–61. doi: 10.2307/2077819.

Shaban, M., Duygun, M., Anwar, M., and Akbar, B. (2014) Diversification and banks' willingness to lend to small businesses: Evidence from Islamic and conventional banks in Indonesia, *Journal of Economic Behavior & Organization*,103, S39-S55.

Sherman, H.D. & Zhu, J. (2006) Service Productivity Management: Improving Service Performance Using Data Envelopment Analysis, (DEA). New York: Springer

Soldatos, G. T. (2020) Dominant bank oligopoly and economic stability. *International journal of finance and economics*. doi: 10.1002/ijfe.2128.

Solomon, E. H. (1970). Bank merger policy and problems: a linkage theory of oligopoly. *Journal of Money, Credit and Banking*, *2*(3), 323-336.

Stigler, G. J. (1964). A theory of oligopoly. *Journal of political Economy*, *72*(1), 44-61.

Sueyoshi, T., & Aoki, S. (2001). A use of a nonparametric statistic for DEA frontier shift: The Kruskal and Wallis rank test. *OMEGA,* 29, 1-18.

Swank, J. (1996). Theories of the Banking Firm: A review of literature. *Bulletin of economic research*, 48(3), 173–207.

Tortosa-Ausina, E. (2002) Exploring efficiency differences over time in the Spanish

banking industry. *European journal of operational research*, 139(3), 643–664.

Werner, R. A. (2014). Can banks individually create money out of nothing?—The theories and the empirical evidence. *International Review of Financial Analysis*, *36*, 1-19.

Werner, R. A. (2016). A lost century in economics: Three theories of banking and the conclusive evidence. *International Review of Financial Analysis*, *46*, 361-379.

Williamson, S.D. (1987) Recent Developments in Modeling Financial Intermediation. Federal Reserve Bank of Minneapolis, *Quarterly Review*, summer, 19-29.

Xia, M. & Chen, J.X. (2017) Data Envelopment Analysis Based on Choquet Integral. *International Journal of Intelligent Systems*, 32 (12), 1312–1331.

Yamazaki, S., & Miyamoto, H. (2004). A note on bank behavior and monetary policies in an oligopolistic market. *Industrial Organization*, *408003*.

Yang, H. & Chang, C. (2008) Using DEA window analysis to measure efficiencies of Taiwanese integrated telecommunication firms. *Telecommunications policy*, 33, 98-108.

Yao, S. (2007) On the Efficiency of Chinese Banks and WTO Challenges. *Applied economics*, 39(5), 629–643.

Yao, S., Han, Z., & Feng, G. (2008) Ownership Reform, Foreign Competition and Efficiency of Chinese Commercial Banks: A Non-parametric Approach. *World economy*, 31(10), 1310–1326.

Yu, P. & Van Luu, B. (2003) Banking Mergers: The Impact of Financial Liberalization on the Taiwanese Banking Industry. *Review of quantitative finance and accounting*, 20(4), 385–413.

Zhu, J. (2020) DEA under big data: data enabled analytics and network data envelopment analysis. *Annals of Operations Research*, doi: 10.1007/s10479-020-03668-8.

Zouari, S. B. S., & Taktak, N. B. (2014). Ownership structure and financial performance in Islamic banks: Does bank ownership matter?. *International Journal of Islamic and Middle Eastern Finance and Management*, *7*(2), 146-160.