Notre Dame University-Louaize
Faculty of Business Administration & Economics
Graduate Division

Measurement of the Efficiency of Lebanese Commercial Banks Using Data Envelopment Analysis

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of the Master of Business Administration (M.B.A.)

NDU-Lebanon
2015

Approval Certificate

Measurement of the Efficiency of Lebanese Commercial Banks Using Data Envelopment Analysis

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DECLARATION

I hereby declare that this thesis is entirely my own work and that it has not been submitted as an exercise for a degree at any other University.

JOELLE JOSEPH CHUKRI

ABSTRACT

Purpose – The banking sector is the backbone of the Lebanese economy, and Lebanese banks hold over half of the public debt. Therefore it is critical to periodically assess their efficiency and profitability. Failure to do so could lead the country to a debt crisis or even bankruptcy. The purpose of this study is to measure the efficiency and productivity of 24 Lebanese commercial banks in 2008, 2011 and 2013.

Design/methodology/approach – To measure relative efficiency, the study employed three Data Envelopment Analysis (DEA) models which are the CCR, BCC and A&P. The Wilcoxon matched pairs signed rank test was used to compare the efficiency scores of the different time periods. Finally, the Malmquist Total Factor Productivity (TFP) index was implemented to compute the productivity of the banks.

Findings – The CCR and BCC scores were high for the three years under study. 2013 witnessed the best efficiency levels, and an investigation of its scores showed that overall technical inefficiency was mainly due to pure technical inefficiency. The Wilcoxon matched pairs signed rank test revealed that the average CCR and BCC efficiencies didn't significantly change in the aftermath of the Global Financial Crisis, but they significantly increased after the eruption of the Arab Spring. A comparison of the A&P scores with some key ratios of banks performance exposed no clear association between them. Finally, the Malmquist TFP index demonstrated that the productivity of banks improved by 6.3% from 2008 to 2013.

Research limitations/implications – The limitations of this study are the accuracy of the published data for banks, and the drawbacks of the DEA methodology.

Practical implications – The profitability challenges that banks are facing in the aftermath of the Global Financial Crisis make cost cutting and adopting more efficient operating models as important as ever. Additionally, the banking sector plays a crucial role in economies and namely the Lebanese economy. Therefore regulators and banks should periodically implement models similar to the DEA technique proposed in this study for efficiency measurement.

Originality/value – Despite the continuous need for monitoring the efficiency of Lebanese banks, previous studies covered a period till 2009. Therefore, as a result of the rapid developments the sector has witnessed since then, their results are no longer credible. This study seeks to fill this gap by measuring the efficiency and productivity of Lebanese banks in more recent years.

Keywords: Banks; Lebanon; Efficiency; Data Envelopment Analysis; CCR; BCC; A&P; Scale Efficiency; Productivity; Malmquist TFP index; Wilcoxon Matched Pairs Signed Rank Test; Global Financial Crisis; Arab Spring

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ACKNOWLEDGEMENTS

I wish to extend my deep admiration and gratitude to my supervisor Dr. Viviane Naimy. In addition to being a great source of inspiration, her expertise and guidance were indispensable for the completion of this work.

I would also like to thank my thesis reader Dr. Roy Khoueiri, and all the committee members.

Additionally, I am genuinely appreciative for all those who supported me while writing this MBA thesis. Namely, I want to thank:

My parents, who showed me that the keys to achievement are hard work, love and sacrifice.

My uncle, who has always been an immense source of motivation and inspiration.

My siblings, who make my world an amazing place.

My relatives, of whom I am really proud.

My friends, who constantly fill my heart with joy. I extend particular appreciation to the person who unrelentingly supported and encouraged me throughout this work.

Finally, I am thankful for NDU and all its directors, academic and administrative staff, for seven years of invaluable education and everlasting memories and friendships.

I ultimately thank God and Virgin Mary for their continuous and splendid blessings of Grace, Peace and Love!

CONTENTS

CHAPTER 1

Introduction

1.1 Brief Overview of the 2007-08 Financial Crisis

The collapse of Lehman Brothers, a global bank headquartered in New York, in September 2008 nearly brought down the world's financial system. This failure was one of the incidents of the 2007-08 financial crisis which was the most significant crisis faced by the banking industry since the great depression. It proved to the world that banks are no longer modest middlemen solely fulfilling their core function of accepting deposits and granting loans. However they have developed to become "too big to fail" interconnected institutions having at their command most of the money capital of the global economy.

Among the most considerable causes for the crisis were subprime mortgages. Before 2000, only prime borrowers had the opportunity to obtain residential mortgages in the U.S. However, homeownership for riskier borrowers was a long sought national goal. To achieve this goal, a favorable environment for the rapid growth of the subprime mortgage market was created in the U.S. This market is based on the securitization process in which subprime mortgages are pooled together and securities, significantly mortgage backed securities (MBS) and collateralized debt obligations (CDOs), backed by the cash flows of the pools are structured. These securities became popular as they offered the attractive feature of high return while risk was tailored to meet investors preferences. Moreover, they were insured against default using Credit Default Swaps (CDS).

The subprime mortgage market in the states took off becoming over a trillion market by 2007. It was aided by liquidity inflows from countries like China and India, lower interest rates and increase in overall consumption and leverage in the U.S. Decreasing underwriting standards was another contributor since mortgage brokers or banks had little incentive to verify that the mortgage is a good credit risk. Their main concern was earning fees from a higher sale volume of securities. U.S. homeownership rates rose to

the highest level in history which distracted regulators from noticing the risks accumulating in the financial system. Credit rating agencies highly rated these securities as they did not understand their downturn. The structured products were increasing in complexity in that it was hard to determine their cash flows and their ultimate owners, therefore it became hard to value them.

As demand and funding for subprime mortgages increased, the housing price bubble surfaced. However after prices reached their peak in 2006, the bubble burst and prices started to fall revealing the rot in the financial system. Mortgages exceeded the value of houses leading to defaults and foreclosures. A run on the shadow banking system started. In this system, financial institutions have short-term liabilities such as repurchase agreements (or repos) which use longer-term assets like MBS as collateral. As uncertainty increased, liquidity decreased and institutions were unable to refinance their long term obligations. As a result they started deleveraging and selling off assets which led to further uncertainty and price decreases.

The first disruption of credit markets came from Europe which signals how interconnected financial markets have become. It was when BNP Paribas announced on August 9th, 2007 that it was incurring large subprime mortgage losses. Following was the British bank Northern Rock which ran out of liquid assets in September 2007 and asked the Bank of England for a loan resulting in the first bank run in the UK for over a century. The next unpleasant surprise was the collapse of the large investment bank Bear Stearns, in March 2008. After the Federal Reserve agreed to guarantee $30 billion of the banks' toxic assets, it was forced to sell itself to J.P. Morgan for less than 5% of what it was worth a year before. Despite the losses that resulted at this stage of the crisis, forecasters predicted only a mild recession and hoped the worst was over.

However, in mid-September 2008 the financial crisis entered into a more virulent phase. On Monday September 15, 2008 Lehman's brothers, the fourth-largest investment bank by asset size filed the largest bankruptcy in U.S. history. The bank had over USD 600 billion in assets and 25,000 employees. Significant events that occurred after this failure are the collapse of the insurance giant AIG on September 16, 2008; the run on the reserve

primary fund on the same day and attempts to get the Troubled Asset Relief Plan (TARP) approved by congress over the following couple of weeks.

After September 2008, runs on the shadow banking system worsened which resulted in severe losses for financial institutions. Uncertainty increased and banks were unwilling to lend each other despite liquidity injections by Central banks to maintain the market and prevent the failure of individual institutions. The crisis then became a full-fledged, global financial crisis. The treasury Bill-to-Eurodollar rate (TED) spread which is a good measure of liquidity in the interbank market, rose from 300 bp (basis points) before Lehman's bankruptcy to 450 bp in October 10, 2008. Funding costs increased, liquidity nearly disappeared from vital markets, the stock market plunged and by the end of 2008 had fallen by over half from its peak in the fall of 2007.

1.2 The Need for Measuring the Efficiency of the Global Banking Industry

As described previously, the recent financial crisis revealed several inefficiencies in the banking sector, most significantly inefficiencies in the implementation of risk management practices, in diversifying sources of income and in containing costs. In the aftermath of the crisis, it is crucial for banks to measure and address these inefficiencies in order to overcome their short-term and long-term challenges.

On the short run banks should repair their balance sheets. This will include writedowns of bad assets; thus incurring losses on stakeholders, and recapitalization; which could be assisted by public funds. With their balance sheets repaired, banks will regain markets' confidence. Consequently their liquidity position will improve by having access to traditional funding sources both domestically and internationally.

On the long run, banks will have to adjust to the new financial environment molded by the lessons learnt from the crisis. As regulators are re-writing their rulebook and increasing capital requirements, banks profitability is put under great pressure. Profitability is also threatened by a rise in funding costs. In the post-crisis period the role of central counterparties will increase and the collateral they require for financial

transactions will most likely encumber a greater share of banks assets. All else being equal, high asset encumbrance along with the new resolution frameworks entailing greater losses on bondholders in the case of a bank's default, will permanently increase banks funding costs. Additionally, the withdrawal of official support constitutes another source of upward pressure on banks funding costs. These challenges require banks to seek ways in which they can boost their profitability and offset their increasing financing costs. This could be done through adopting more aggressive cost management strategies and efficient operating models. Cost cutting, which is a natural post-crisis strategy in any sector, has the potential to lead to a sustained recovery and a more agile business model more responsive to the turbulent risk environment, thus decreasing the possibility of bank failure.

1.3 The Need for Measuring the Efficiency of the Banking Industry in Lebanon

Lebanese banks remained to a large extent shielded from the effects of the financial crisis, however they are subject to the resulting regulations and stringent capital requirements. Consequently, they face similar profitability challenges as banks worldwide and need to adopt more efficient operating models. Furthermore, characteristics of the industry in Lebanon and national goals increase the importance of efficiency measurement.

The banking sector remains the backbone of the republic's service oriented economy. This sector has shielded the economy against major shocks that had the potential to destroy it, such as the Financial crisis and the Arab spring (to list the recent events). Lebanese banks are also the major creditors of the Lebanese government as they hold over half of the public debt. Therefore it is critical to make sure they are operating efficiently and profitably. Failure to do so could undermine the economy's ability to withstand future disruptions. It could also lead the country to a debt crisis or even bankruptcy.

There are 73 active banks (including foreign banks) operating a total of 985 branches in Lebanon (Association of banks in Lebanon, 2013). This large number of banks serving an almost saturated market results in an intense rivalry in the industry which increases the importance of operating at optimal efficiency levels and reducing costs. Some banks have chosen geographical expansion to cater the needs of new markets instead of (or along with) competing for further market share in Lebanon. Still, this strategy requires certain efficiency standards.

In addition to this, amidst the ongoing turmoil in neighboring countries, the profitability of the Lebanese banks is stagnating. Further analysis of profitability and efficiency ratios (return on average equity, return on average assets and cost-to-income) show that Lebanese banks are underperforming compared to other emerging markets (Bank Audi, 2014). Therefore, they need to start working seriously on improving their efficiency, which could help them boost their profitability despite regional tensions.

Finally, an accelerated consolidation activity will probably start in the Lebanese banking sector after the World Bank and the U.S. Treasury Department proposed to Central Bank Governor to reduce the number of working banks to 25 within a period of five years. Efficiency scores will be helpful in assessing the success of these consolidations by measuring the efficiency of banks before and after the mergers and acquisitions.

1.4 Data Envelopment Analysis as the Efficiency Measurement Method

Performance evaluation and benchmarking are methods used to identify and adopt best practices. Data Envelopment analysis (DEA) is a non-stochastic, non-parametric, linear programming (LP) based method used for this purpose, it measures the relative efficiency of similar decision-making units (DMUs) with common inputs and outputs.

DEA is superior to alternative measures of efficiency because it allows the usage of multiple inputs and outputs without prior assumptions of the production function or the weights of the factors of production. It is a generic method that has been used in analyzing DMUs in different industries such as hospitals, universities, cities, banks,

courts and business firms. We will implement DEA to measure the relative technical efficiency of Lebanese Commercial Banks (LCBs).

Despite the large literature discussing usage of DEA to measure bank's efficiency in several countries, studies remain limited in the Lebanese context. Moreover, even with the urgent need for periodically monitoring the efficiency of Lebanese banks, previous studies covered a period till 2009. Therefore their results are no longer credible since they don't reflect the latest developments in the industry. For this purpose it is crucial to conduct new studies that cover the more recent years which is the ultimate aim of this research.

1.5 The Purpose of the Study

This study seeks to implement DEA to compute the technical efficiencies of Lebanese commercial banks in 2008, 2011 and 2013. Since 2013 is the most recent year, its results are explored in depth in order to reveal the specific sources of inefficiency, and suggest strategies for improvement. As for 2008 and 2011, they are included since they represent respectively the year of the outbreak of the global financial crisis, and the year of the eruption of the Arab spring. Their efficiency scores are calculated and compared together and with those of 2013, in order to examine the performance of Lebanese banks during this turbulent time period. Additionally, the banks are ranked according to their 2013 efficiency results and the scores are compared to some key ratios of banks performance. Finally, the Malmquist TFP index is implemented to calculate and decompose the productivity of the banks.

The study covers the following banks:

1. B.L.C Bank S.A.L.
2. Bank Audi S.A.L.
3. Bank of Beirut S.A.L.
4. BankMed S.A.L.
5. Banque Bemo S.A.L.

6. Banque de L'industrie et du Travail S.A.L.
7. Banque Libano-Francaise S.A.L.
8. Banque Pharaon et Chiha S.A.L.
9. BBAC S.A.L.
10. BLOM Bank S.A.L.
11. BSL Bank S.A.L.
12. Byblos Bank S.A.L.
13. Credit Libanais S.A.L.
14. CreditBank S.A.L.
15. Fenicia Bank S.A.L.
16. First National Bank S.A.L.
17. Fransabank S.A.L.
18. IBL Bank S.A.L.
19. Jammal trust Bank S.A.L.
20. Lebanese Swiss Bank S.A.L.
21. Lebanon and Gulf Bank S.A.L.
22. MEAB S.A.L.
23. Near East Commercial Bank S.A.L.
24. Société Générale de Banque au Liban S.A.L.

1.6 Brief Overview of all Chapters

This paper is organized in the following fashion. Chapter two presents an overview of the Lebanese economy and banking industry.

Chapter three covers the methodology. It explains the de+rivation of the DEA and elaborates the different models that are implemented. It also introduces the Wilcoxon matched pairs signed rank test and the Malmquist index that are used respectively to compare the scores of the different years under study and calculate the productivity of banks.

Chapter four explores the literature of efficiency measurement, namely DEA. It presents an overview of the previous studies conducted on the banking sector worldwide and in Lebanon. It is also devoted to the selection of the input and output factors.

Chapter five presents the DEA scores of 2008, 2011 and 2013. It further investigates the 2013 results, and evaluates the performance of the banks during the different years under study. It also lays out a ranking of the banks in 2013, and compares the efficiency scores obtained during that year to some key ratios of banks performance. Finally the Malmquist TFP index is implemented in order to compute the productivity of banks.

Chapter six concludes the thesis and recommends measures to improve the efficiency scores. It also presents the limitations of the study, and provides suggestions for future research.

CHAPTER 2

The Lebanese Economy and Banking Sector

2.1 Introduction

The purpose of this chapter is to present an overview of the Lebanese economy and banking sector. The overview will serve primarily as a further elaboration to highlight the necessity of measuring the efficiency of the Lebanese banking sector. This in turn will reinforce the need for our study which aims at implementing Data Envelopment Analysis to measure the efficiency of the Lebanese commercial banks.

2.2 The Lebanese Economy

The rebellious nature of the economy of Lebanon confuses economists. Axel Shimmelpfennig and Edward Gardner stated in an IMF working paper that Lebanon has few competitors in challenging models of financial crisis and debt sustainability. Then, they conveyed that the country has one of the highest public debt levels in the world and based on what is already known from economic models or experience, it should have undergone a debt crisis long ago. Instead, Lebanon managed to withstand a large number of shocks that had the potential to completely destroy its economy.

In order to understand the background of this puzzling economy, an overview of the Lebanese economic system will be first presented. It will be followed by a summary of the milestones in the history of the economy's development. Finally the current state of the economy will be discussed.

a. Economic System

Lebanon has a long and established tradition of an open and free market economy. The country enjoys domestic free trade and investment policies, free market pricing for the majority of goods and services, unrestricted exchange and trade systems and extensive ties with the developed world in almost all economic activities (Ministry of Finance, 2013).

The economy continues to be based on private initiative while public ownership has generally been limited to infrastructure and utilities. The major role of the private sector is favored by a liberal policy environment and the lack of restrictions on the movement of capital and goods by residents and non-residents of the republic. To illustrate, there are no legal restrictions on establishing and operating private businesses in the republic (subject to limited exceptions) and foreign investors can import or export capital in any form they want as there are no exchange controls (Ministry of Finance, 2013).

However, despite the favorable liberal policy system, it is worth noting that the Lebanese investment climate suffers from several issues such as red tape, corruption, arbitrary licensing decisions, complex customs procedures, high taxes, tariffs and fees, archaic legislation, and weak intellectual property rights (Central Intelligence Agency, 2014) .

The Lebanese economy is service-oriented and the main growth sectors include banking and tourism. Between 1997 and 2011, the services sector accounted on average to 73.5% of real GDP and as shown in figure 1 it is still the major contributor to the country's GDP.

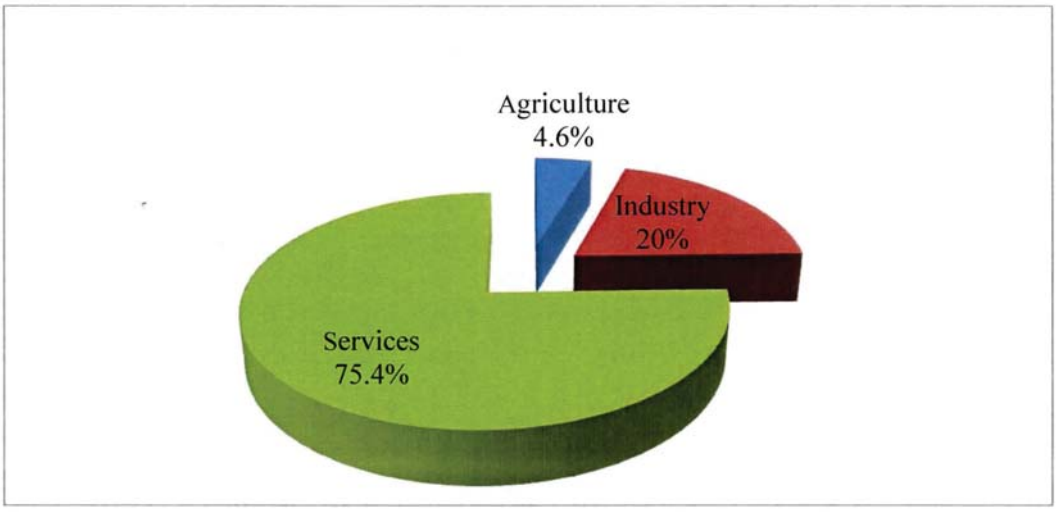

Figure 1 : Composition of GDP by Sector of Origin

(Source : Central Intelligence Agency)

b. Historical Overview

1960-1975 : Prosperity

The economic system described above allowed Lebanon to become in the 1970s a democratic upper-middle income country serving as a regional service center on the crossroads between Europe and the Middle East. At that time the country had little debt, a low dollarization rate, a floating exchange rate and a good trade balance. The economy was driven by a vibrant private sector supported by a small sized public sector. Economic growth averaged 5% during the period from 1960-1970 and it accelerated to 7% per year from 1970 to 1975 (Ministry of finance, 2013). The main driver of growth was the services sector particularly banking, tourism, insurance and free port activities. The banking sector supported by a stable liberal regime, a freely convertible currency, proper regulations and talented management allowed Beirut to become a financial center to the Middle East.

1975-1990 : The Civil War

However, Lebanon was at the crossroads of international politics and regional conflicts as well, which have contributed to the outbreak of the war that lasted from 1975 to 1990. This war caused aggregate national output to decline, ended the dominance of Beirut as the shipping center of the Eastern Mediterranean, and destroyed the country's reputation as the banking sector of the Middle East. Resulting damage to infrastructure and physical assets amounted to $25 billion according to U.N. estimates. Loss of human resources was even more dramatic; 131,000 deaths and 500,000 emigrants. Confidence in the Lebanese Lira eroded. Inability to collect government revenue during the war was coupled with increased spending on public services. As a result the government was incurring large and rapidly growing fiscal deficits that were often financed by loans from the Lebanese Central Bank. These negative developments plunged the country into a vicious cycle of large fiscal deficits leading to monetary expansion and inflation. This in turn translated into dollarization of the economy and capital outflows which caused a striking depreciation of the Lebanese Pound and further inflation.

1991-2006: Post-War Period and the Public Debt

The Lebanese Central Bank continued providing loans to fund the budget deficit until the end of 1992, thus sustaining the rise in inflation and the deterioration of the exchange rate. Starting 1993, to renew confidence in the Lebanese pound and attract FDIs (Foreign Direct Investments) a pegged exchange system was adopted fixing the LBP against the U.S. dollar[1]. At this stage, the

Lebanese Central Bank discontinued financing the budget deficit, which started relying on market borrowings (mainly from commercial banks) at extremely high interest rates reaching 45% per annum. The official guarantee, fixed exchange rate and high returns made public debt financing very attractive.

This plan was accompanied with postwar reconstruction and a massive expansionary budget policy that continued until 1998. Between 1993 and 1997 public expenditures were rising at a real average of 22.4% per annum against a 9.6% yearly rise for revenues. Consequently, the budget deficit jumped from USD 2.5 billion in 1992 to USD 19.47 billion in 1998 and 31.5 billion in 2002 (Naimy, 2004). Gross debt to GDP ratio rose from 50% in 1993 to 109% in 1998 and 153% in 2002 (Ministry of finance, 2014).

The costly financing of the rising public deficits, the unfavorable macroeconomic context and the paradoxical government policies carried the public debt servicing to a point of no return. Naimy (2004) elaborated the root causes of the deteriorating economic situation that has been prevailing in Lebanon since the beginning of the post-war period until today under the following titles:

- **Administrative shortcomings:** Public administration in Lebanon has been suffering from corrupt leadership and management, low efficiency and productivity, and unqualified personnel, etc. These problems led to budget burdens for the economy. They can be mainly attributed to the divisive nature of the Lebanese political system (based on familial and confessional differences) which hinders the formation of a modern state where the rule of citizenship prevails.

[1] The Lebanese Pound expressed in USD: 1 dollar = 1500 Lebanese Pounds

- **Costly reconstruction:** Post-war reconstruction projects were financed by short-term external loans at high interest rates. They were less effective in aiding the recovery of the economy because of their extremely high costs, bribes, and tenders which were concluded sometimes by mutual agreement instead of legal competition. Additionally, since these projects required time to become profitable, the reimbursement of their loans was done through new loans which further contributed to increasing total debt.

- **An economy that serves its currency:** Confidence in the Lebanese pound is temporary since it has been favored by the higher returns earned on this currency and not by conviction. Moreover, the fiscal deficit has been consuming a large portion of the total budget revenue, which drained the country's earnings and failed to make the national currency a real reserve currency. Both dilemmas have contributed to the high dollarization of the economy. Foreign currency has been mostly used by the private sector to fulfill payments and obtain loans, since the domestic currency has been devoted to financing the public sector.

- **Fiscal inequality:** The fiscal system in Lebanon requires major reforms to make it favorable for economic recovery and social justice. The reforms should include fighting illegal enrichment, increasing public revenues (by adopting a progressive tax system and improving collection procedures) and reducing the budget deficit.

- **Low return on investment:** Lebanon has been suffering from a severe crowd-out effect since 1995. The high yields generated by investing in Lebanese treasury bonds discouraged investments in the private sector, which generate lower returns. Consequently, this sector has been suffering from financing difficulties.

c. Recent Developments

The Global Financial Crisis

Despite its weaknesses, Lebanon defied odds with its economic resilience amidst the global financial crisis introduced in the previous chapter. As shown in figure 2, the country managed to achieve a real GDP growth rate of 9.1% in 2008 when paradoxically,

many emerging market countries were deeply embroiled in the global economic crisis. After Lehman's bankruptcy, the crisis intensified and a recessionary environment prevailed in the world. Lebanon looked extremely vulnerable for an emerging market financial crisis. It had one of the highest government debt-to-GDP ratios in the world, a well developed and largely dollarized banking system highly exposed to the government and a currency pegged to the dollar (IMF, August 2009). Fortunately, Lebanon mocked the doomsayers and its economy remained solid growing at 10.3% in 2009. This unexpected resilience was the result of a strong banking sector, a prudent central bank and an unprecedented rebound in tourism activity.

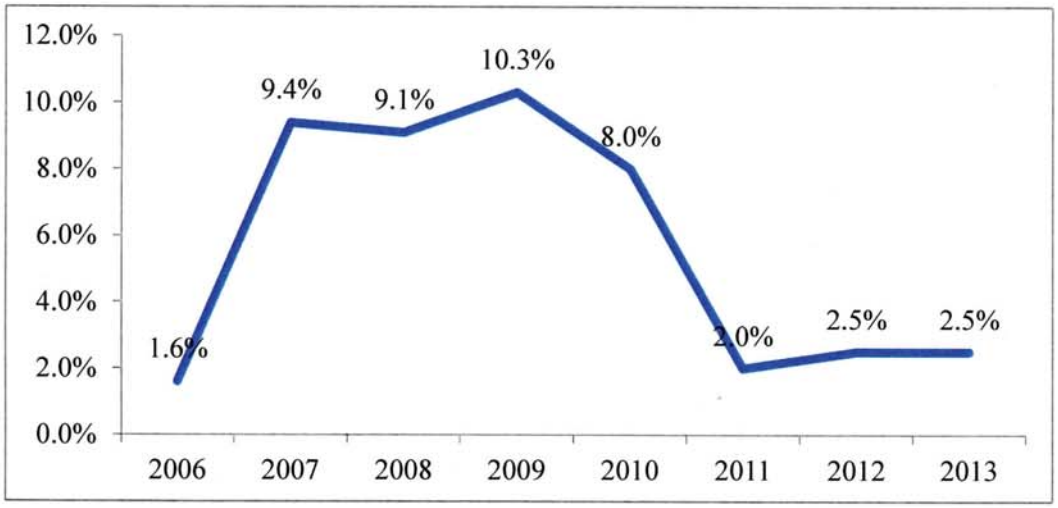

Figure 2 : Real GDP Growth Since 2006 (%)

Association of banks in Lebanon ABL 2013 annual report (Source : Banque Du Liban)

The Arab Spring

After the financial crisis, the Arab spring surely made it to the highlights of Lebanon's economic history. For decades, several Arab countries were ruled by authoritarian regimes and dictators who restricted civil liberties and exploited the resources of the economy for their own benefits. The years of oppression these countries were subjected to, caused a sentiment of resent to build up among citizens resulting in a viral wave of pro-democracy demonstrations and protests (both non-violent and violent), riots and civil wars. The revolutionary events started in Tunisia in December 2010 and spread

throughout the Arab League and its surroundings. By December 2013, leaders were forced out from power in Tunisia, Egypt, Libya and Yemen while civil unrest erupted in Bahrain and Syria. Rulers in Algeria, Jordan, Morocco and Oman presented various concessions to stop the spread of protests in their countries (Encyclopædia Britannica, 2015).

Lebanon was shielded from the Arab spring phenomenon, however it is suffering from its political and economic spillovers. The reasons for this are the republic's proximity to Syria where civil war clashed in 2011, and Lebanon's connections with the various neighboring Arab countries.

Deteriorating Macroeconomic Conditions

The neighboring turmoil has negative implications on the Lebanese economy. As shown in figure 2, real GDP growth rate slumped reaching 2% in 2011 and 2.5% in both 2012 and 2013. The 2.5% growth in 2013 is below the world average of 3% and below the average of oil-importing MENA countries of 2.7% (Association of banks in Lebanon, 2013). The decline in economic growth was caused by a decrease in security and an increase in uncertainty which depressed traditional drivers of growth; real estate, construction and tourism.

Inflation was controlled at an average of 4 percent, while the external current account deficit remained large. Unemployment and poverty increased as Lebanon was open to receiving an unprecedented inflow of refugees, estimated to make up a quarter of the Lebanese population in 2014. They came mainly from Syria, settled throughout the country and in some regions their number exceeds the Lebanese population (IMF, May 2014).

Additionally, fiscal imbalances increased as the primary fiscal position became negative in 2012 for the first time since 2006, and it further decreased in 2013. This was the result of spending pressures coupled with a revenue decline from weak economic activity and policy decisions (such as the introduction of a VAT exemption on gasoline and the implementation of a cost of living adjustment for public sector wages) (IMF, May 2014).

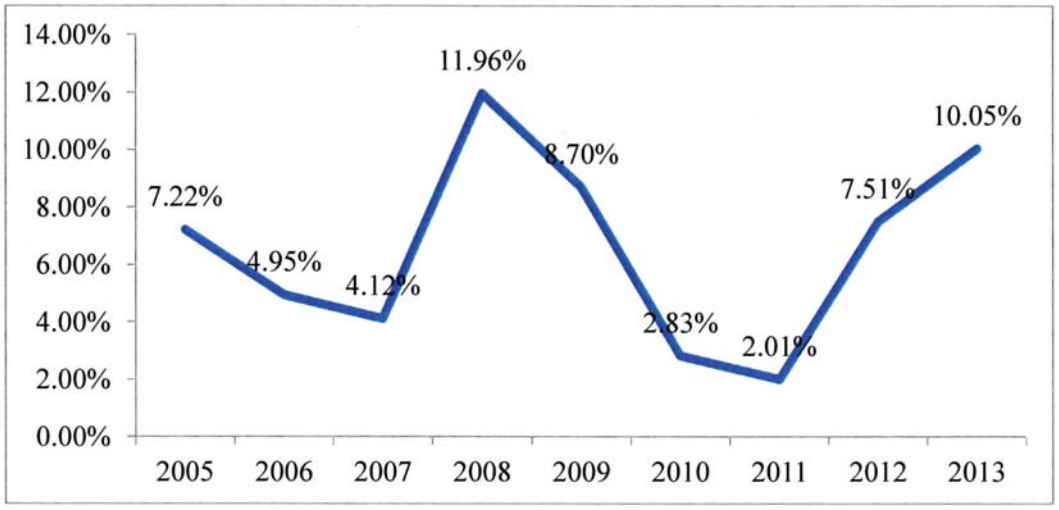

Figure 3 : Percentage Change in Gross Total Debt (%)

(Source : Ministry of Finance / Banque du Liban and author's calculation)

This is illustrated in figure 3, which shows that the growth in gross total debt followed a steep upward trend after a significant decrease in 2011 to 2.01%, when gross total debt was LBP 80,887 billion. In 2013, this growth stood at 10.05% resulting in LBP 95,696 billion in net total debt (Ministry of Finance, 2014).

Gross public debt as a percentage of GDP, which is an important measure of a country's indebtedness, has been very high for the Lebanese economy signaling that public debt has been increasing at a rhythm superior to GDP. Additionally, this ratio stands at alarming levels according to global benchmarks. In fact, Finger and Mecagni found in an IMF paper published in May 2007 that 60% of sovereign debt crises in emerging economies occurred when debt levels in the year preceding the crisis exceeded 39% of GDP. Moreover, a 50% probability of being in a debt crisis is associated with a debt-to-GDP ratio of 80%. In Lebanon, as shown in figure 4, the debt to GDP ratio far exceeds the cutoff level between sustainable and unsustainable debt levels. However, till now, the country is shielded against a debt crisis since 75.7% (The World Bank, 2014) of gross public debt is held by the highly liquid commercial banks and the central bank.

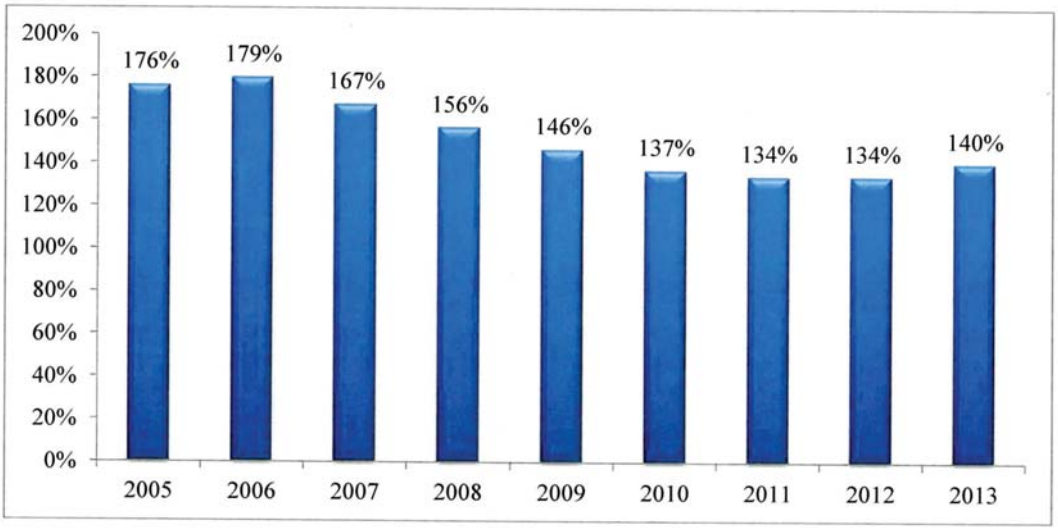

Figure 4 : Gross Public debt as a Percentage of GDP (%)

(Source : Ministry of Finance)

Rating agencies downgrade the Republic of Lebanon

The worsening macroeconomic conditions described above, caused concerns among rating agencies. Consequently, as shown by Table 1, the republic was downgraded by two agencies as of December 2014. The major reasons stated in their reports for the lower ratings can be summarized as follows:

1- Deterioration of Lebanon's macroeconomic fundamentals including its fiscal balances and growth prospects

2- Large and rising public debt burden (Lebanon is the third most heavily indebted rated sovereign)

3- Constrained policy making reflecting a divisive political environment and adverse spillover effects from the Syrian crisis on political stability

Rating Agency	Tenor	Previous Rating	New Rating	Outlook
Standard & Poor's	Long-term Short-Term	B B	B- B	Negative(Nov.1,2013)
Moody's Investors Service	Long-term	B1	B2	Negative(Dec.16,2014)
Fitch IBCA Ltd.	Long-term Short-Term	B B	B B	Negative(Jun.13,2014)

Table 1 : Republic of Lebanon Sovereign Ratings

(Source : Rating Agencies Press Releases and Research Updates)

Signs of Resilience

After they explained their motives behind downgrading the republic, rating agencies added to their reports that Lebanon's creditworthiness is favored by the strong confidence in the large, liquid and well-regulated banking sector. This sector continues to channel deposits mostly from the large Lebanese Diaspora to the Lebanese government, which has a perfect track record of public debt repayment. Deposit growth, despite being slightly lower than its 9% level in 2013, reached 7.9% year over year at end April-2014. This growth level is enough to cover the financing needs of the government (Fitch IBCA Ltd., 2014).

They also added that Lebanon is a net external creditor which is also considered a sign of resilience. This is due to local banks holding of the public debt and the stable buildup of foreign exchange reserves which reached USD 45.6 billion (including gold) at end-April 2014. These reserves are crucial to maintain the peg of LBP to the US dollar given the high dollarization of the economy and the structural current account deficit. (Fitch IBCA Ltd., 2014).

Another sign of resilience in the Lebanese economy was discussed by the IMF in its 2014 Consultation Mission Concluding Statement. It is the central bank's continuous efforts to preserve stability by financing the government, accumulating reserves and supporting

credit to the private sector by providing banks with low-cost funds to lend to specific sectors.

2.3 The Lebanese Banking Sector

a. Overview

The previous section emphasized ways in which the banking sector has been a crucial pillar of Lebanon's economy. Namely, the sector has shielded the economy against major shocks and it has been the major creditor of the Lebanese government. Banks have also played other equally important roles such as financial intermediation, payments, guarantor, investment adviser, agency and policy roles .

The global financial crisis described in the previous chapter, was one of the recent shocks the Lebanese banking sector successfully withstood. As a result, the sector earned international attention and admiration. While governments in most developed countries rushed to bailout major banks and financial institutions during the crisis, the Lebanese Central Bank did not intervene to support financial intermediation, nor did it pump additional liquidity. No changes were witnessed in interest rates of monetary policy instruments. Moreover, no liquidity imbalances arose in the interbank market and no measures were taken in favor of dealing with bad assets or restructuring and recapitalizing banks. Instead, as shown in table 2, important banking aggregates were growing at a rapid pace.

	2008	2009	2010
Assets	12.8%	21.7%	11.9%
Loans to Customers	24.9%	15.6%	25.2%
Customer Deposits	13.9%	23.4%	12.4%
Net Profits for the year	26.6%	17.4%	28.6%

Table 2 : Growth Rates of Banking Aggregates During and After the Financial Crisis

Bank Audi Lebanon Banking Sector Report 2014 (Source : Bankdata Financial Services)

However, the rapid growth enjoyed by the banking sector during and after the financial crisis did not last long. The outlook for the republic didn't seem promising after the eruption of the Arab spring in December 2010. Internal factors relating to the Lebanese economy and political situation also worsened the situation. Consequently, the performance of the banking sector slowed compared to the 2008-2010 period. Nevertheless it remained good and the sector remained resilient as further elaborated in the following sector analysis.

b. Lebanese Banking Sector Analysis: 2013[2]

As previously mentioned, the Lebanese banking sector remained resilient amidst the Arab spring. The sector enjoyed a strong activity performance and a sound risk profile despite the contracting return indicators. The below analysis further explains the different aspects of the sector's performance in 2013.

Growth

We will start our analysis by the total sector activity. It is measured by the aggregation of assets of banks operating in Lebanon which increased by 9.7% in 2013 to reach USD 199 billion in assets at year end-2013. Deposits were the main contributors to banking sector activity as they have increased by 9.5% in 2013 which was their highest growth rate in three years. The USD 14.3 billion increase in deposits strengthened banks funding base, with deposits accounting for 82.6% of the aggregate balance sheet at year end-2013.

Lending Quality and Provisioning

Lebanese banks witnessed in 2013 the highest growth in loans since the beginning of the Arab Spring. Net loans increased by 15.2% to reach a total of USD 62 billion at end-2013. This growth was partially supported by significant stimulus packages from the Central Bank .

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[2] All Figures in the sector analysis are from "Bank Audi - Lebanon Banking Sector Report 2014" unless otherwise stated. The report used the following sources: Bankdata Financial Services, Central Banks, Fitch, Bankscope and IMF

Despite the worsening economic conditions, asset quality slightly improved as a result of active remedial management and progress in risk management. This was represented by the decrease in the ratio of doubtful loans to gross loans (NPLs/Total loans) from 7.1% in 2012 to a record low over the past decade of 6.8% in 2013. While this ratio was above the regional average of 4.6%, it was in line with emerging markets and world ratios of 6.7% and 6.6% respectively. Provisioning

level as measured by the coverage ratio (LLRs/NPLs) for the Lebanese banking sector was good as it stood at 77.7% compared to a regional average of 88.3% and 84.7% and 74.3% emerging markets and world averages.

Liquidity and Sovereign Exposure

In addition to a strong activity and lending growth, the Lebanese banking sector remained highly liquid by all standards as proved by the loans/deposits ratio which constitutes a parallel image to banks liquidity. As shown by figure 5 this ratio was 37.7% for Lebanese banks which was significantly below MENA, Emerging markets and World averages of 70.2% 77.1% and 83.1% respectively. The high liquidity was mainly due to the central bank's reserve requirements (25% for local currency sight deposits and 15% for all other deposits) and the steady and growing deposits Lebanese banks receive. However, high liquidity indicates bad liquidity management among Lebanese banks.

Sovereign exposure increased for Eurobonds, as the ratio of Lebanese sovereign Eurobonds to deposits in FC (Foreign Currency) rose from 13.4% in 2012 to 15.7% in 2013. While for CDs, the ratio of BdL's (Banque du Liban) CDs in FC to deposits in FC decreased from 6.8% in 2012 to 4.3% in 2013. Similarly, exposure on the Lebanese Pound (LBP) increased for Treasury Bills (TB) as the ratio of TBs in LBP to deposits in LBP rose from 39.6% in 2012 to 41.5% in 2013. The ratio of BDL CDs in LBP to deposits in LBP decreased from 33.6% in 2012 to 32.1% in 2013. While exposure was high for the LBP which holds no genuine default rate, it was quite bearable on the foreign currency side which is riskier.

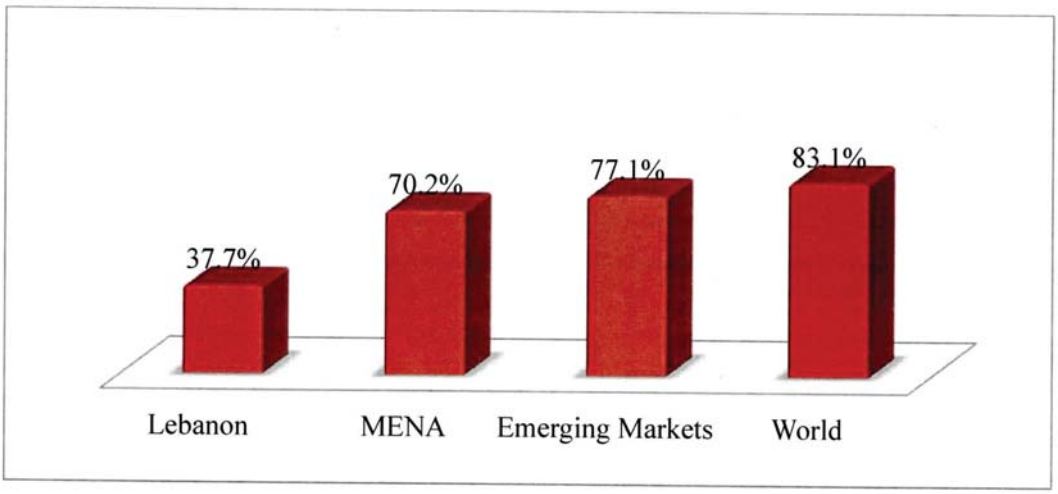

Figure 5 : Loans/Deposits (2013)

Bank Audi, Lebanon Banking Sector Report 2014 (Source : Bankdata Financial Services, Central Banks, Fitch)

Capital Adequacy and Solvency

The parallel image of capitalization, which is the leverage ratio of average assets to average equity, decreased from 11.3 in 2012 to 11.1 in 2013. Nevertheless, benchmarking with international standards showed that Lebanon had an acceptable level of leverage .

Lebanon is currently working toward meeting the capital requirements of Basel III by the end of 2015, which implies minimum common equity Tier 1, Tier 1 and total capital ratios of 8%,10% and 12% respectively. Banks are ready to meet these more stringent capital requirements since they have high Basel II Tier 1 and capital adequacy ratio and their capital is largely made of common equity. However, the way banks calculate the risk-weighted assets (RWA) and the credit equivalent amount (CEA) is still unknown.

Profitability and Efficiency

Profitability was the worst performer among the other aspects discussed above. Profits were stagnating registering a mild 0.5% increase relative to 2012. The profits slowdown came in the context of a net interest income increase of 5.7% and a net fee and

commission income rise of 4.2%. Both lead to a 3.9% increase in total operating income, however this was offset by an 8.4% rise in operating expenses.

The observed deceleration in profits wasn't solely the result of the regional turmoil and economic slowdown. Other facets of the Lebanese banking sector could potentially contribute to it such as the intense competition, and the low efficiency of Lebanese banks.

In 2013, 73 banks were operating in Lebanon including 56 commercial banks and 17 investment banks. The Lebanese banking sector employed 23,136 individuals in 985 branches spread throughout the country (BdL, 2013). This large number of banks and branches made competition in the industry rather intense and put great pressure on the sector's profitability

Additionally, analyzing the profitability and efficiency ratios in figure 6 shows that Lebanese banks were underperforming compared to international benchmarks. Return on average equity which measures how efficiently banks are converting their equity in profits was the lowest in Lebanon compared to the MENA region, emerging markets and the world. The same conclusion can be made to the ratio of return on average assets which measures how efficiently the bank converts its assets into income. The cost-to-income ratio which measures the efficiency of banks in minimizing costs while increasing profits was 51.8% in Lebanon which was lower than the world average of 53.7%. However it was higher than the averages of 40.% and 46.9% for the MENA region and Emerging markets respectively.

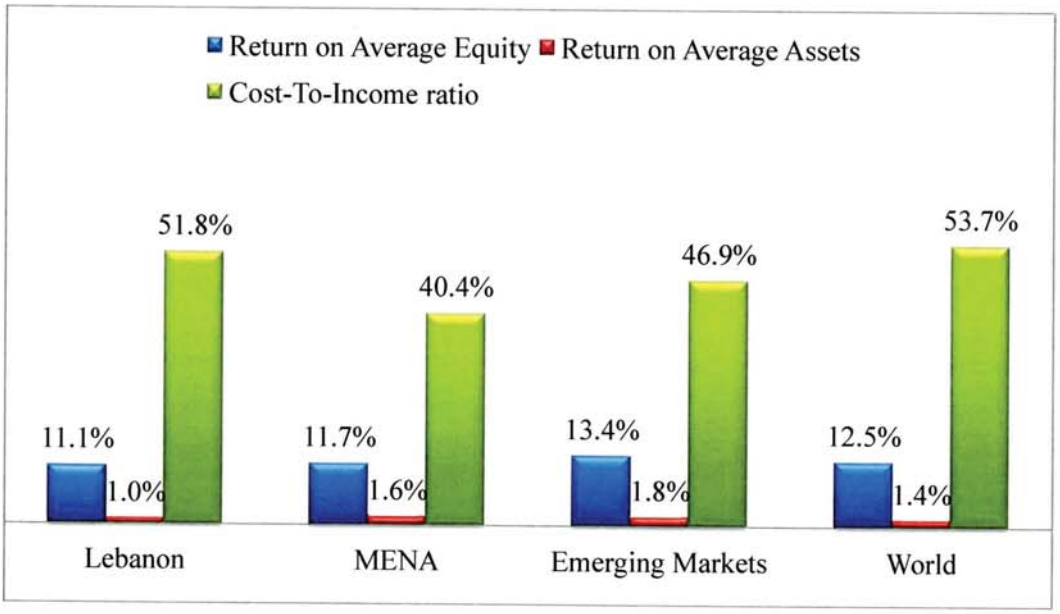

Figure 6 : Profitability and Efficiency Ratios (2013)

Bank Audi, Lebanon Banking Sector Report 2014 (Source : Bankdata Financial Services, Bankscope, IMF)

c. Main Characteristics

Despite the stagnation in profitability, the preceding sector analysis proves that the Lebanese banking remained rigid amidst the Arab spring. Moreover, as described previously, this sector managed to withstand the effects of the financial crisis. The resilience the sector has shown is mainly favored by confidence in its activities and several other characteristics summarized in the following.

Strong Supervision

Confidence in the Lebanese banking sector is supported by the strict oversight and laws the Lebanese Banking Sector is subject to. The bodies in charge of the supervisory and regulatory tasks are the Central Bank (BdL) and the Banking Control Commission (BCC) established in 1963 and 1967 respectively.

BdL is an independent public body with "the general mission of safeguarding the national currency in order to ensure the basis for sustained social and economic growth". BdL's

main duties with regard to banks include controlling banks liquidity, regulating their credit, imposing reserve requirements and penalties when shortfalls occur, and granting licenses for the establishment of new banks.[3]

The BCC works closely with the Governor of the Central Bank and exclusively supervises banks and other financial entities. Its major tasks include periodical on-and off-site examinations of the entities it oversees and the evaluation of their financial reliability. It also makes sure that these institutions comply with the provisions of the Lebanese code of money and credit, Basel committee requirements, BdL's regulations, BCC's circulars and instructions and International Accounting Standards. BCC has the authority to impose corrective sanctions on individual banks.[4]

In addition to BDL and BCC, the banking sector is subject to investigations done by the Lebanese Special Investigation Commission (SIC or FIU as Financial Intelligence Unit). SIC is

an independent legal body in charge of investigating any suspicious activity that may involve money laundering or terrorism financing. It has the authority to review and freeze any suspicious

bank account and to grant the bank permission to disclose information to third parties. It also monitors compliance with anti-money laundering laws and works closely with the banking and financial community to propose anti-money laundering regulations.

Conservative Banking Policies

In addition to strong supervision, conservative banking policies favor confidence in the banking sector. Lebanese banks have a long history of operating in a risky and unstable political environment. Consequently, to safeguard the sector's stability BdL developed the tradition of adopting conservative banking policies and laws. They serve as a cushion

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[3] See http://www.bdl.gov.lb/pages/index/1/137/Role-and-Functions.html for a detailed description of BdL's role

[4] See the Banking Control Commission website http://www.bccl.gov.lb/

for banks against upcoming risks and include:

- Reserve Requirements (Decision No 7835 dated June 2001)
- Capital Adequacy (Law No 6939 dated 25 March 1998)
- Reserves for Unspecified Risks (Decision No 7129 dated 15 October 1998)
- Credit Limit (Decision No 7055 dated August 1998)

International Cooperation and Compliance

The sector's commitment to meeting international standards and best practices also sustains confidence in it. Lebanese banks comply with FATF (Financial Action Task Force) which fights money laundering and the financing of terrorism. The strict commitment was proven in BdL's swift, decisive and satisfactory action toward the Lebanese Canadian Bank 2011 after it was accused by the US treasury of money laundering. Furthermore, Lebanese banks are preparing to meet FATCA (Foreign Account Tax Compliance Act) and OECD (Organisation for Economic Co-operation and Development) requirements which are the new standards concerning tax evasion imposed by US legislation. Banks are also compliant with all international sanctions against Iran and US sanctions against Syria. They conform with International Accounting Standards (IAS), International Financial Reporting Standards (IFRS), and world standards and guidelines set by the Bank for International Settlement (BIS), the International Monetary Fund (IMF) and other international bodies.

The Expat Factor

The years of war and the unstable economic and political condition in Lebanon encouraged the immigration of many Lebanese. In fact, 15 to 20 million people of Lebanese origin live outside Lebanon compared with 4.3 million living in it (The Economist, 2013). There is a vibrant Gulf Diaspora, African Diaspora, and Latin American Diaspora. The Lebanese also have a large presence in North America, Europe, and Australia. The large number of expatriates plays a vital role in the economy of the country as they inject in it almost 7 billion annually.

Banking Secrecy Law

The banking secrecy law is what mainly gave the Lebanese banking sector the longstanding importance it still enjoys as it contributed to drawing and retaining customer deposits. Another country offering banking secrecy is Switzerland, however with the current tax evasion scandals the pressure is on Switzerland to drop this service. If this happens, Lebanon will definitely be among the countries that will benefit.

International Openness

In addition to the banking secrecy law, the international openness of the Lebanese banking sector has historically attracted deposits and contributed to the growth of the sector. This openness is favored by a freely convertible currency and a lack of restrictions on the flow of capital and earnings into and out of the economy. It is also supported by the branches and representative offices several Arab and Foreign banks have in the republic, and the large network of correspondent banks Lebanese banks benefit from.

The geographical expansion of Lebanese banks has also reinforced their international openness. Given the limited size of the Lebanese market and the instability of its operating environment, many Lebanese banks significantly Audi, BLOM, Byblos, Bank of Beirut, Fransabank and BEMO have centered their income diversification strategy on geographical expansion. They have mostly targeted markets that are known to be large and profitable such as Arab neighboring countries, Gulf region, Europe, Africa, Australia and the United States. Lebanese banks function abroad through branches, affiliated companies, subsidiaries, sister banks and representative offices spread in 33 countries with more than 90 units. The number of branches relating to subsidiaries and sister banks abroad amounts to more than 200 units (ABL, 2011). To illustrate the size of the Lebanese banking sector abroad, figure 7 presents the geographic concentration of Lebanese banks in 2013.

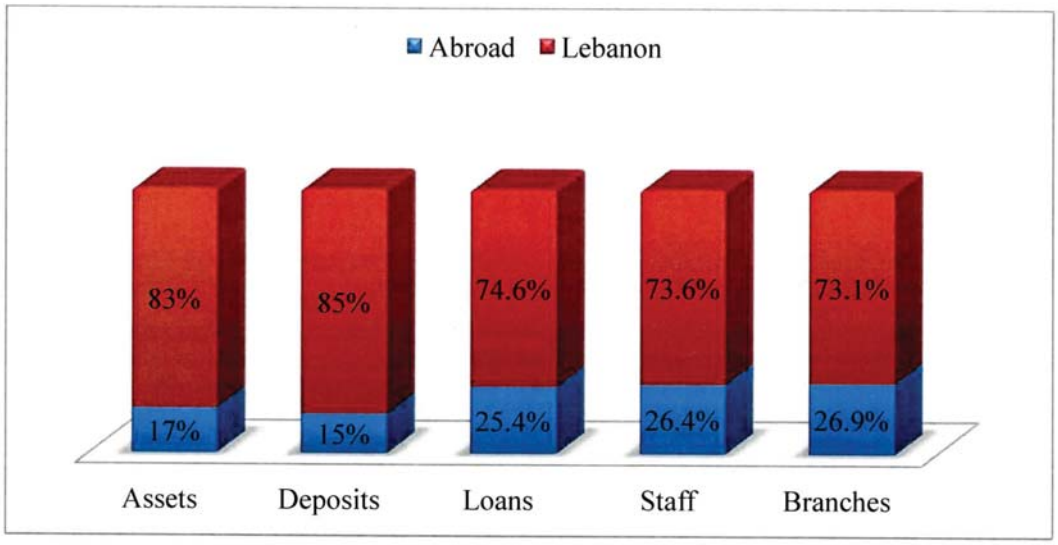

Figure 7 : Geographic Concentration (2013)

Bank Audi, Lebanon Banking Sector Report 2014 (Source : Bankdata Financial Services)

d. The Lebanese Banking Sector and the Public Debt

Despite the positive characteristics discussed above, the Lebanese banking sector suffers from a major drawback. It is the over-reliance on the financing of the public debt and overexposure to this debt. Lebanese banks support the government financing needs in two ways: they buy government debt directly or they purchase certificates of deposit (CDs) issued by BdL which in turn buys government debt. At end August-2013 general government debt constituted 21% of total banking system's assets and BdL CDs represented 32.5% of total banking system's assets (Standard & Poor's, 2013). The exposure of the government to Lebanese banks is even more dramatic since as shown in figures 8&9 Lebanese banks hold the largest share of the public debt.

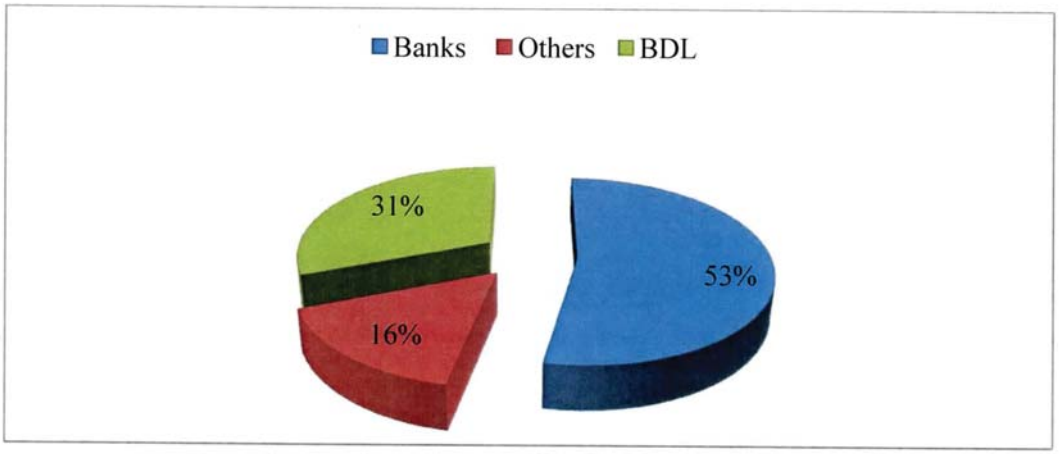

Figure 8 : Financing Sources to the Public Debt denominated in LBP end 2013 (%)

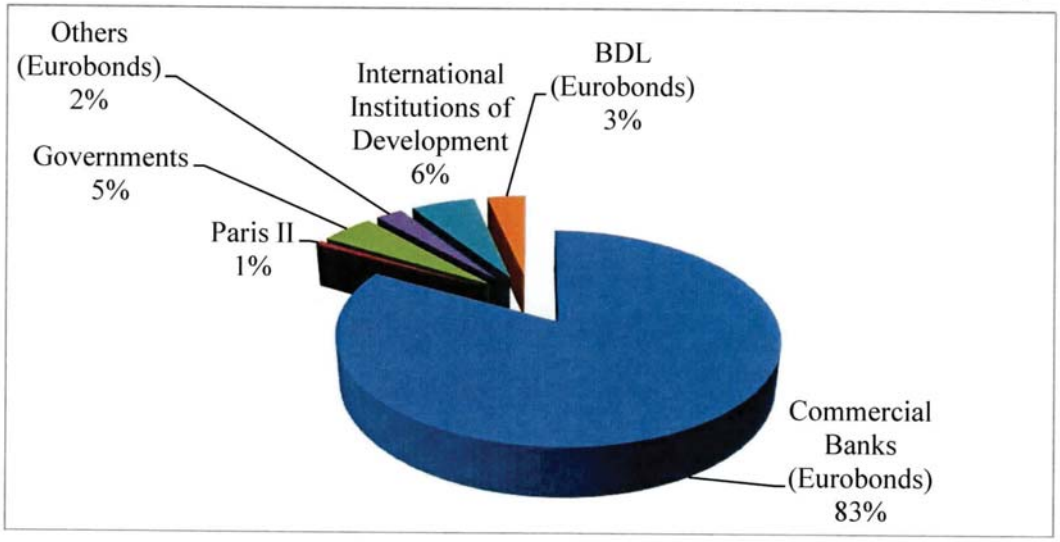

Figure 9 : Financing Sources to the Public Debt denominated in foreign currencies end 2013 (%)

(Source figures 8 & 9 : ABL 2013 annual report)

The nexus between Lebanese banks and the government debt started during the postwar reconstruction period (1990s-early 2000s). Banks bought securities issued by the government at extremely high interest rates coupled with the usual official guarantee. This allowed local commercial banks to offer high interest rates, attract more deposits (mainly non-resident) and buy more government securities.

As a result of this cycle, the banking sector has grown very large and the ratio of bank assets to GDP became among the highest in the world standing at 379.0% in 2013, exceeding averages of 161.9% for the world, 277.3% for the European Union, and 106.0% for Emerging Markets (Investment Development Authority of Lebanon IDAL, 2013). Another outcome of this cycle is that banks became overly dependent on this easy and highly profitable way of making money and therefore they were detached from their traditional role of financing the private sector. Consequently, the private sector has been facing difficulties in obtaining financing especially that Lebanon's financial system is bank-oriented and bank loans constitute the main financing mean for firms (Naimy, 2004). Finally, this cycle increased the riskiness of banks since they became overly exposed to the highly indebted public sector.

2.4 Conclusion

The above description of the Lebanese economy and banking sector demonstrates several reasons why it is crucial to monitor the efficiency of Lebanese banks. We summarize them as follows:

- The banking sector is one of the major growth sectors of the Lebanese economy
- Lebanese banks have shielded the economy against major shocks that were strong enough to destroy it
- The government is highly exposed to Lebanese banks since they hold over half of the public debt
- A large number of banks operate in Lebanon which intensifies competition in the industry
- Analysis of efficiency and profitability ratios show that Lebanese banks are underperforming compared to other emerging markets
- Lebanese banks are expanding to other geographical regions
- Operating at higher efficiency levels will decrease costs for Lebanese banks making private sector lending activities more profitable and allowing banks to decrease their reliance and exposure to public debt

Having justified the need for efficiency measurement within the Lebanese banking sector, we will discuss in the following chapter the corresponding methodology, steps, and procedures.

CHAPTER 3

Methodology

3.1 Introduction

This chapter elaborates the different methodologies that are implemented in the study. It starts with a brief introduction of performance evaluation and benchmarking, then it explains efficiency and its importance in determining productivity. Additionally, it illustrates the data envelopment analysis (DEA) process along with its most significant models, namely the CCR, BCC and A&P models. Finally, it introduces and describes the Wilcoxon matched pairs signed rank test and the Malmquist Total Factor Productivity (TFP) index.

3.2 Performance Evaluation and Benchmarking

Performance evaluation is becoming an ever more important aspect to consider as organizations are required to become even more effective and efficient, execute better on business strategy, and do more with less in order to remain competitive. To evaluate their performance, companies use organizational assessments that consist of a systematic process which focuses on the company as the primary unit of analysis to obtain information about its performance and the factors affecting it. This diagnostic tool can help organizations identify important factors that aid or impede their achievement of results, and situate themselves with respect to competitors a process known as benchmarking.

Benchmarking is defined as the process of measuring company's strategies, products and operations against "best-in-class" companies, both inside and outside the company's industry. This practice has become the darling of the continuous process-improvement movement. To cite an example among many others, benchmarking allowed Xerox to increase quality while decreasing production costs by 40%-50%, reducing product

development cycle time by 25%-50% and reducing inventory by 75% (Finein, 1990). Virtually, every benchmarking analysis has the following steps: (1) determine what to benchmark (2) form a benchmarking team (3) identify benchmarking targets (4) collect and analyze information and data (5) take action. Commonly used benchmarking analytical frameworks and methodologies are somehow limited in their usefulness. More complexities arise when attempting to benchmark companies in the services sector since services are more difficult to measure. Overcoming these limitations requires an innovative approach, such as DEA which will be explained shortly.

3.3 Efficiency and Productivity

Efficiency measurement comes in the context of performance evaluation of organizations described previously. It is an increasingly important aspect to measure, as resources such as labor, raw material, time, energy, and capital are becoming more scarce. Efficiency is concerned with the optimal usage of these scarce resources to produce a certain amount and quality of outputs. It can be assessed in several types such as technical, allocative, productive, profit, revenue, cost, dynamic, social and distributive efficiencies. This study aims at measuring technical efficiency, since it is the most common aspect of efficiency used. A DMU is said to be technically efficient if it produces the maximum amount of output using a minimum amount of input. Commonly used measures of efficiency take the below form:

$$Efficiency(E) = \frac{Output}{Input} \tag{3.1}$$

Efficiency is an important factor in the calculation of productivity, which also assumes this ratio form. Productivity is defined as the measure of output produced from the use of a given quantity of inputs. Two measures are used to address productivity: partial productivity and total factor productivity. The former aims at measuring the ratio of a single output to a single input (or a subset of inputs to a subset of outputs), whereas the latter aims at measuring the ratio of all outputs to all inputs. Moving from partial to total factor productivity helps us avoid attributing gains in production to the wrong inputs. For

example, when a single output to input ratio is used, an increase in output due to an increase in capital might be mistakenly attributed to labor when actually labor performance has worsened during the period. However, moving to total factor productivity presents difficulties in choosing the right inputs and outputs and assigning the proper weights in order to reach a single output to input ratio.

3.4 Data Envelopment Analysis

DEA is an innovative benchmarking tool that does not require prescribing weights for each input and output, but rather weights are obtained directly from observational data subject only to a set of constraints. DEA does not necessitate any prior assumptions regarding the production function, consequently it is favored in cases where the relation between the multiple inputs and outputs is complex or unknown. It is a non-parametric model based on linear programming techniques which allows it to handle a large number of variables and relations (constraints) and deal with complex problems.

In addition to this, DEA is a method directed to frontiers and not to central tendencies. It uncovers the relationships between inputs and outputs in contrast to other methodologies such as statistical regression that keep them hidden by trying to fit a regression line through the center of the data.

DEA deals with relative efficiency which was defined by Cooper et al. in 2011 in the following manner "A DMU is to be rated as fully (100%) efficient on the basis of available evidence if and only if the performances of other DMUs does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs". This definition of relative efficiency is what avoids the need to assign weights to inputs or outputs and the need to specify the relations that exist between them. In economics, this basic kind of efficiency is known as "technical efficiency" and it can be extended to other kinds of efficiency when data such as prices and unit costs are available for use with DEA.

The target of DEA is to evaluate the performance of a set of peer entities called Decision-Making Units (DMUs). It does so by converting the multiple input and output measures used by each DMU into one single measure of efficiency to compare these entities. DEA locates a best-practice frontier linking efficient DMUs and calculates efficiency measures for each inefficient DMU relative to this frontier. The definition of DMU is left unrestricted to allow the usage of DEA over a wide range of applications. Example of DMUs include hospitals, banks, universities, business firms, even cities, regions and countries.

The efficiency measure of each DMU is a score between 0 and unity, with one being the score of efficient units. The weights produced by the DEA model allow users to identify changes in the inputs and outputs needed to achieve efficiency. These weights can also be used to conduct sensitivity analysis to determine changes across all DMU data that will result in a reclassification of DMUs from "efficient" to "inefficient". Sensitivity analysis can also be beneficial to identify the ranges of data variations that can be allowed before a reclassification occurs.

The principles of DEA date back to Farrell (1957). However it was formally developed by Charnes, Cooper and Rhodes in 1978 in response to the thesis efforts of Edwardo Rhodes supervised by W.W. Cooper. Since its development, DEA has appeared in more 4,000 articles and studies in the nonprofit, regulated and private sectors. The rapid growth and widespread acceptance of the methodology prove its strengths and applicability.

To better understand the concepts behind DEA, a series of examples are explained below, starting with efficiency measurement in the case of one input-one output, two inputs-one output and one input-two outputs. The multiple input-multiple output case will be then elaborated illustrating the transformation from a fractional program to a linear program. Finally we will conclude with the original CCR model and its extensions.

Example 1 : Single Input-Single Output case

Suppose we have 8 bank branches labeled A to H. Each branch has a single input which is the number of employees and a single output which is total transactions (measured in 1000 transactions). The performance of these branches is detailed in table 3.

Branch	A	B	C	D	E	F	G	H
Number of Employees	2	3	3	4	5	5	6	8
Total Transactions	1	3	2	3	4	2	3	5
Transactions/Employee	0.5	1	0.667	0.75	0.8	0.4	0.5	0.625

Table 3 : Data

For example branch A has two employees with 1000 total transactions.

To measure and compare the efficiency of the branches, we apply the ratio (3.1) which becomes in this case:

$$Efficiency = \frac{Total\ Transactions}{Number\ of\ Employees}$$

The result of applying this equation to each individual branch is presented in the last row of table 3. Using this measure we may identify B as the most efficient branch and F as the least efficient.

Figure 10 is an illustration of the data in table 3 with number of employees represented on the horizontal axis and total transactions represented on the vertical axis. The slope of the line connecting each point to the origin corresponds to the transactions per employee and the highest slope is attained by the line passing from the origin to point B. This line is called "the efficient frontier" which touches at least one point while all other points are below it. This frontier envelops the data, thus from this property comes the name "Data Envelopment Analysis".

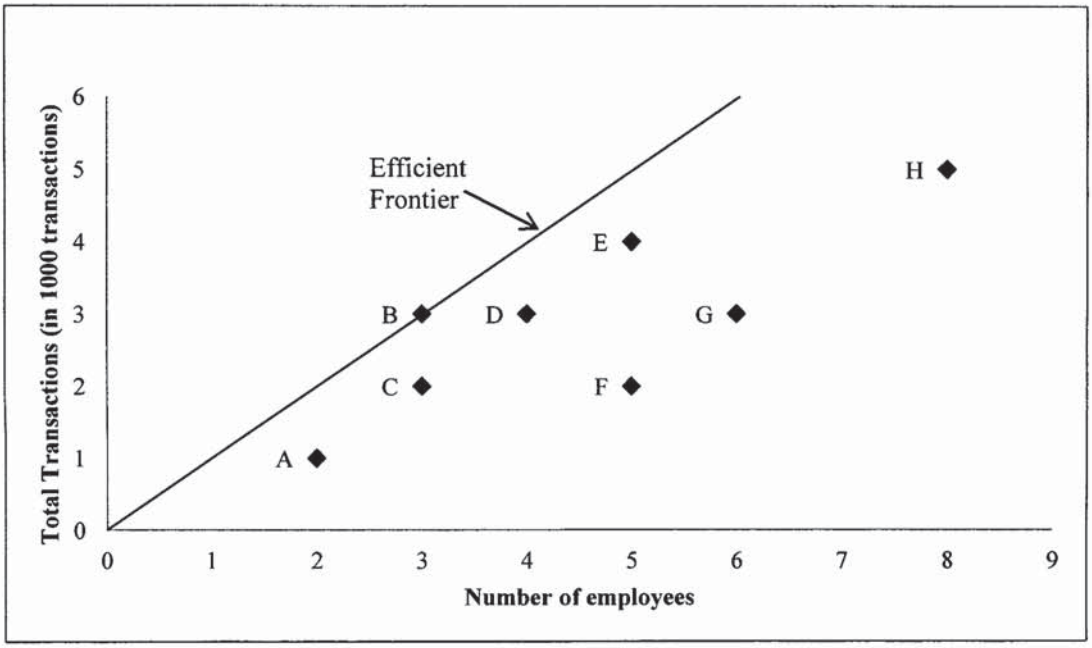

Figure 10 : Single Input - Single Output case

To explain the difference between the statistical regression and DEA methods we add a regression line to figure 10. We obtain figure 11 in which the dotted line represents the regression line expressed, under the least square principle, by the equation $y = 0.6223x$. As known from statistics, this line passes through the mean of the data points. Therefore any point above it corresponds to an over performing branch and any point below it corresponds to an underperforming branch. The degree of excellence or inferiority is measured by the deviation from this regression line, whereas the frontier line designates the performance of the best branch and measures the efficiency of all other branches by deviations from it.

Therefore, a fundamental difference exists between the statistical regression and DEA methods. The former reflects average or central tendency behavior of the observations while the latter designates the best performance and evaluates all other performances according to it. As a result of their differences, both methods can yield different results when used as methods of evaluation. They can also suggest different approaches for improvement. DEA suggests improvements according to the frontier line representing the

best performance while statistical regression suggests improvements according to the regression line which represents average performance.

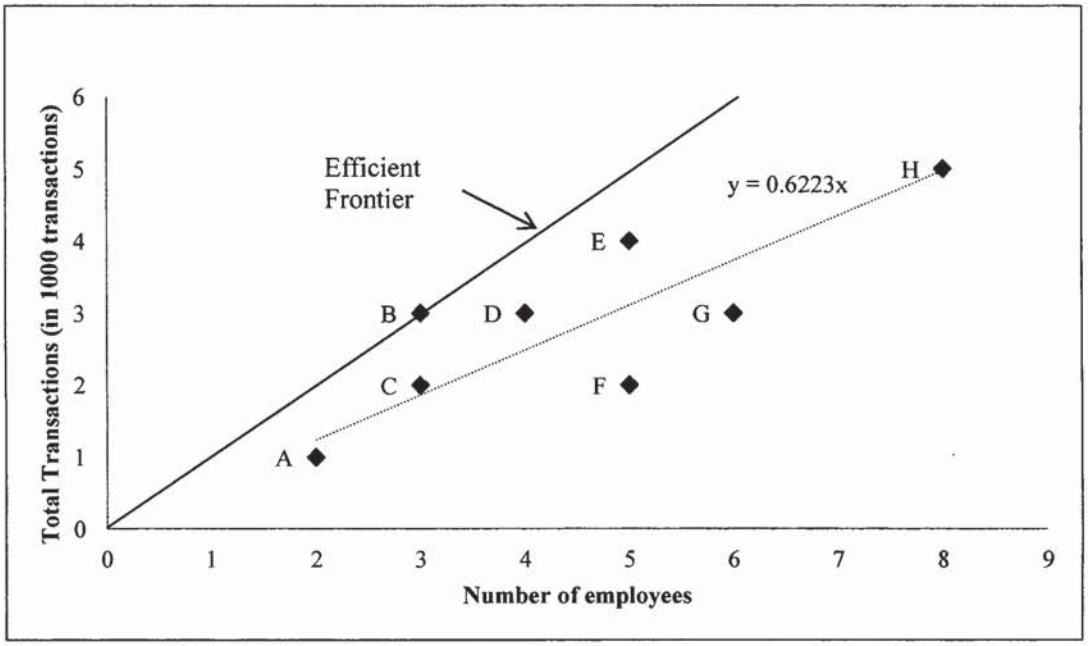

Figure 11 : Regression Line Vs. Frontier Line

It is worth mentioning at this stage that we are assuming constant returns-to-scale as the frontier line stretches to infinity with the same slope. However this assumption is not really reasonable and it will be dealt with later by using different DEA models.

We are concerned now with the calculation of efficiency scores for each branch using the DEA approach. For this purpose we return to table 3. Since B is the best performing branch, we evaluate all other performances according to it using the ratio below:

$$Relative\ Efficiency\ (RE) = \frac{Transactions\ per\ Employee\ of\ x}{Transactions\ per\ Employee\ of\ B} \qquad (3.2)$$

Where $X = \mathrm{A, B, C, D, E, F, G, H}$ and $0 \leq RE \leq 1$

We obtain the scores in table 4.

Branch	A	B	C	D	E	F	G	H
Relative Efficiency	0.5	1	0.667	0.75	0.8	0.4	0.5	0.625

Table 4 : Relative Efficiency

We can say for example, the worst performing branch F attains 0.4 x 100 = 40% of B's efficiency.

We move now to the problem moving the inefficient branches up to the efficiency frontier to make them efficient. For example branch A in figure 12 can be improved in many ways depending on whether we choose an input oriented approach or output oriented approach or a combination of both. First we can improve A's efficiency by reducing the number of employees by 1 to reach point A_1 on the efficient frontier with the coordinates (1,1). Another way to improve the efficiency of branch A is by increasing total transactions by 1000 in order to reach A_2 on the efficient frontier with the coordinates (2,2). Any point on the line segment $[A_1A_2]$ offers a chance to effect improvements assuming that number of employees should not be increased, and total transactions should not be decreased.

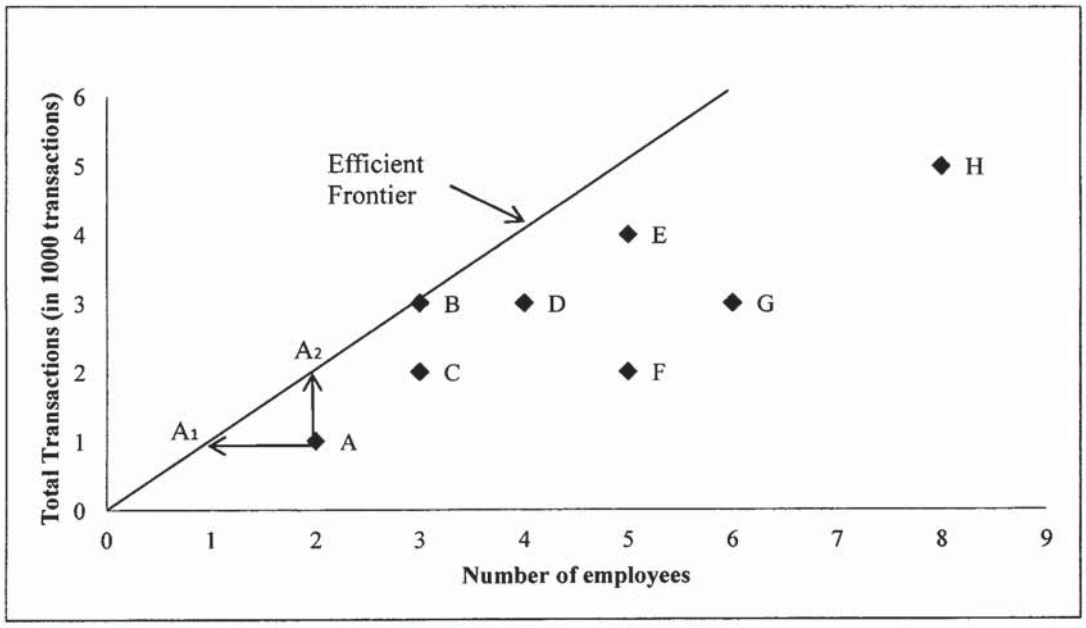

Figure 12 : Improvement of Branch A

Example 2 : Two Inputs and One Output Case

To extend our analysis we will tackle the case of two inputs and one output. Suppose we want to compare the performance of the sales departments labeled A to I in 9 different banks. We assume two inputs; salespeople and department area (measured into 1000 m^2) and one output which is sales (in 100,000 USD). Table 5 details the performance of the different departments.

Department	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Number of Salespeople	4	7	8	4	2	5	6	5.5	6
Department Area (100 m^2)	3	3	1	2	4	2	4	2.5	2.5
Sales (100,000 USD)	1	1	1	1	1	1	1	1	1

Table 5 : Data

We notice that sales are set at 1 under the constant returns-to-scale assumption. Therefore, inputs are normalized to values for getting 1 unit of sales. We plot the scatter representing the departments with Department Area/Sales on the Y axis and Number of Salespeople/Sales on the X axis and obtain figure 13.

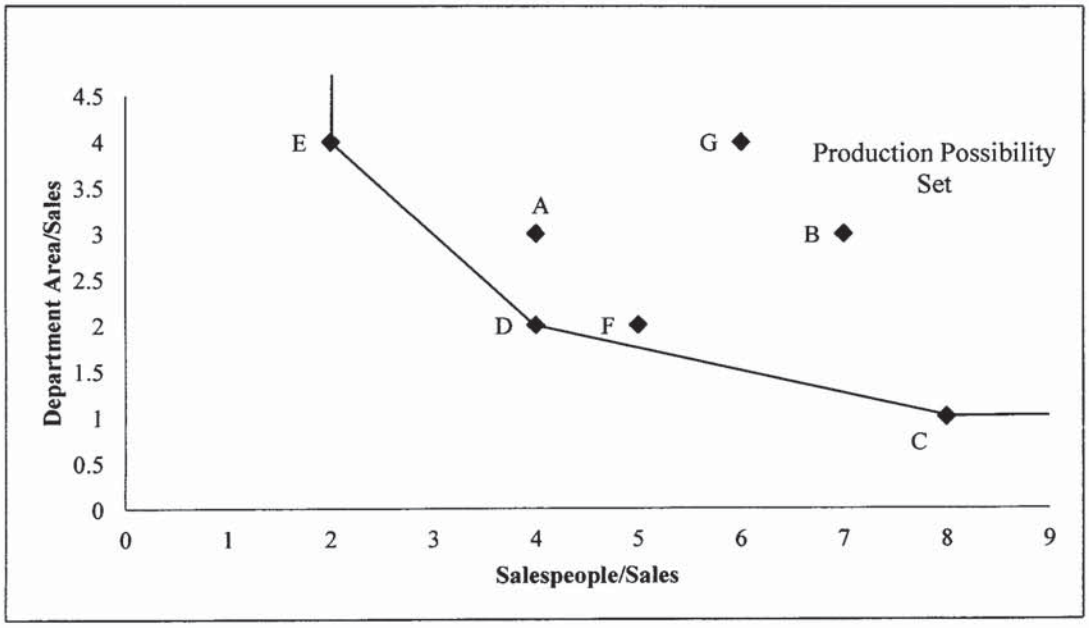

Figure 13 : Two Inputs - One Output Case

From an efficiency point of view, it is natural to consider sales departments that use less inputs in producing one unit of output as more efficient. Therefore, we recognize the line connecting E, D and C as the efficient frontier. It is worth noting that no point on this frontier can improve one of its input values without worsening the other input. We identify the area enveloped by the efficiency frontier and by the horizontal line passing through C and the vertical line passing through E, as the *production possibility set*. This means that that the points within the set are supposed to provide empirical evidence that production is possible at the rates specified by the coordinates of any point in the region.

To measure the relative efficiency of the departments not on the frontier line we proceed as follows. Let us take department A as an example. To measure its efficiency, let (OA) the line from zero to A cross the efficiency frontier at P as illustrated by figure 14. Then the efficiency of A is calculated as the distance from O to P divided by the distance from O to A:

$$\frac{d(O,P)}{d(O,A)} \tag{3.3}$$

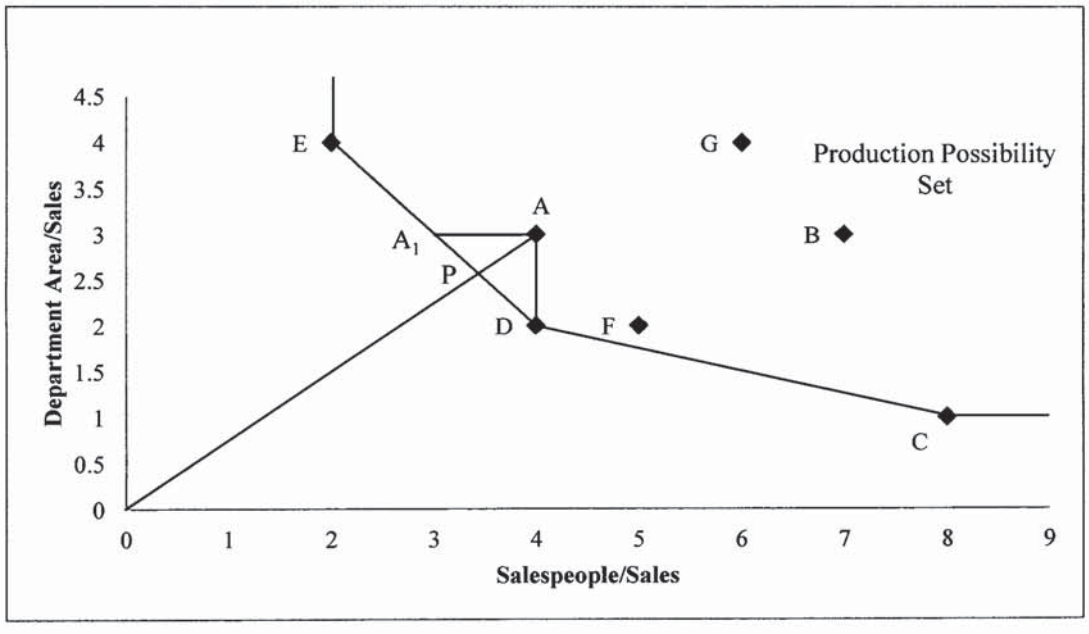

Figure 14 : Two Inputs - One Output Case

This means that the inefficiency of A is calculated with reference to E and D, since P is on the [ED] part of the efficiency frontier. Consequently, we call D and E the *reference set* for A. Other departments can have a difference reference set, for example the reference set for G is D and C. We notice that all the departments have D in their reference sets, therefore we can say that D is an efficient department which is "representative".

We move now to the investigation of ways to improve performance. For example A, can be improved by moving to P. Any other point on the line segment [DA_1] can be used for improvement. For instance, A can reduce department area and attain D or reduce salespeople and attain A_1. Another alternative for improvement would be increasing output without changing input, depending on whether we favor an input or output oriented method for improvement.

Example 3 : Single input and Two Outputs

Our last example deals with the single input two outputs case. We compare the performance of insurance firms A to G. Insurance brokers constitute the only input and we assume they produce two outputs which are the number of customers (unit =10) and sales (in USD 100,000). Table 6 details the performance.

Insurance firm	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Insurance Brokers	1	1	1	1	1	1	1
Customers	1	2	3	4	4	5	6
Sales	5	7	4	3	6	5	2

Table 6 : Data

We also notice that outputs are normalized to 1 unit of input. We divide the outputs by insurance brokers to obtain the unitized axis in figure 15.

Again, it is normal to consider insurance brokers who produce the largest amount of outputs to be more efficient. The efficient frontier then consists of the lines connecting B, E,F and G as shown in figure 15. The production possibility set is the region enveloped by the frontier and horizontal and vertical extensions of B and G respectively.

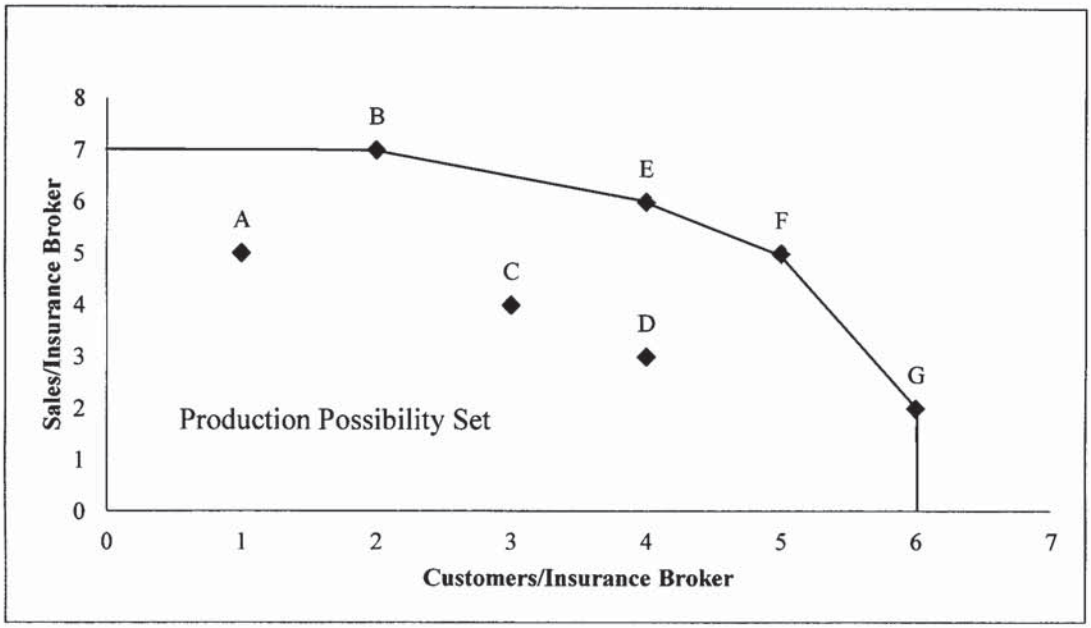

Figure 15 : One Input - Two Outputs case

Insurance brokers A, C and D are inefficient. We take for example A to illustrate the method to measure relative efficiency. As shown in figure 16, we draw the line OA that crosses the efficiency frontier at Q. Inefficiency of A would then be measured as:

$$\frac{d(O,A)}{d(O,Q)} \tag{3.4}$$

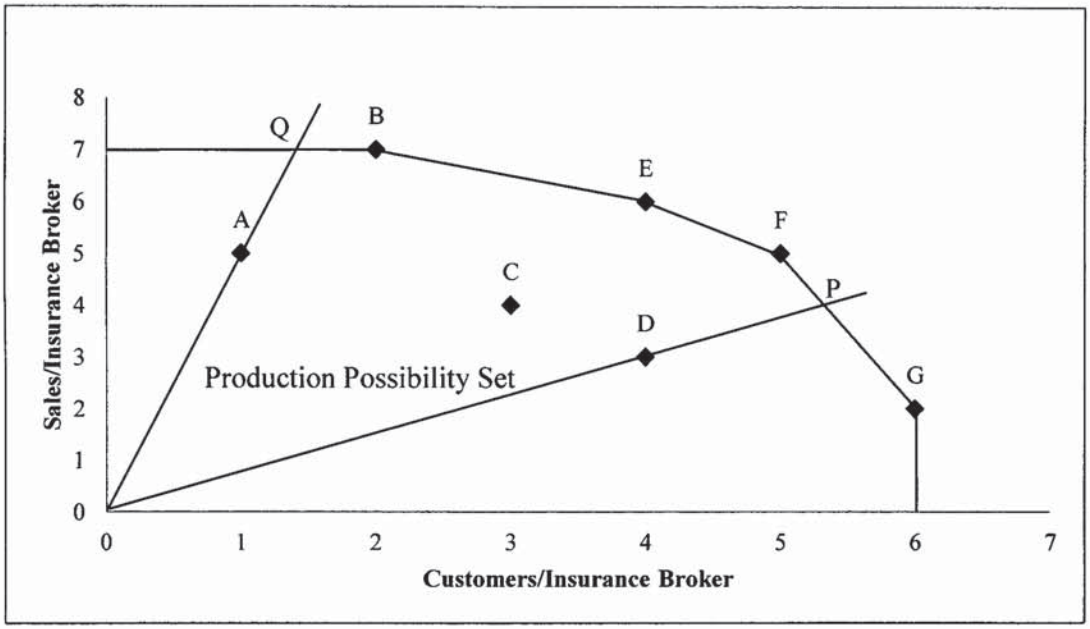

Figure 16 : Improvement of Branches A and D

This inefficiency is caused by inefficiency in both outputs of A. To improve A's performance we move to Q by increasing both outputs without changing their proportions. This type of inefficiency that can be eliminated without changing proportions is what we know as *purely technical efficiency*. However, although Q is on the frontier, it is not on an efficient part of the frontier. We notice that B is a better performing broker having more customers for the same sales performance. Thus the best performance that can be achieved by A is B. This kind of inefficiency that can be eliminated by altering the proportions in which outputs are produced (or inputs utilized) is referred to as *mix efficiency*. We mention at this level that technical efficiency refers to all sources of waste (purely technical and mix) which can be eliminated without worsening any other input or output.

Efficiency of D can be improved by moving to P on the efficiency frontier or by doing the following:

- Reducing inputs while keeping the same level of output if we favor an input oriented method (This could mean employing the brokers part time)

- Increasing both outputs while keeping the same number of inputs if we favor an output oriented method
- Doing a combination of both

Multiple Inputs - Multiple Outputs: From a Fractional to a Linear Program

The examples explained above were helpful to understand the basics of efficiency and they presented several concepts we will encounter in our study. They were limited in the number of inputs and outputs used which had the advantage of allowing the usage of simple graphical illustrations. However in practice, multiple inputs-multiple outputs cases are more common and they cannot be solved using graphical illustration. We need in this case a reliable approach capable of computing the efficiencies without burdening users with excessive analysis, computations or assumptions. Thus we resort to mathematics rather than graphs.

Suppose we want to calculate the efficiencies of four banks. We have 2 inputs; managers and employees and 2 outputs; retails clients and corporate clients. Data is presented in table 7.

Banks	**A**	**B**	**C**	**D**
Managers	20	19	25	27
Employees	151	131	160	168
Retail Clients	100	150	160	180
Corporate Clients	90	50	55	72

Table 7 : Data

This data can be represented in a matrix form as follows:

$$X = \begin{pmatrix} 20 & 19 & 25 & 27 \\ 151 & 131 & 160 & 168 \end{pmatrix}$$

$$Y = \begin{pmatrix} 100 & 150 & 160 & 180 \\ 90 & 50 & 55 & 72 \end{pmatrix}$$

Where x_{1j}= number of managers and x_{2j} = number of employees in bank j, y_{1j}=number of retail clients and y_{2j}= number of corporate clients in bank j.

To measure the efficiency of each bank (the DMU in our case) we need 4 optimizations, one for each DMU. We will take as an example the calculation of the efficiency of bank A. Using a fractional program and an input oriented method, we proceed as follow:

$$Max\ E_A\ (u,v) = \left(\frac{100\ u_1 + 90\ u_2}{20\ v_1 + \ 151\ v_2}\right) \tag{3.5}$$

Subject to :

- $0 \leq \frac{u_1 y_{1j} + u_2 y_{2j}}{v_1 x_{1j} + v_2 x_{2j}} \leq 1\ (j = A, B, C, D)$
- $v_1, v_2 \geq 0$
- $u_1, u_2 \geq 0$

Where:

- E_A is the efficiency of bank A
- u_1 is the weight assigned to retail clients
- u_2 is the weight assigned to corporate clients
- v_1 is the weight assigned to managers
- v_2 is the weight assigned to employees

The above fractional program is difficult to solve numerically. To simplify matters we can convert it to a linear program (LP). Linear programming is a mathematical optimization technique aimed at maximizing or minimizing a linear expression. A linear model includes:

- An objective function (In this case it is to $Maximize\ E_A$)
- A set of decision variables (The unit weights for each of the inputs and outputs)
- A set of constraints (Linear equations of linear inequalities)

The model (3.5) yields an infinite set of solutions. For this reason, when converting to linear programming we select a representative solution. The selected solution in DEA is (u, v) when the sum of weighted inputs is unitized $(20\ v_1 + \ 151\ v_2 = 1)$. This

solution yields an equivalent linear programming program in which variables change from (u, v) to (μ, v). Our LP model becomes:

$$Max\ E_A\ (\mu, v) =\ (100\ \mu_1 + 90\ \mu_2) \tag{3.6}$$

Subject to:

- $\mu_1 y_{1j} + \mu_2 y_{2j} \leq v_1 x_{1j} +\ v_2 x_{2j}\ (j = A, B, C, D)$
- $20\ v_1 +\ 151\ v_2 = 1$
- $v_{1,}\ v_2 \geq 0$
- $\mu_1, \mu_2 \geq 0$

a. The CCR Model

We generalize the CCR model based on the preceding multiple input-multiple output example. The CCR is the first DEA model introduced by Charnes, Cooper and Rhodes in 1978. Starting from the input orientation, it assumes:

- There are n DMUs to be evaluated
- Each DMU consumes varying amounts of m different inputs to produce s different outputs
- $x_{ij} > 0$ and $y_{ij} > 0$ and each DMU has at least one positive input and one positive output value

$$Max\ h_0\ (u, v) = \frac{\sum_{r=1}^{s} u_r\ y_{r0}}{\sum_{i=1}^{m} v_i\ x_{i0}} \tag{3.7}$$

Subject to :

- $\frac{\sum_{r=1}^{s} u_r\ y_{rj}}{\sum_{i=1}^{m} v_i\ x_{ij}} \leq 1$ For $j = 1, \ldots, n$

- $u_r\ , v_i \geq\ \varepsilon\ \geq 0$ For all i and r

Where:

- h_0 is the efficiency of DMU_0 (The DMU to be evaluated)
- x_{ij} is the amount of input i consumed
- y_{ij} is the amount of output r produced
- v is the weight of input i
- u is the weight of output r
- ε is a non-Archimedean element smaller than any positive real number

Turning it into a linear programming model we obtain:

$$Max\ h_0(\mu, v) = \sum_{r=1}^{s} \mu_r\ y_{r0} \tag{3.8}$$

Subject to :

- $\sum_{i=1}^{m} v_i\ x_{i0} = 1$
- $\sum_{r=1}^{s} u_r\ y_{rj} \leq \sum_{i=1}^{m} v_i\ x_{ij}$ for $j = 1, \ldots, n$
- $\mu_r, v_i \geq\ \varepsilon\ \geq 0$

Alternatively, we could have opted to use the output oriented method and thus we would consider the ratio of inputs to outputs. This would revert the objective function from max to min as follows:

$$Min \frac{\sum_{i=1}^{m} v_i\ x_{i0}}{\sum_{r=1}^{s} u_r\ y_{r0}} \tag{3.9}$$

Subject to:

- $\frac{\sum_{i=1}^{m} v_i\ x_{i0}}{\sum_{r=1}^{s} \mu_r\ y_{r0}} \geq 1\ j = 1, \ldots, n$
- $u_r, v_i \geq\ \varepsilon\ \geq 0$

The LP would become:

$$Min \sum_{i=1}^{m} v_i \, x_{i0} \tag{3.10}$$

Subject to:

- $\sum_{i=1}^{m} v_i \, x_{ij} - \sum_{r=1}^{s} \mu_r \, y_{rj} \geq 0$
- $\sum_{r=1}^{s} \mu_r \, y_{r0} = 1$
- $\mu_r \, , v_i \geq \varepsilon \geq 0$

b. The BCC Model

The CCR is built on the *constant returns-to-scale* assumption as depicted for the production frontier in example 1. The CCR model was extended to the BCC model in 1984 by Banker, Charnes, Cooper to account for *variable returns-to-scale*. The production frontiers of BCC stretch by the convex hull of the existing DMUs and they have piecewise linear and concave characteristics. To illustrate, we go back to example 1 and add to figure 10 the BCC production frontier to obtain figure 17. We notice that A, B, E and H are on the BCC frontier and thus are BCC efficient whereas only B is CCR efficient. Moreover, we identify 3 cases for *variable returns-to-scale:*

- The line extending from A to B corresponds to increasing returns to scale (IRS). This means that when inputs are increased by an amount m, outputs increase by more than m.
- The line extending from B to E corresponds to decreasing returns to scale (DRS). This means that when inputs are increased by an amount m, outputs increase by less than m.
- The point B corresponds to constant returns to scale (CRS). This means that when inputs are increased by an amount m, outputs increase by the same amount m.

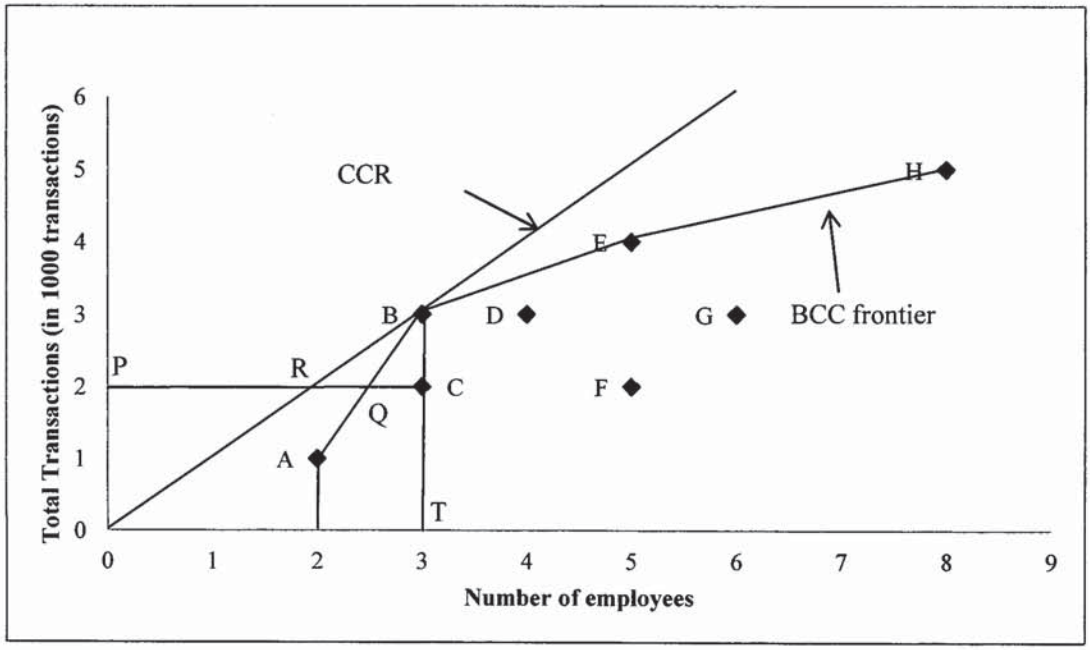

Figure 17 : Comparison of CCR and BCC Frontiers

Reading from figure 17 the BCC relative efficiency of C is evaluated by:

$$RE(C) = \frac{PQ}{PC} \tag{3.11}$$

While its CCR relative efficiency is evaluated by:

$$RE(C) = \frac{PR}{PC}$$

In the output oriented BCC, we read from the vertical axis of figure 17 to find C evaluated as:

$$RE(C) = \frac{BT}{CT}$$

The multiplier form of the BCC differs from the CCR by the addition of a new constraint. Equation (3.8) becomes in this case:

$$Max\ h_0(u,v) = \sum_{r=1}^{s} u_r\ y_{r0} - u_0 \tag{3.12}$$

Subject to:

- $\sum_{i=1}^{m} v_i \, x_{i0} = 1$
- $\sum_{r=1}^{s} u_r \, y_{rj} - \sum_{i=1}^{m} v_i \, x_{ij} - u_0 \leq 0$ for $j = 1, \ldots, n$
- $v_i, u_r \geq \varepsilon \geq 0$
- u_0 free in sign and an indicator of returns to scale where:
    - $u_0 > 0$ IRS
    - $u_0 < 0$ DRS
    - $u_0 = 0$ CRS

c. Scale Efficiency

It is interesting to investigate whether the inefficiency of a certain DMU is caused by the inefficient operation of the DMU itself or by the disadvantageous conditions under which it is operating. For this purpose we further analyze the overall technical efficiency (OTE) of a DMU measured by the CCR model and comprising two mutually exclusive and non-additive components:

- Pure Technical Efficiency (PTE) measured by the BCC model and reflecting how the DMU utilizes its resources under exogenous environments. Practically, it reveals managerial performance in organizing the inputs in the production process, by comparing the performance of the DMU to other units of similar scale size.
- Scale Efficiency (SE) was introduced by Färe et al. (1983) but is often attributed to Banker (1984). A DMU is considered scale efficient when its size of operations is optimal so that any changes in its size will render the DMU less efficient. Practically, SE reflects the ability of management to choose the optimum scale of production that will lead to the desired production levels. Scale inefficiency takes

two forms: DRS which implies that a DMU is too large to take full advantage of scale and IRS which implies that a DMU is too small for its scale of operations.

SE can be calculated based on the CCR and BCC scores using the following ratio:

$$SE = \frac{OTE}{PTE} \tag{3.13}$$

The maximum value this ratio can take is 1, which is obtained for a BCC efficient DMU operating at its optimal scale size. We illustrate our analysis in the single input-single output case illustrated in figure 18.

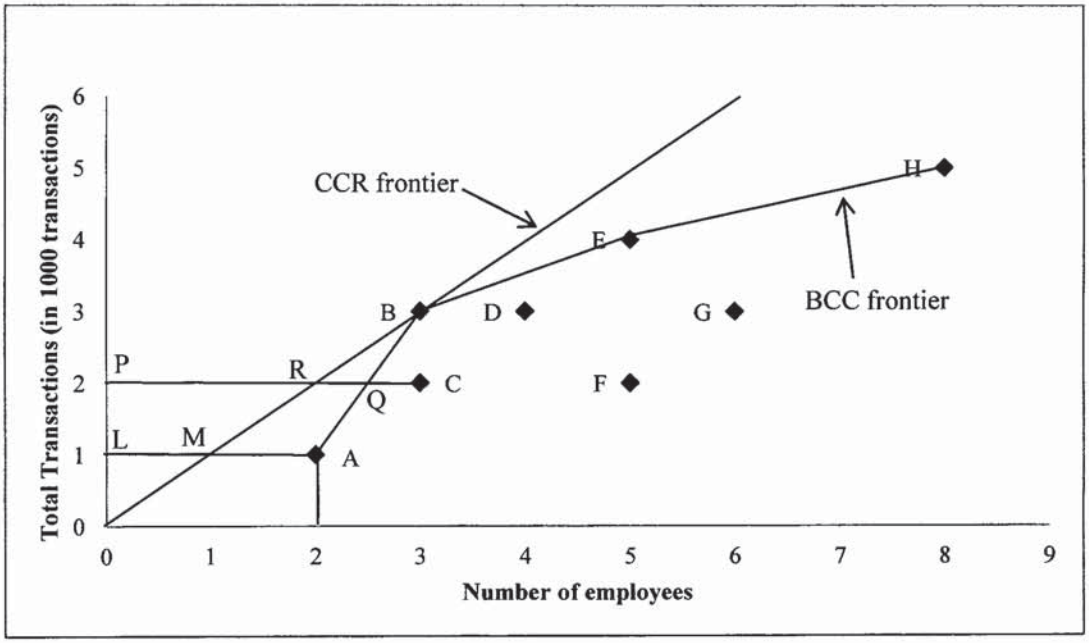

Figure 18 : Scale Efficiency

For the BCC efficient A with increasing returns to scale, SE is given by :

$$SE(A) = \frac{LM}{LA} \tag{3.14}$$

which denotes that A is PTE efficient, however its overall technical inefficiency is the result of failure to achieve SE as represented by LM/LA. The scale efficiency of DMU B

is equal to 1 which means it is both scale and technically efficient for the CCR and BCC model.

d. Super-Efficiency

Super-efficiency is a concept utilized in DEA applications for many purposes such as ranking efficient DMUs, evaluating the Malmquist productivity index and comparing performances of two groups. Two types of approaches are used to measure super-efficiency: radial and non-radial. Our study employs the Andersen and Petersen (A&P) model which is a radial approach to calculating super-efficiency. We will use it in order to rank our efficient DMUs. The A&P takes the form of a CCR model and does not include the unit under evaluation in the reference set. Consequently, under this model, efficient DMUs will be assigned scores equal or greater than 1.

For example in figure 19 E, D and C are efficiency DMUs. Taking D as an example, its efficiency under the standard DEA approach is equal to:

$$\frac{OD}{OD} = 1$$

While under super-efficiency approach it is:

$$\frac{OD'}{OD} > 1 \tag{3.15}$$

Efficiency scores are calculated under Super-Efficiency by excluding D from the original reference set E, D, C an and comparing it to the new reference line EC. Under the Super-Efficiency approach efficiency scores change only for the efficient DMUs whereas the inefficient ones keep the same score as in the standard DEA approach.

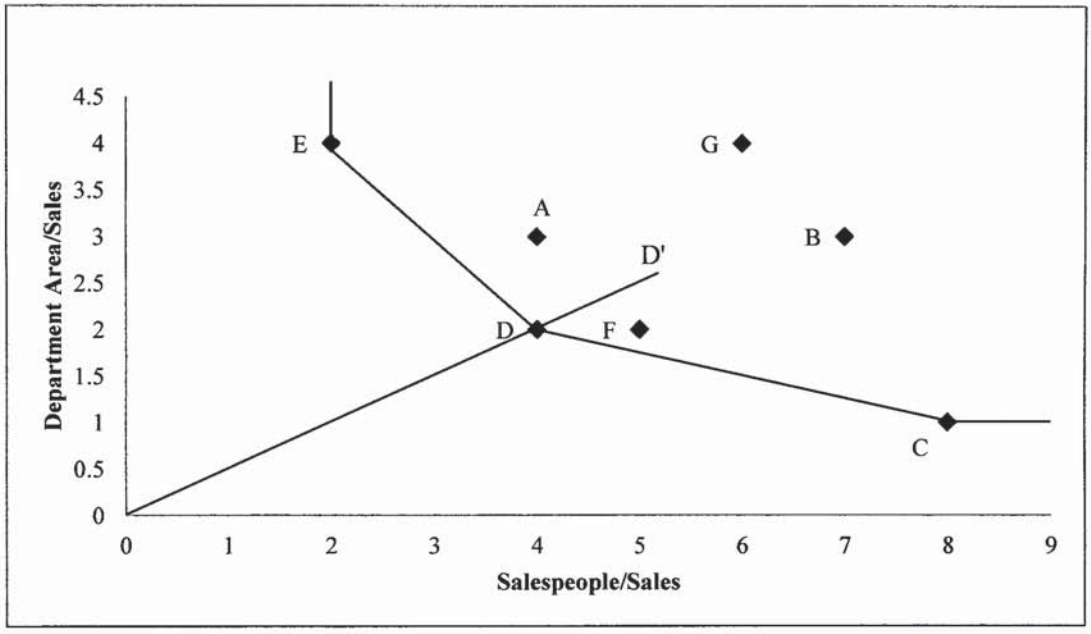

Figure 19 : Super-Efficiency

3.5 Paired Difference Test

To test the significance of the efficiency scores variations over the years under study, a Wilcoxon matched pairs signed rank test is conducted. This test is used to analyze hypotheses about two populations when no assumption can be made about the form of the probability distributions for these populations. In collecting data for this test, each element in the sample must generate two paired or matched data values, one from population 1 and one from population 2. Differences between the paired or matched data values are ranked and used to test for a difference between the two populations (Encyclopædia Britannica, 2014).

In our case, the hypotheses to be tested through the implementation of the Wilcoxon matched pairs signed rank test are as follows:

- H_0: There is no significant difference in the efficiency scores for the two years under study

- H_1: There is a significant difference in the efficiency scores for the two years under study

The alpha used to test the hypotheses is $\alpha = 0.05$. The Wilcoxon matched pairs signed rank test statistic and its corresponding p-value, are computed by IBM SPSS Statistics Version 22. The analysis can yield two outcomes:

- P-value $< \alpha$, Reject H_0
- P-value $> \alpha$, Do not reject H_0

3.6 Malmquist Total Factor Productivity (TFP) Index

The Malmquist TFP index was first introduced by S. Malmquist in 1953 and has further been studied and developed in the non-parametric framework by several authors. It evaluates the total factor productivity change of a DMU between two time periods and is defined as the product of two terms. The first, technical efficiency change (TEC), relates to the degree to which a DMU improves or worsens its managerial efficiency. The second, the technological change (TC), reflects innovation and the change in the efficient frontier between two time periods. Furthermore, technical efficiency change can be decomposed into pure efficiency change (PEC) and scale efficiency change (SEC).

Suppose we have a set of n DMUs (x_j, y_j) $(j = 1, \dots, n)$ each having m inputs denoted by a vector $x_j \in R^m$ and q outputs denoted by a vector $y_j \in R^q$over the periods 1 and 2. We assume $x_j > 0$ and $y_j > 0$. The notations $(x_0, y_0)^1 = (x_0^1 y_0^1)$ and $(x_0, y_0)^2 = (x_0^2 y_0^2)$ are used to designate DMU_o $(o = 1, \dots, n)$ in periods 1 and 2 respectively.

Technical Efficiency Change (TEC)

The following formula measures the technical efficiency change from period 1 to period 2:

$$TEC = \frac{Efficiency\ of\ (x_0, y_0)^2\ with\ respect\ to\ period\ 2\ frontier}{Efficiency\ of\ (x_0, y_0)^1\ with\ respect\ to\ period\ 1\ frontier} \quad (3.16)$$

- $TEC > 1$, Progress in relative efficiency from period 1 to 2
- $TEC = 1$, No change in relative efficiency from period 1 to 2
- $TEC < 1$, Regress in relative efficiency from period 1 to 2

Technological Change (TC)

We have at $(x_0, y_0)^1$:

$$\emptyset_1 = \frac{Efficiency\ of\ (x_0, y_0)^1\ with\ respect\ to\ period\ \ period\ 1\ frontier}{Efficiency\ of\ (x_0, y_0)^1\ with\ respect\ to\ period\ period\ 2\ frontier} \quad (3.17)$$

Similarly we have at $(x_0, y_0)^2$:

$$\emptyset_2 = \frac{Efficiency\ of\ (x_0, y_0)^2\ with\ respect\ to\ period\ period\ 1\ frontie}{Efficiency\ of\ (x_0, y_0)^2\ with\ respect\ to\ period\ period\ 2\ frontier} \quad (3.18)$$

TC is defined by the geometric mean of $\emptyset_1$ and $\emptyset_2$:

$$TC = \emptyset = \sqrt{\emptyset_1 \emptyset_2} \quad (3.19)$$

- $TC > 1$, Progress in the frontier technology around DMU_o from period 1 to 2
- $TC = 1$, No change in the frontier technology around DMU_o from period 1 to 2
- $TC < 1$, Regress in the frontier technology around DMU_o from period 1 to 2

Malmquist Index

The Malmquist index can be stated as follows :

$$M(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\ x\ \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}\ x\ \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right]^{1/2} \quad (3.20)$$

Where the notation $D^{t+1}(x^t, y^t)$ is the distance between the period t observation and the period $t + 1$ technology. The term outside the bracket relates to TEC and the term inside the bracket relates to TC. The index can be decomposed as follows:

$$TFPCH\ = TEC\ x\ TC = PEC\ x\ SEC\ x\ TC \quad (3.21)$$

- $TFPCH > 1$, Progress in the total factor productivity of the DMU_o from period 1 to 2
- $TFPCH = 1$, No change in the total factor productivity of the DMU_o from period 1 to 2
- $TFPCH < 1$, Regress in the total factor productivity of the DMU_o from period 1 to 2

3.7 Conclusion

DEA is a non-stochastic, non-parametric, linear programming based method that has been extensively used to measure the relative efficiency of similar DMUs with common inputs and outputs. It has been widely employed to measure the efficiency of the banking sector, therefore its choice as the methodology for this study. Below is a summary of the characteristics that make DEA a powerful measurement tool:

- A solid economic and mathematical foundation
- The ability to consider the tradeoffs and substitutions among inputs and outputs
- The possibility to handle multiple inputs and outputs stated in different measurement units
- Lack of assumptions requirements regarding the production function
- Information requirements include input and output quantities and not necessarily prices to calculate efficiency scores
- Calculation of a best-practice frontier for efficient DMUs and comparison of other DMUs according to that frontier
- Production of estimates for desired changes in input and/or outputs that result in projecting the DMUs on or below the efficient frontier

To explore the significance of the variations in DEA scores for the years under study, it is not enough to compare averages. Therefore, an appropriate paired difference test has to be conducted. For the purpose of this study, the test that will be applied is the Wilcoxon

matched pairs signed rank test since we have two paired samples, ordinal data and no prior knowledge of the shape of the population distribution. Finally, the last implemented methodology is the Malmquist TFP index based on DEA, which investigates the productivity of the Lebanese banks under study.

This chapter served as an introduction to the methodology that will be implemented in this study. The following chapter will present the review of literature with regard to the use of DEA in the banking sector. It will be also devoted to the inputs/outputs selection and to the data collection.

CHAPTER 4

Literature Review and Data Collection

4.1 Introduction

This chapter is composed of two sections. The first section introduces the efficiency measurement in the banking sector and depicts previous studies implementing DEA on this sector nationally and internationally. The second section is devoted to the input/output selection and to data collection.

4.2 Review of Previous Studies

a. Efficiency Measurement in the Banking Sector

The need for performance evaluation and efficiency measurement in the banking sector has increased as a result of the global contemporary developments. However it has been present for a long time since banks have always played a vital role in economies as they are the principal mean of making payments and financial intermediation. Additional reasons that make it crucial to evaluate banks efficiencies can be looked at from four perspectives. From a regulator's perspective, efficiency measurement is important to direct future banking policies, and spot inefficient banks which are considered riskier and having a higher likelihood of failure. As to customer's perception, efficient banks can offer a better customer experience at reasonable prices. The standpoint of stakeholders is that efficient banks usually earn superior returns. Finally, managers are interested in efficiency measurement to survive the cutthroat competition in the banking industry.

Before we start reviewing previous studies, we will outline some of the performance evaluation and efficiency measurement methods that were used by banks well before the DEA was introduced.

Ratio Analysis

Ratio analysis is a standard performance evaluation technique that has long been used. A ratio measures the relationship between two variables in order to provide insights about the different aspects of a bank's performance (efficiency, liquidity, profitability, capital adequacy, asset quality, risk management and many others). Any number of ratios can be used, depending on the needed analysis and comparisons are generally made for the same bank over different time periods or for different banks for the purpose of benchmarking certain aspects.

Traditional ratio measures are attractive to analysts due to their simplicity and ease of understanding. However, they present several limitations summarized as follows:

- Ratios assume comparable units which implies constant returns-to-scale
- Each ratio presents one aspect of the company's performance and combining many ratios usually yields an unsatisfactory measure of performance
- The different ratios that can be calculated from financial statements are sometimes contradictory and confusing
- Ratio analysis doesn't offer an objective way to identify inefficient units

For example difficulties arise when attempting to rank two banks where one has a better return on equity with a worse cost to income ratio. The choice will most probably depend on a subjective weighting of those ratios.

Frontier Efficiency Methodologies

To address the limitations of ratio analysis, research on the assessment of financial institutions performance has focused in the recent years on production frontier based models. These models estimate how banks perform relative to the best performing banks that form the empirically efficient frontier, considering they work under the same operating conditions. The main advantage of production frontier based models is that they compute overall objective efficiency scores in complex operational environments. They also spot the sources of inefficiency along with improvement strategies and provide

management with a framework that supports the planning, decision-making and control processes.

In the past three decades, five frontier methodologies have been used to measure the efficiency of banks. We distinguish between parametric methodologies; including stochastic frontier approach (SFA), thick frontier approach (TFA) and distribution-free approach (DFA); and non-parametric including data envelopment analysis (DEA) and free disposal hull (FDH) which is a special case of DEA. Their differences are mainly due to assumptions regarding the shape of the efficient frontier, the existence of random error and the distribution of inefficiencies and random error. Parametric methods require assumptions regarding the shape of the production curve and include two error components: an error term that reflects inefficiency and a random error. Whereas, non-parametric methods require few assumptions when specifying the optimal frontier and do not account for random errors. Berger and Humphrey (1997) discuss which of the methods is more effective and conclude that there is still no consensus on the superiority of the methods.

Other Performance Evaluation Methods

Other performance evaluation methods include multivariate statistical analysis, analytic hierarchy process, grey relational analysis and balanced scorecard. Multivariate statistical analysis refers to any of several advanced methods for examining multiple variables at the same time, usually two or more independent variables and one dependent variable. Examples of methods include: path analysis, factor analysis, principal component analysis, multiple regression analysis, MANOVA, MANCOVA, structural equation modeling, canonical correlations, and discriminant analysis. The analytic hierarchy process (AHP) is a theory developed by T.L. Saaty in 1971-1975. Modeling a problem using the AHP requires a hierarchic or network structure to represent that problem and pairwise comparisons based on expert judgments to establish relations within the structure. In general a hierarchical model descends from an overall objective, down to criteria, down further to subcriteria and finally to the alternatives from which the choice is to be made (Saaty, 1987). The grey relational analysis (GRA) was first proposed by Deng in 1982. It is a method that deals with grey information which refers to incomplete

or unknown information. It measures the changing relations between two systems or between two elements that occur in a system over time by predicting the unknown information based on the known information in order to understand the whole system. If the elements develop in a consistent trend, the two elements have a high level of relation. If two elements develop in an inconsistent trend, they have a low level of relation (Ho, 2006). The balanced scorecard (BSC) was introduced by Kaplan and Norton in 1992. It was based on the belief that if the improvement of the performance of intangible assets was among management goals, measurements of these intangible assets have to be integrated in the management system. The BSC preserves the financial metric as the most important metric to measure a company's performance and success. Additionally, it supplements it with metrics from three further perspectives: customer, internal process, learning and growth which are considered drivers for creating long-term shareholder value (Kaplan, 2010).

b. Literature Review of the Banking Sector Studies Using DEA

Our study aims at measuring the efficiency of Lebanese commercial banks using the non-parametric DEA method. The banking sector is probably the most heavily studied sector in the DEA literature and the methodology has been used in numerous applications, summarized as follows:

- Countrywide/ cross-national banks analysis
- Banks Mergers and Acquisitions (M&A)
- Bank branch analysis and branch deployment strategies
- Internal performance evaluation along the production process
- Customer service quality analysis
- Project selection and planning and staff allocation efficiency
- Personnel retention and work intensity targets
- Analysis of the impact of new technology, deregulation, ownership, economic/political/corporate events
- Forecast of banks performance
- Prediction of banks failure

From 1997 to 2010, according to a survey done by Cooper et al. in 2011, 225 applications of DEA were identified in the banking industry. Among them, 162 were at the institutional level and 63 were at the branch level because it's more difficult to obtain data in the latter case. The applications cover 43 countries/regions and among them 28 studies have an international scope. Implementation of DEA will surely continue, especially because of the new regulatory, policy and operational challenges resulting after the 2007/2008 financial crisis.

In order to investigate the approaches that can be implemented in our analysis, we will review some of the significant DEA studies conducted on commercial banks nationally and internationally.

Siems and Barr (1999) evaluated the productive efficiency of U.S. commercial banks in 3 chosen years. They implemented a constrained-multiplier, input-oriented DEA model on 11,397 U.S. commercial banks in 1991, 10,224 in 1994 and 8,628 in 1997. The authors conducted a survey on twelve experienced Federal Reserve Bank of Dallas banks examiners to determine the correct set of inputs and outputs for their model. As a result, the chosen inputs included salary expense, premises and fixed assets, other noninterest expense, interest expense and purchased funds while selected outputs were earning assets, interest income and noninterest income. The survey also aimed at evaluating the importance of each variable relative to the other to prescribe weights for the constrained-multiplier model. To evaluate the input and output factors driving the efficiency results, the banks were divided into quartiles for each of the three analysis periods based on their DEA scores. Comparing the most efficient quartile of banks to the least efficient quartile in 1991 revealed that the most efficient banks had significantly lower salary expense, premises and fixed assets, purchased funds and other non-interest expense and they had significantly higher relative levels of earning assets, interest expense and interest income. By 1997, only interest expense, premises and fixed assets and purchased funds had statistically significant differences among the input variables. On the output side, significant differences still existed for earning assets, interest income and non-interest income. The study also sought to check whether efficiency scores correlate with

performance. The average values for a few important bank performance measures by DEA efficiency score quartile were calculated for each analysis period. It was concluded for the three years under study that the most efficient banks earned a significantly higher return on average assets, held higher equity capital (as measured by equity/total assets) and managed relatively smaller loan portfolios that tended to have less risky assets than the least efficient institutions (as measured by total loans/total assets and non performing loans/gross loans). Banks were also analyzed in asset size quartiles. Largest institutions were found to be significantly less efficient than the smallest ones in 1991, while no significant differences were found in 1994 and 1997. Finally, it was found that banks that receive higher CAMEL (Capital Adequacy, Asset Quality, Management Quality, Earnings Ability, Liquidity) ratings by banking regulators, were significantly more efficient.

Ataullah and Le (2006) examined the relationship between three elements of economic reform - namely fiscal reform, financial reform, investment liberalization - and technical efficiency of banks in India. For this purpose, the study started by measuring the output-oriented BCC efficiency scores of banks operating in India during the period 1992-1998 by implementing two DEA models; model A (the loan-based model) and model B (the income-based model). Both models used operating and interest expenses as inputs but they differed in their outputs selection. Model A used loans & advances and investments as outputs while model B used interest and non-interest income. A "grand-frontier" was constructed to envelop all banks in the sample for all years in the period 1992-1998 instead of calculating a different frontier for each separate year. Results showed that according the model A, average efficiency of the Indian banking industry increased from 60.1% in 1992 to 75.83% in 1998. Model B also showed that average efficiency increased from 75.8% in 1992 to 80.68% in 1998. This development in efficiency was due to an improvement in the efficiency of all three ownership groups: public sector, domestic private and foreign banks. To deepen the investigation, the efficiency scores of both models were analyzed separately using the Ordinary Least Squares (OLS) and the Generalized Method of Moments Estimation (GMM) against macroeconomic variables affected by the economic reforms (fiscal deficit as a percentage of GDP, private

investment as a percentage of GDP, the Herfindahl index of concentration representing competition, share of foreign banks in total credit) and some bank specific variables (total assets, operating expenses/total income, investments/total assets, return on assets). Efficiency of the previous year was included with the independent variables as well. Results of the OLS and GMM estimates revealed that, from an economic reforms perspective, a negative relationship existed between efficiency of banks, fiscal deficits and presence of foreign banks. On the other hand, a positive relationship was uncovered between the level of competition and banks efficiency.

Chortareas et al. (2009) investigated the Greek banking system's efficiency under the new environment imposed by participation in the Economic and Monetary Union (EMU). Cost and profit efficiency as well as productivity change were calculated using the DEA and TFP Malmquist index for 85 commercial banks. The period under study was 1998-2003 covering Greece's entry into the Euro area in 2001. Two DEA models were used to calculate the efficiency scores. They both used one input; total cost, and two outputs; total customer loans and total other earning assets. One of the models included the nominal value of Off-Balance Sheet (OBS) items with outputs. Results showed that the addition of OBS to the DEA model did not provide additional information on the efficiency of Greek banks, therefore results were analyzed according to the model excluding OBS. Average cost efficiency ranged between 82.6% and 91.1% and increased by 4.3% over the 1998-2003 period. As to profit efficiency, it averaged 75% for the whole study period and increased by 93% from 1998 to 2003. TFP Malmquist index results showed that the Greek banking sector experienced a significant productivity growth of 15% over the study period caused seemingly by a positive TC (Technological Change). Finally, a censored Tobit regression model was employed to investigate cost efficiency, profit efficiency and productivity separately against the independent variables: return on average equity, total assets and equity to assets (proxy for risk). The regression yielded mixed results regarding the impact of profitability and size on efficiency and productivity measures. Whereas controlling for risk preferences was established as an important determinant of the efficiency for Greek banks.

Chiu et al.(2010) used DEA to measure the technical efficiency of 34 domestic banks in Taiwan from 2001 to 2003. Two DEA models were implemented to calculate the BCC and Super-Efficiency scores. They both used total deposits, number of employees and fixed assets as inputs while output factors were total loans, total investment and noninterest income. The only difference between the models was that one of them included credit ratings with the outputs to reflect its impact on efficiency scores. Results showed that there was a positive relationship between efficiency scores and credit ratings. In order to test the significance of the difference between the efficiency scores before and after the credit rating is taken into consideration a Wilconxon two-sample test of non-parametric statistics was conducted. The test proved that a significant difference existed in the BCC and Super-Efficiency scores before and after the credit rating was considered in the DEA model. The authors also noticed that efficiency scores improved specifically in the case of investment grade and speculation grade when credit rating is added to the DEA model. After this analysis, banks were divided into four quadrants according to their efficiency and credit rating with each quadrant having certain characteristics. The Malmquist Total Factor Productivity (TFP) index was employed and showed that all the efficiencies improved on average during the years 2001-2003. Thus total productivity, which is the product of efficiency changes and technical changes also improved. Results showed that the main factors affecting the efficiency changes can be mainly attributed to the changes of pure technical efficiency and scale efficiency.

Sufian et al.(2012) attempted to examine the effect of the Mergers and Acquisitions (M&A) that were forced by the Malaysian Central Bank on Malaysian banks revenue efficiency. These M&A were imposed due to three main factors: competition from foreign banks, large number of domestic commercial banks and financial crisis in Asia. Revenue efficiency is defined as how effectively a bank sells its outputs and is composed of technical and allocative efficiency. Along with cost efficiency, revenue efficiency determines profit efficiency. To study the effects of the forced M&A, the authors selected a sample of 34 commercial banks and analyzed the data into two event windows: the pre-merger (1995-1996) and post-merger (2002-2009). The Asian financial crisis period (1997 to 1999), merger period (2000) and cooling off period (2001) were excluded to

avoid possible biases. DEA model inputs consisted of deposits, labor and physical capital and corresponding input prices were price of loanable funds, price of labor and price of physical capital. Outputs included loans, investments and off-balance sheet items while output prices comprised respectively price of loans, price of investment and price of off-balance sheet items. The results showed that all efficiency concepts under study improved during the post-merger period. Cost efficiency, revenue efficiency and profit efficiency increased respectively from 83%, 79.7%, 69.5% to 91.4%, 80.7% and 88.8%. To test the robustness of the results, parametric tests (T-Test) and non-parametric tests (Mann-Whitney and Kruskal-Wallis) were conducted. All three tests confirmed that cost and profit efficiencies of the banks under study improved during the post-merger compared to the pre-merger period. As for revenue efficiency, the parametric test concluded that it increased in the post-merger period however this increase was not statistically significant at any conventional level. The non-parametric test concluded that this difference was significant at 10% level. Since the significance level is low, the study found that the Malaysian banking sector revenue efficiency did not significantly improve in the post-merger period. Authors concluded that the result of their study is consistent with earlier studies where it was discovered that although cost and profit efficiency may have improved, M&A do not improve bank's revenue efficiency if the level of cost efficiency is higher than profit efficiency.

Osman et al. (2008) conducted an 8 year period study on all Lebanese banks. They started with 60 banks in 1997 and ended with 45 in 2004 due to bank failures and M&A. The banks were classified into four groups according to their total deposits (1) Alpha (2) Beta (3) Gamma (4) Delta. DEA input directed models were used to measure the technical efficiencies of banks and study the impact of mergers and failures. Chosen inputs were interest expenses, general expenses, total deposits, number of employees and number of branches while chosen outputs were interest income and non-interest income. TE results showed decreasing trends for some banks leading to the closure of low efficiency banks or their merger with high efficiency banks. On average, 9 out of 60 banks were fully technically efficient out of which 75% belong to the Gamma and Delta groups of lower sized banks. The average TE score over the study period was 70% which

was lower than the average PTE of 85% due to scale efficiency. It was found that 70% of the M&A involved at least one Alpha efficient bank, and initially after the M&A the TE value may drop up to 10% until gaining full efficiency in most cases. However M&A among other banking groups, even if they involve efficient banks are not managing to gain back their original TE scores before the merger with a declining pattern in TE average values. This could be due to the lack of experience to handle well the larger sized entities. Finally a DEA based model was presented for the Banking Control Commission (BCC) of the Lebanese Central Bank to provide early warning signals of banks at risk. The model determined the lower bound and upper bound of a warning interval of TE scores. When a bank obtains a TE score outside this warning interval, it should be subject to immediate scrutiny and investigation by the BCC.

Saad and El-Moussawi (2009) considered 43 commercial banks operating in Lebanon over a period from 1992 till 2005. They used two approaches to compute cost efficiency over that period: DEA and SFA. The inputs used for their DEA model included deposits, fixed assets and number of employees while outputs comprised earning assets, other earning assets and off- balance sheet items. After the efficiency scores were computed, their first conclusion was that the average cost efficiency for the whole period was high, around 86% (SFA) and 81% (DEA). The coefficient of variation over the study period was 13.1% for the efficiency estimated using the SFA method against 15.85% for the efficiency estimated using DEA method, therefore dispersion of scores is lower for SFA. The second conclusion was that cost efficiency increased over the study period as measured by both methods. The average SFA efficiency score increased from 76.35% in 1992 to 89.12% in 2005 and the average DEA efficiency score increased from 73.96% in 1992 to 84.02% in 2005. There is also a reduction in dispersion of efficiency scores over the period 1992 to 2005. It is measured by the standard deviation which decreased from 16.6% to 9.18% with respect to SFA and from 15.91% to 12.5% with respect to DEA. The authors attempted to test the convergence of the efficiency scores and they concluded that there has been a convergence of the efficiency levels of Lebanese banks between 1992 and 2005. Finally an OLS regression analysis was conducted to investigate the determinants of efficiency scores determined by DEA and SFA methods. The financial

and economic explanatory variables included GDP growth, equity/total assets, total assets, provisions for bad debt/size of balance sheet and return on assets. The regression results showed that internal factors and the economic environment seem to contribute significantly to the evolution of efficiency scores.

Zreika and Elkanj (2011) attempted to identify whether Lebanese banks were operating at full efficiency and they wanted to investigate the impact of the 2007 financial crisis on the efficiency scores. For this purpose, they implemented an input-oriented DEA model on a sample of 40 private and foreign banks operating in Lebanon for the period 2002-2009. Their study used the production approach which views banks as entities who use labor and capital as inputs to produce deposits and loans as outputs. To present a clear comparison of the results, the authors split the banks in two groups using two methods. The first method is according to asset size and the second is according to whether the bank is local or foreign. The period under study was also split into two sub-periods: 2002-2006 and 2006-2009. The authors investigated technical efficiency (TE) which measures a DMU's ability to minimize inputs and maximize outputs, pure technical efficiency (PTE) which reveals managerial efficiency, and scale efficiency (SE) which reflects economies of scale due the DMU size. Results showed that in general, TE increased in all bank categories after the financial crisis due to increases in PTE in large and small banks and increases in SE for medium and small banks. However, TE scores remained very low for small banks during both sub-periods due to problems in SE, therefore the authors suggested that mergers could be a possible solution for this situation. It was also noticed that large banks outperformed both small and medium banks in term of TE and PTE improvements, however their SE scores decreased after the crisis. Finally, local banks outperformed foreign banks in TE after the financial crisis due to a considerable increase in SE for local banks.

Table 8 summarizes some key aspects of the studies we have just discussed. Namely, it lists the chosen inputs and outputs to facilitate our selection of factors.

Title of Study	Period	Methodology(ies)	Variables	
			Input(s)	Output(s)
Benchmarking the Productive Efficiency of US Banks	1991 1994 1997	Constrained-Multiplier DEA	1-Salary expense 2-Premises and fixed assets 3-Other noninterest expense 4-Interest expense 5-Purchased funds	1-Earning assets 2-Interest income 3-Noninterest income
Economic Reforms and Bank Efficiency in Developing Countries: The Case of the Indian Banking Industry	1992-1998	1-DEA 2-OLS and GMM	*Models A&B:* 1-Operating expenses 2-Interest expenses	*Model A:* 1-Loans & Advances 2-Investments *Model B:* 1-Interest Income 2-Noninterest income
Efficiency and Productivity of Greek Banks in the EMU Era	1998-2003	1-DEA 2-TFP Malmquist index 3-Tobit regression	1-Total Cost (cost of deposits + total operating expenses)	1-Total customer loans 2-Total other earning assets 3-Off-Balance Sheet items (In the second model)
Efficiency and Credit Rating in Taiwan Banking: DEA Analysis Estimation	2001-2003	1-DEA 2-Wilconxon two-sample test 3-TFP Malmquist index	1-Total deposits 2-Number of employees 3-Fixed assets	1-Total loans 2-Total investment 3-Noninterest income 4-Credit rating(In the second model)
Assessing the Effect of Mergers and Acquisitions on Revenue Efficiency: Evidence from the Malaysian Banking Sector	1995-1996 & 2002-2009	1-DEA 2-T-test 3-Mann-Whitney and Kruskal-Wallis	1-Deposits 2-Labor 3-Physical capital *Input prices:* 1-Price of loanable funds 2-Price of labor 3-Price of physical capital	1-Loans 2-Investments 3-Off-balance sheet items *Output prices:* 1-Price of loans, 2-Price of investment 3-Price of off-balance sheet items

Table 8 : Comparative Table of DEA studies

Title of Study	Period	Methodology(ies)	Variables	
			Input(s)	Output(s)
Data Envelopment Analysis: A Tool for Monitoring the Relative Efficiency of Lebanese Banks	1997- 2004	1-DEA	1-Interest expenses 2-General expenses 3-Total deposits 4-Number of employees 5-Number of branches	1-Interest Income 2-Non-interest income 3-Total loans
Evaluating the Productive Efficiency of Lebanese Commercial Banks: Parametric and Non-Parametric Approaches	1992-2005	1-DEA 2-SFA 3-OLS	1-Deposits 2-Fixed assets 3-Number of employees employed at the bank *Prices of inputs:* 1-Financial burdens to total deposits 2-General operating expenses to capital expenditures 3-Staff cost to number of employees	1-Earning assets 2-Other earning assets 3-Off balance sheet
Banking Efficiency in Lebanon: An Empirical Investigation	2002-2009	1-DEA	1-Labor 2-Capital	1-Deposits 2-Loans

Table 8 : Comparative Table of DEA studies

4.3 Data Collection

a. Input and Output Factors Selection

A difficulty that arises with DEA consists in choosing the correct input and output factors. We notice in the studies previously discussed that the input and output selection depends on the focus of the respective study. We also note that two alternative approaches were used to define the inputs and outputs. The production approach assumes the bank is supposed to use labor and capital factors to generate loans and deposits,

whereas the intermediation approach assumes that the bank collects deposits using the labor and capital factors to transform them into loans and investments.

Seven out of the eight studies elaborated before and most of the studies that have implemented DEA in the banking sector employed the intermediation approach. Thus it is the approach we choose to adopt. Additionally, our study aims at measuring technical efficiency, and as described in the previous chapter, a DMU is technically efficient if it produces the maximum amount of output using a minimum amount of input. Both definitions of the intermediation approach and technical efficiency will guide our input and output selection.

It is easier to start by selecting the output factors, which are usually dependent on the business strategy and goals of the DMU, and then link them to their corresponding inputs. According to the intermediation approach, banks produce loans and investments. Hence technically efficient banks are the ones that maximize loans and investments given a certain inputs level. For the purpose of our study, we use total interest income and total non-interest income as proxies for loans and investments. Off-balance sheet items would have been an interesting addition to output factors however they were not included for the below reasons:

- Huge discrepancies exist when attempting to collect off-balance sheet figures for Lebanese banks from different sources (Bankscope and Bilanbanques in our case) which puts the accuracy and consistency of the reported figures under question.
- Off-balance sheet items aren't really significant in the Lebanese context. They mainly include letters of credit (LCs), letters of guarantee (LGs), fiduciary accounts and assets under management. In addition, Lebanese banks aren't involved in derivatives trading activities, therefore DEA scores would remain unaffected.

As for the inputs, the intermediation approach assumes that the bank collects deposits using the labor and capital. Thus, technically efficient banks are the ones that minimize deposits, labor and capital given a certain output level. We operationalize these factors by

choosing the following inputs: number of employees for labor, total interest expense for deposits and number of branches for capital.

Table 9 summarizes our chosen inputs and outputs along with a detailed description when required.

Inputs	**Details**
Number of Branches	-
Number of Employees	-
Total Interest Expense	Interest & similar expense (Interest expense on customer deposits + Other interest expense)
Outputs	**Details**
Total Interest Income	Interest & similar income (Interest income on loans + Other interest income + Dividend income)
Total Non-Interest Income	Net fees & commission income + Net gain/loss on financial assets and/or investments + Net profits on foreign exchange + Other operating income + Other net non operating income

Table 9 : Inputs and Outputs

b. Sample

To minimize estimation bias, the DMUs considered for a DEA study should be homogenous; they must perform the same tasks and have similar objectives. The selection process for this study strictly adhered to these conditions.

The Association of Banks in Lebanon classifies banks in five categories: Lebanese banks S.A.L., Lebanese banks S.A.L. with Arab control, Lebanese banks S.A.L. with foreign non-Arab control, Arab banks and foreign banks. To maintain homogeneity, the sample selected for the purpose of this study comprises Lebanese banks S.A.L. and namely commercial banks. They consist of:

1. B.L.C Bank S.A.L..
2. Bank Audi S.A.L.
3. Bank of Beirut (BOB) S.A.L.
4. BankMed S.A.L.

5. Banque Bemo S.A.L.
6. Banque de L'industrie et du Travail (BIT) S.A.L.
7. Banque Libano-Francaise (BLF) S.A.L.
8. Banque Pharaon et Chiha S.A.L.
9. BBAC S.A.L.
10. BLOM Bank S.A.L.
11. BSL Bank S.A.L.
12. Byblos Bank S.A.L.
13. Credit Libanais S.A.L.
14. CreditBank S.A.L.
15. Fenicia Bank S.A.L.
16. First National Bank (FNB) S.A.L.
17. Fransabank S.A.L
18. IBL Bank S.A.L.
19. Jammal trust Bank (JTB) S.A.L.
20. Lebanese Swiss Bank (LSB) S.A.L.
21. Lebanon and Gulf Bank (LGB) S.A.L.
22. MEAB S.A.L.
23. Near East Commercial Bank (NECB) S.A.L.
24. Société Générale de Banque au Liban (SGBL) S.A.L.

Some commercial banks belonging to the Lebanese banks S.A.L. category were excluded from the study since they don't comply with DEA data requirements. For instance, Al-Mawarid Bank S.A.L. and Banque de Credit National S.A.L. were ruled out since they recorded negative figures for total non-interest income in 2008. In addition to this, Federal Bank of Lebanon S.A.L. was also eliminated since it did not publish its results in 2011.

Saudi Lebanese Bank S.A.L. has only 1 branch and 21 employees and its financials are consolidated with BankMed. Therefore it was also excluded from the sample since it is not comparable with the banks under study. Credit Libanais S.A.L is a Lebanese bank

with Arab control, however we have included it because of its significance in the Lebanese market. Moreover, its operations are similar to the banks under study.

c. Restrictions in the Variables Selection

In order to properly run a DEA model several conditions should be met. DEA requires that the data is complete and greater than zero for all the chosen inputs and outputs, which is the case of the selected variables in this study. Two additional and equally important restrictions for DEA are discussed below.

The number of DMUs

Including a larger set of DMUs increases efficiency discrimination among DMUs, raises the probability of capturing high performance units and results in a sharper identification of the relations that exist between the inputs and outputs. Nevertheless, the increase in the number of DMUs should be done carefully by including homogenous units that conform with the set of units under study. A rough rule of thumb is to choose:

$$n \geq max\ \{m\ x\ s\ , 3(m + s)\}$$

Where:

- n is the number of DMUs
- m is the number of inputs
- s is the number of outputs

For the purpose of this study we have $n = 24, m = 3\ and\ s = 2$. Therefore the number of DMUs comply with this equation. ($24 > 15$)

Isotonicity Test

The isotonicity principle is another restriction that inputs and outputs have to comply with. Increasing the value of any input while keeping all other factors constant should not decrease any output but should result in an increase in the value of at least one output.

To determine this isotonicity property, a correlation analysis on the input and output variables was performed. Table 10 presents the results and shows that all coefficients are

greater than 0.8. This indicates a strong positive correlation between the input and output variables for the 3 years under study.

2008	Total Interest Income	Total Non-Interest Income
Number of Branches	0.9482	0.9062
Number of Employees	0.9761	0.9547
Total Interest Expense	0.9976	0.9394
2011	**Total Interest Income**	**Total Non-Interest Income**
Number of Branches	0.9471	0.8331
Number of Employees	0.9854	0.8966
Total Interest Expense	0.9967	0.9278
2013	**Total Interest Income**	**Total Non-Interest Income**
Number of Branches	0.9716	0.8852
Number of Employees	0.9904	0.9325
Total Interest Expense	0.9970	0.9570

Table 10 : Pearson Correlation Coefficient Between Inputs and Outputs

d. Data

The data for the inputs and outputs selected above was collected from Bilanbanques (editions 2010, 2011, 2013, 2014), which is a yearly publication containing aggregates of data and performance ratios on the banking sector in Lebanon. Table 11 shows a statistical description of the data.

2008	Mean	Median	Minimum	Maximum	Standard Deviation
Number of Branches	40	21.5	5	143	39
Number of Employees	907	343.5	74	4200	1075
Total Interest Expense (USD)	171,426,289	81,319,947	5,811,162	724,150,202	210,007,780
Total Interest Income (USD)	259,923,109	115,329,800	8,445,225	1,147,155,510	329,079,111
Total Non-Interest Income (USD)	37,321,537	8,827,657	2,122,618	238,569,973	54,746,952

2011	Mean	Median	Minimum	Maximum	Standard Deviation
Number of Branches	51	28	5	154	47
Number of Employees	1198	665	95	4560	1312
Total Interest Expense (USD)	212,836,568	127,623,357	7,485,485	841,625,343	235,571,452
Total Interest Income (USD)	327,491,969	173,959,051	11,989,062	1,364,492,319	383,463,177
Total Non-Interest Income (USD)	64,296,973	29,579,712	1,624,303	437,539,789	97,474,522
2013	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
Number of Branches	55	30	6	189	52
Number of Employees	1286.791667	734.5	107	5894	1487
Total Interest Expense (USD)	261,417,755	150,084,972	8,829,952	1,151,746,245	291,662,549
Total Interest Income (USD)	397,373,295	216,273,621	17,781,935	1,807,143,715	458,751,931
Total Non-Interest Income (USD)	74,648,147	22,277,234	2,375,974	398,049,998	101,965,283

Table 11 : Descriptive Statistics of Input and Output Variables

Bank Audi and BLOM Bank were identified as outliers. To overcome this problem they were excluded from the descriptive statistics in table 12.

2008	Mean	Median	Minimum	Maximum	Standard Deviation
Number of Branches	32	18	5	105	29
Number of Employees	650	320	74	2,362	644
Total Interest Expense (USD)	123,546,170	62,933,457	5,811,162	452,497,916	139,351,761
Total Interest Income (USD)	182,056,282	83,629,200	8,445,225	688,421,227	205,653,391
Total Non-Interest Income (USD)	24,570,966	7,765,664	2,122,618	98,372,139	29,741,609
2011	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
Number of Branches	42	24	5	142	38
Number of Employees	901	464	95	3,074	883
Total Interest Expense (USD)	161,564,298	92,342,677	7,485,485	557,461,360	165,320,492
Total Interest Income (USD)	239,432,270	132,178,572	11,989,062	836,079,602	251,233,118
Total Non-Interest Income (USD)	41,372,278	27,207,345	1,624,303	180,190,381	49,023,827
2013	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
Number of Branches	44	26	6	154	39
Number of Employees	931	505	107	3,265	887
Total Interest Expense (USD)	196,078,356	119,440,518	8,829,952	627,499,171	191,556,737
Total Interest Income (USD)	290,590,718	173,112,829	17,781,935	912,772,964	286,153,413
Total Non-Interest Income (USD)	51,583,931	20,922,164	2,375,974	236,126,218	65,092,345

Table 12 : Descriptive Statistics of Input and Output Variables excluding Bank Audi and BLOM

Table 13 depicts the input and output aggregates for the years under study and reveals some interesting results. The increase in the number of branches and employees from

2008 to 2011 was much higher than the increase witnessed from 2011 to 2013. This could be a result of the thriving growth the Lebanese banking sector witnessed after the beginning of the financial crisis in September 2008, and the slowdown caused by the eruption of the Arab spring in December 2010. Total interest expense and total interest income increased in both periods signaling an increase in deposits and lending activity. Total non-interest income also increased significantly from 2008 to 2011, possibly illustrating an attempt by banks to diversify their sources of income.

	2008	2011	2013
Number of branches	965	1220	1314
Number of employees	21768	28744	30833
Total Interest Expense (USD)	4,114,230,947	5,108,077,639	6,274,026,112
Total Interest Income (USD)	6,238,154,624	7,859,807,258	9,536,959,088
Total Non-Interest Income (USD)	895,716,898	1,543,127,351	1,791,555,532

Table 13 : Inputs and Outputs Aggregates

e. Data Envelopment Analysis

As explained in the previous chapter, 3 DEA models will be used to calculate the relative technical efficiency scores of the 24 selected banks:

1. The basic CCR model
2. The BCC model
3. The A&P model

The purpose of implementing three different DEA models is to capture the entirety of the bank's performance.

The input-oriented model is selected for the calculation of the efficiency scores. This model measures how much less inputs a bank can employ to produce the same amount of outputs. It is the model of choice since a bank has better control over its inputs. The outputs can be driven by various factors beyond the control of banks such as competition.

The Basic CCR Model

As elaborated in the previous chapter, efficiency is the ratio of the weighted sum of outputs to weighted sum of inputs. Therefore the efficiency formula adapted to this study becomes as follows:

$$Efficiency\ (E) = \left(\frac{II\ u_1 + NII\ u_2}{Emp\ v_1 + Br\ v_2 + IE\ v_3}\right)$$

Where:

- u_1 is the weight given to the total interest income output
- u_2 is the weight given to the total non-interest income output
- v_1 is the weight given to the number of employees input
- v_2 is the weight given to the number of branches input
- v_3 is the weight given to the total non-interest income input

To solve this equation without prior knowledge of u_1, u_2, v_1, v_2, v_3 it is transformed into linear programming as done by Charnes, Copper and Rhodes. It becomes:

$$Max\ E_{1,1} = IIu_1 + NII\ u_2 \text{ For bank 1 in year 1}$$

Subject to:

- $Emp\ v_1 + Br\ v_2 + IE\ v_3 = 1$
- $\sum IIu_1 + NII\ u_2 - \sum Emp\ v_1 + Br\ v_2 + IE\ v_3 \leq 0$ for all banks in year 1
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$

The BCC Model

It was also explained in the previous chapter that the CCR model takes into account constant returns to scale. However, banks don't always operate at optimal scale and are subject to variable returns to scale (VRS). For this purpose, the BCC model is also implemented in this study since it includes a variable u_0 that accounts for variable returns to scale. The linear programming formula in the BCC model becomes:

$$Max\ E_{1,1} = IIu_1 + NII\ u_2 - u_0 \text{ For bank 1 in year 1}$$

Subject to:

- $Emp\ v_1 + Br\ v_2 + IE\ v_3 = 1$
- $\sum IIu_1 + NII\ u_2 - \sum Emp\ v_1 + Br\ v_2 + IE\ v_3 - u_0 \leq 0$ for all banks in year 1
- $u_1, u_2, v_1, v_2, v_3 \geq \varepsilon \geq 0$
- u_0 free in sign

Scale Efficiency

After the computation of the CCR and BCC scores, they will be compared to check if they are similar because if they are, then there is no scale efficiency. As explained in the previous chapter scale efficiency is expressed as the ratio of overall technical efficiency (OTE) obtained from the CCR model, to pure technical efficiency (PTE) obtained from the BCC model.

$$SE = \frac{OTE}{PTE} = \frac{CCR}{BCC}$$

Therefore once CCR and BCC scores are calculated, it will be possible to calculate SE of all the banks during the three years under study.

Super-Efficiency

The CCR and BCC model measure the relative efficiency of all banks under study. They assign a score of 100% for all the efficient banks outperforming their peers. However, in some situations it would be helpful to rank the efficient banks and this can't be done by using the DEA models discussed above. The A&P model covers this weakness by allowing a differentiation between efficient DMUs.

4.4 Comparison Between A&P Scores And Key Ratios of Bank Performance

After the computation of the A&P scores, they will be compared to some key ratios representing the most important aspects of banks performance. The chosen ratios are:

1. **Total Assets:** This is a balance sheet item rather than a ratio. It is important to compare it to A&P efficiency scores to conclude whether they vary with the size of the bank. The higher the value of total assets, the higher the ranking assigned to the bank.

2. **Loan Loss Reserves on gross doubtful loans (DLs)/DLs**: This ratio is used as a proxy for risk. It measures the bank's ability to absorb losses from its non-performing loans. The banks are ranked in decreasing order for this ratio.

3. **Loans to deposits:** As mentioned in chapter 2, this ratio constitutes a parallel image to banks liquidity. The lower it is, the more liquid a bank is. Therefore the bank ranked number 1 is the one having the least score.

4. **Capital adequacy ratio:** This ratio determines the bank's capacity to meet the time liabilities and other risks such as credit risk, operational risk, etc. It is calculated as follows:

$$CAR = \frac{Tier\ 1\ Capital + Tier\ 2\ Capital}{Risk\ Weighted\ Assets}$$

   The higher the ratio, the higher the capital adequacy ranking of the bank.

5. **Return On Average Assets (ROAA):** This ratio measures how efficiently the bank converts its assets into income. The banks are ranked in decreasing order according to this ratio.

6. **Cost-to-Income:** This ratio reflects the efficiency of banks in minimizing costs while increasing profits. The lower the cost-to-income ratio, the higher the ranking of the bank.

All the data for the above ratios are collected from Bilanbanques.

4.5 Conclusion

This chapter illustrated several interesting implementations of DEA in the Lebanese and global banking sectors. The discussed studies guided our selection of the input and output factors which were chosen to include the number of branches, number of employees and total interest expense as inputs, and total interest income and total non-interest income as outputs.

The sample of banks that will be covered in the study was identified and the accuracy of the DEA model was confirmed through some variables restrictions. Finally, the equations of the CCR and BCC models were adapted to the study by taking into consideration our chosen variables, and the key performance ratios to be compared to the A&P scores were described.

CHAPTER 5

Findings

5.1 Introduction

This chapter presents and analyzes the outcomes of applying the DEA in its different models. The CCR and BCC scores are computed for 2008, 2011 and 2013. The results of 2013 are compared with the remaining years under study. Additionally, scale efficiencies (SE) and returns to scale are determined for all banks during that year to further examine the sources of inefficiency. Paired difference tests are conducted with regard to the evolution of efficiency over this time period. The 2013 A&P scores are calculated, and compared to some key performance ratios of the banks during that year. Finally, the Malmquist TFP index is implemented to investigate the productivity of the banks.

5.2 Data Envelopment Analysis Results

The software used to compute the DEA results is Efficiency Measurement System (EMS) version 1.3 by Holger Scheel (available from http://www.holger-scheel.de/ems/). It was chosen since it comprises all the DEA models we want to use for efficiency measurement, and it is free of charge for academic users.

a. Preparing and Loading the Data

The input/output data to be analyzed with EMS should be collected in an Excel 97 (or older) worksheet as illustrated in table 14. The strings {I} and {O} allow the software to differentiate between the input and output factors. Three different workbooks were prepared for each year under study.

Bank	Branches {I}	Employees {I}	Interest Expense {I}	Interest Income {O}	Non-Interest Income {O}

Table 14 : Data format in EMS 1.3

Once the input/output worksheet for a given year is ready, the excel file is loaded into EMS in order to run the different DEA models according to the three conditions illustrated in figure 20.

The structure should be set to convex since all three models assume convexity. As to the distance, we select radial distance which measures a DMU's efficiency score depending on its proportional distance to the efficiency frontier. The input orientation should be selected as justified in the previous chapter.

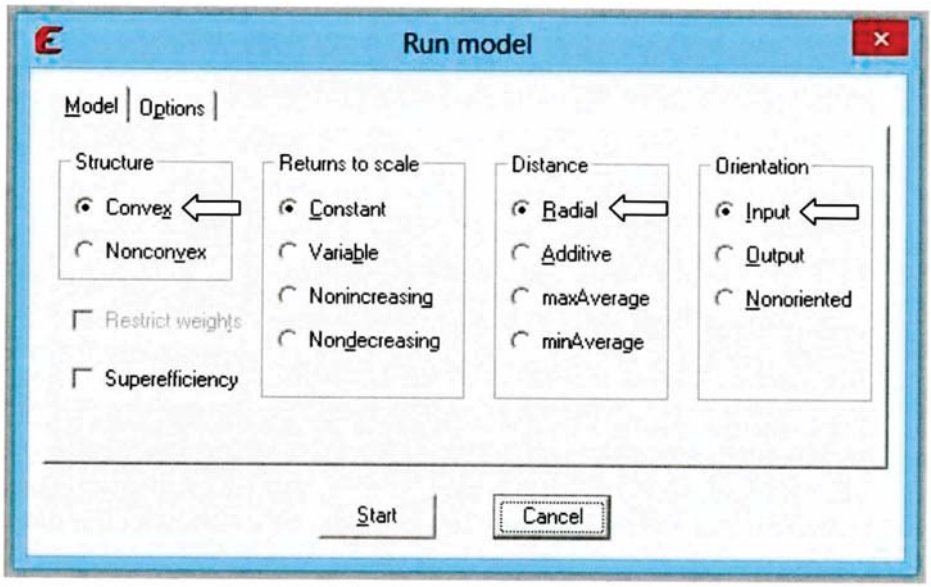

Figure 20 : Model Conditions

b. CCR and BCC Model Results

We start by running the CCR model, which assumes constant returns to scale. Figure 21 illustrates the necessary input required by EMS to measure the CCR scores.

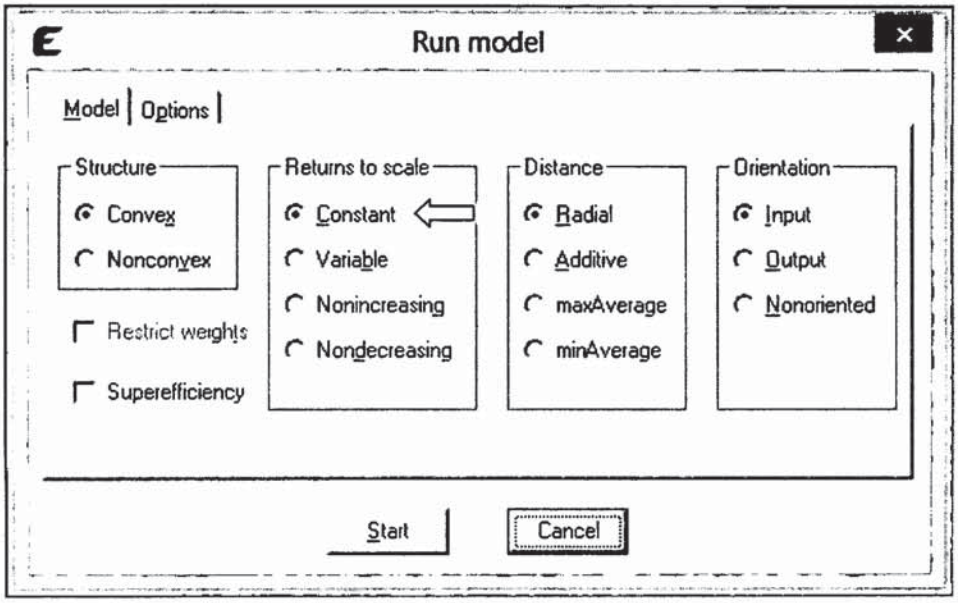

Figure 21 : CCR Model

To account for variable returns to scale, we also run the BCC model as illustrated in figure 22.

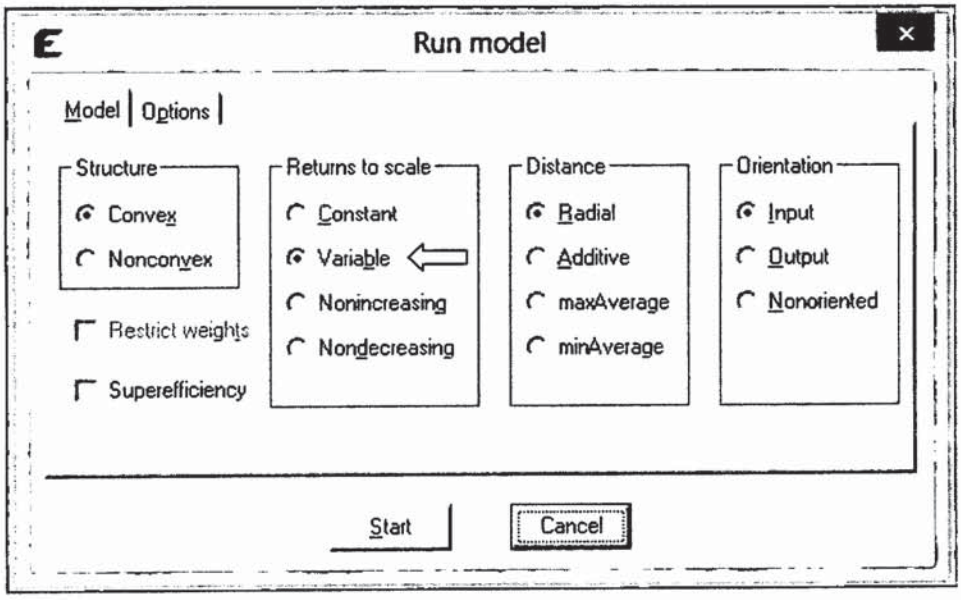

Figure 22: BCC Model

The obtained scores and their descriptive statistics are presented in table 15. A preliminary glance at the results brings three fundamental conclusions to our attention. The first is that the average efficiency of the Lebanese banks under study is quite high whether we are assuming constant or variable returns to scale. The high efficiency levels reflect the condition of the banking industry in Lebanon driving banks to function as efficiently as possible. This could be due to the high competition in the sector, and the strong supervision it is subjected to. The second conclusion is that a difference exists between the CCR and BCC scores for some banks which signals the presence of scale efficiency. Finally Bank Audi, Banque Pharaon et Chiha, BLOM bank and IBL seem to be leaders in efficient operations, as they remained fully efficient throughout the years under study.

Bank	CCR scores			BCC Scores		
	2008	2011	2013	2008	2011	2013
B.L.C Bank S.A.L..	0.900	0.913	**1.000**	0.904	0.926	**1.000**
Bank Audi S.A.L.	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Bank of Beirut S.A.L.	**1.000**	0.929	**1.000**	**1.000**	0.931	**1.000**
BankMed S.A.L.	**1.000**	0.968	**1.000**	**1.000**	0.979	**1.000**
Banque Bemo S.A.L.	**1.000**	0.762	0.861	**1.000**	0.887	0.964
Banque de L'industrie et du Travail S.A.L.	0.784	0.805	0.791	0.801	0.818	0.821
Banque Libano-Francaise S.A.L.	**1.000**	0.964	0.992	**1.000**	0.964	0.994
Banque Pharaon et Chiha S.A.L.	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
BBAC S.A.L.	0.842	0.907	0.899	0.851	0.917	0.901
BLOM Bank S.A.L.	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
BSL Bank S.A.L.	0.815	0.776	0.802	0.827	0.780	0.803
Byblos Bank S.A.L.	0.948	0.960	0.939	0.949	0.975	**1.000**
Credit Libanais S.A.L.	0.890	0.867	0.888	0.891	0.872	0.889
CreditBank S.A.L.	0.829	0.865	0.854	0.838	0.920	0.881
Fenicia Bank S.A.L.	0.920	0.921	0.908	0.939	0.977	0.930
First National Bank S.A.L.	0.832	0.877	0.908	0.859	0.936	0.932
Fransabank S.A.L	0.951	0.913	0.968	0.951	0.922	0.975
IBL Bank S.A.L.	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Jammal trust Bank S.A.L.	0.861	0.977	0.922	0.870	**1.000**	**1.000**
Lebanese Swiss Bank S.A.L.	0.884	0.833	0.837	0.917	0.889	0.863
Lebanon and Gulf Bank S.A.L.	0.801	0.808	0.947	0.860	0.951	0.985
MEAB S.A.L.	0.823	0.807	0.960	**1.000**	0.974	**1.000**
Near East Commercial Bank S.A.L.	0.970	0.975	**1.000**	**1.000**	**1.000**	**1.000**

Societe Generale de Banque au Liban S.A.L.	1.000	0.894	1.000	1.000	0.952	1.000
Minimum	**0.784**	**0.762**	**0.791**	**0.801**	**0.780**	**0.803**
Efficient Banks	**9**	**4**	**9**	**11**	**6**	**12**
Average	**0.919**	**0.905**	**0.937**	**0.936**	**0.940**	**0.956**
Standard Deviation	**0.079**	**0.076**	**0.069**	**0.070**	**0.059**	**0.063**
Coefficient of Variation	**0.086**	**0.084**	**0.073**	**0.075**	**0.063**	**0.066**

Table 15 : CCR and BCC scores

b.1 Analysis of the 2013 Results

CCR

According to the CCR model, most banks recorded in 2013 the best efficiency results compared to 2011 and 2008. Average efficiency was 0.937, the highest among the three years, signaling superior and improved efficiency levels. The coefficient of variation of the efficiency scores was 0.073, the lowest among the three years, which indicates a smaller dispersion of the efficiency scores around the average. The minimum efficiency level, recorded by Banque de L'industrie et du Travail S.A.L, was higher than the minimum for 2008 and 2011 which further signals an improvement in overall efficiency.

BCC

BCC scores also suggest that banks in 2013 generally recorded the best efficiency results compared to 2011 and 2008. The average efficiency of 0.956 was the highest among the years under study. As to the coefficient of variation, it was lower than its 2008 value but slightly higher than its value in 2011. Half of the 24 banks under study were fully efficient and the minimum efficiency score recorded by BSL Bank was the highest minimum among the three years under study. Therefore it could be concluded that overall BCC efficiency improved in 2013. Finally, since average BCC is greater than average CCR, we conclude that when bank size is taken into consideration, efficiency scores increase, which suggests problems of scale efficiency.

Scale Efficiency

As stated in chapter 3, CCR scores reveal the overall technical efficiency (OTE) of a DMU while BCC scores yield the pure technical efficiency (PTE). Dividing the OTE by

the PTE gives the scale efficiency (SE) of a DMU. At this stage, it becomes possible to conduct an investigation of the sources of inefficiency for each bank by decomposing OTE into PTE and SE.

PTE refers to the bank's managerial and marketing skills in utilizing inputs in order to maximize outputs. It includes skills such as controlling operating expenses, successful screening and monitoring of borrowers, marketing activities focused on attracting depositors, efficient risk management techniques, etc. On the other hand, SE reflects the ability of management to choose the optimum scale of production that will lead to the desired production levels. Therefore OTE is determined by managerial efficiency (PTE), and scale of production (SE).

Returns to scale are important as well to determine the type of scale inefficiency for each DMU. However, they are not generated by EMS 1.3. Thus, we had to use another software which is DEAP Version 2.1 available at http://www.uq.edu.au/economics /cepa/deap.php. The procedure to obtain returns to scale results using this software is:

1. Create 3 notepad documents: one for the data, another for the instruction and one empty document for the output

2. The file containing the data should contain only numbers and it should have the outputs listed before the inputs. It shouldn't include neither the DMU nor inputs and outputs names. For example:

```
300440095.5 21199873.3     56        961      183009769.8
1807143715  398049998      189       5894     1151746245
582246953.2 119954581.1    81        1611     383778763.5
```

Interest Income	Non-Interest Operating Income	Number of Employees	Number of Branches	Interest Expense

3. The instruction file should be as follows (The bold text is only for the purpose of explanation and should not be included in the instruction file):

`Data.txt`	**(Data file name)**
`Output.txt`	**(Output file name)**
`24`	**(Number of DMUs)**
`1`	**(Number of time periods)**
`2`	**(Number of outputs)**
`3`	**(Number of inputs)**
`0`	**(0=Input and 1=Output oriented)**
`1`	**(0=Constant Returns to Scale, 1=Variable Returns to Scale)**
`0`	**0=DEA(Multi-Stage), 1=Cost-DEA, 2=Malmquist-DEA, 3=DEA (1-Stage), 4=DEA (2-Stage)**

4. Once the three files are ready, open the DEAP DOS document and write the instruction file name as shown in figure 23

5. Click on "Enter" to execute the instruction and DOS will save the results automatically in the output file. The obtained scores are exactly the same as the ones calculated using EMS but including additionally returns to scale.

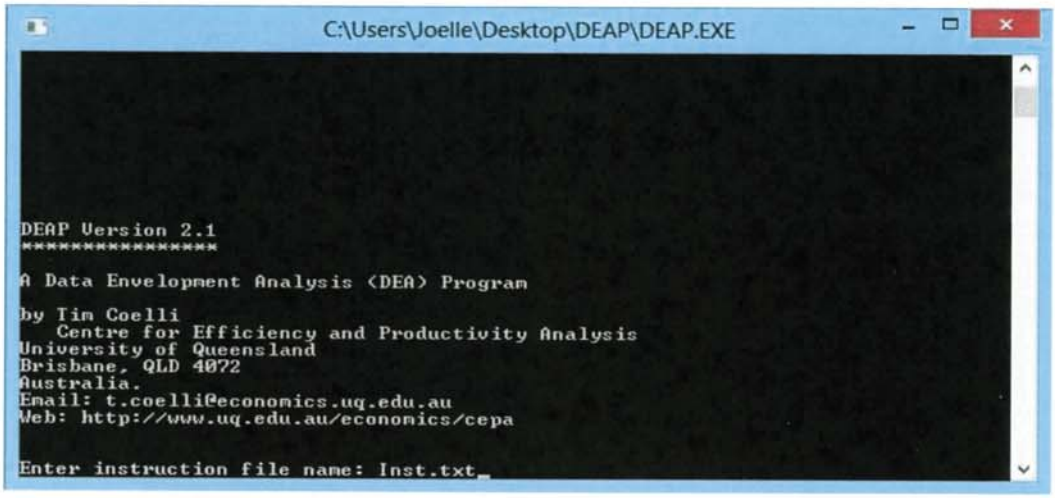

Figure 23: DOS interface

Table 16 presents the results for OTE, PTE, SE and returns to scale.

Bank	OTE (CCR)	PTE (BCC)	SE=OTE/ PTE	Returns to scale
B.L.C Bank S.A.L..	1.000	1.000	1.000	CRS
Bank Audi S.A.L.	1.000	1.000	1.000	CRS
Bank of Beirut S.A.L.	1.000	1.000	1.000	CRS
BankMed S.A.L.	1.000	1.000	1.000	CRS
Banque Bemo S.A.L.	0.861	0.964	0.894	IRS
Banque de L'industrie et du Travail S.A.L.	0.791	0.821	0.963	DRS
Banque Libano-Francaise S.A.L.	0.992	0.994	0.999	IRS
Banque Pharaon et Chiha S.A.L.	1.000	1.000	1.000	CRS
BBAC S.A.L.	0.899	0.901	0.998	IRS
BLOM Bank S.A.L.	1.000	1.000	1.000	CRS
BSL Bank S.A.L.	0.802	0.803	0.999	DRS
Byblos Bank S.A.L.	0.939	1.000	0.939	DRS
Credit Libanais S.A.L.	0.888	0.889	0.999	IRS
CreditBank S.A.L.	0.854	0.881	0.970	DRS
Fenicia Bank S.A.L.	0.908	0.930	0.977	IRS
First National Bank S.A.L.	0.908	0.932	0.975	IRS
Fransabank S.A.L	0.968	0.975	0.992	DRS
IBL Bank S.A.L.	1.000	1.000	1.000	CRS
Jammal Trust Bank S.A.L.	0.922	1.000	0.922	DRS
Lebanese Swiss Bank S.A.L.	0.837	0.863	0.970	IRS
Lebanon and Gulf Bank S.A.L.	0.947	0.985	0.961	IRS
MEAB S.A.L.	0.960	1.000	0.960	IRS
Near East Commercial Bank S.A.L.	1.000	1.000	1.000	CRS
Societe Generale de Banque au Liban S.A.L.	1.000	1.000	1.000	CRS
Efficient Banks	**9**	**12**	**9**	
Average	**0.937**	**0.956**	**0.980**	

Table 16 : Scale Efficiency Scores in 2013

Since average SE of 0.980 is greater than average PTE of 0.956, an initial conclusion that could be made is that the PTE factor, which represents managerial efficiency in utilizing inputs in order to maximize outputs, is a greater contributor to decreasing overall technical efficiency. Several measures could be taken to improve PTE scores, they include improving screening and monitoring of borrowers, developing marketing

activities to attract depositors and adopting tighter cost controls and more efficient risk management techniques.

Scale efficiency reflects the ability of management to choose the optimum scale of production. The scale efficient banks operate at constant returns to scale (CRS) which implies that an increase in their inputs is accompanied by a proportionate rise in their outputs. As to the scale inefficient banks, they operate at variable returns to scale (VRS). We distinguish between 2 cases: increasing returns to scale (IRS) which means that an increase in inputs leads to a more than proportionate rise in outputs, or decreasing returns to scale (DRS) which implies that an increase in inputs is accompanied by a less than proportionate rise in outputs. Out of the 24 banks, 9 were operating at constant returns to scale (optimal scale), 9 were operating at IRS and 6 were operating at DRS.

The banks under study with a PTE score of 1 usually achieved an SE score of 1 as well, except for Byblos Bank, Jammal Trust Bank and MEAB. They obtained SE scores of 0.939, 0.922 and 0.960 respectively. This indicates that these banks enjoy managerial efficiency, however they are not operating at their optimal scale size.

Byblos and Jammal trust bank are operating at DRS, above their optimal scale size. A proper strategy in this case would be a reduction of the scale of operations by branch closures and staff redundancy for example. As to banks showing managerial inefficiency and operating at DRS, they include Banque de L'Industrie et du Travail, BSL Bank, Creditbank and Fransabank. These banks should implement strategies to increase their managerial and scale efficiencies.

On the other hand, MEAB is operating at IRS, below its optimal scale size. In this case increasing the scale of operations would be a good strategy. This could be done for example through opening of new branches, bank mergers and business collaborations. With regard to banks showing managerial and scale inefficiency and operating at IRS, they comprise Banque Bemo, Banque Libano-Francaise, BBAC, Credit Libanais, Fenicia Bank, First National Bank, Lebanese Swiss Bank and Lebanon and Gulf Bank.

Decomposing TE scores into PTE and SE specifies for the bank what can be done on the short-term and on the long-term. Usually, if the inefficiency is mainly due to SE, long-

term strategies are required. Namely, if the bank is operating at IRS it will probably need to increase its scale of operations. Expansionary strategies can be accelerated through mergers and business collaborations, however they are still time consuming. On the other hand, if most of the inefficiency is due to PTE, this can be addressed on the short-run by implementing new input and output combinations observed from the operations of efficient peers.

Benchmarks

DEA classifies a unit as either efficient or inefficient compared to other units in its reference set. The reference set consists of efficient units most similar to the inefficient unit in their configuration of inputs and outputs. Once the analyst knows which efficient banks are the most comparable to the inefficient bank, it will be possible to develop an understanding of the nature of inefficiencies and re-allocate the scarce resources to increase productivity.

Table 17 presents the benchmarks (or reference sets) for each inefficient bank in 2013 under the CCR and BCC approaches. The results are obtained through EMS with the output of the CCR and BCC scores. The number between parentheses is the lambda which represents the reference unit contribution to the calculation of the inefficient unit's score. For efficient banks, the number of banks which have obtained them as benchmarks is presented. It is worth mentioning that even efficient units can have reference sets when the A&P model is implemented, however this won't be covered in this study .

Bank	Benchmarks (CCR)	Benchmarks (BCC)
1.B.L.C Bank S.A.L.	7	3
2.Bank Audi S.A.L.	1	3
3.Bank of Beirut S.A.L.	1	0
4.BankMed S.A.L.	1	0
5.Banque Bemo S.A.L.	8 (0.39) 10 (0.04)	2 (0.01) 8 (0.91) 18 (0.08)
6.BIT S.A.L.	1 (0.02) 8 (1.42) 10 (0.01)	8 (0.85) 10 (0.01) 19 (0.14)
7.BLF S.A.L.	3 (0.01) 10 (0.07) 18 (0.30) 24 (0.50)	8 (0.04) 10 (0.07) 18 (0.30) 22 (0.11) 24 (0.48)
8.Banque Pharaon et Chiha S.A.L.	6	11
9.BBAC S.A.L.	1 (0.19) 10 (0.09) 24 (0.10)	1 (0.13) 8 (0.64) 10 (0.06) 24 (0.17)
10.BLOM Bank S.A.L.	13	8
11.BSL Bank S.A.L.	1 (0.08) 8 (0.99) 10 (0.01)	1 (0.04) 8 (0.95) 10 (0.02)
12.Byblos Bank S.A.L.	2 (0.04) 4 (0.30) 10 (0.26) 18 (0.88)	0
13.Credit Libanais S.A.L.	1 (0.44) 10 (0.17) 24 (0.12)	1 (0.36) 8 (0.31) 10 (0.17) 24 (0.16)
14.CreditBank S.A.L.	8 (2.43) 10 (0.09)	8 (0.51) 10 (0.10) 19 (0.39)
15.Fenicia Bank S.A.L.	1 (0.10) 10 (0.02) 24 (0.01)	8 (0.70) 22 (0.25) 24 (0.06)
16.First National Bank S.A.L.	10 (0.08) 18 (0.08) 24 (0.08)	2 (0.02) 8 (0.74) 10 (0.07) 18 (0.17)
17.Fransabank S.A.L.	1 (1.41) 8 (3.39) 10 (0.32)	10 (0.67) 19 (0.33)
18.IBL Bank S.A.L.	5	4
19.Jammal trust Bank S.A.L.	8 (2.28) 23 (0.32)	3
20.Lebanese Swiss Bank S.A.L.	1 (0.11) 10 (0.01) 24 (0.06)	8 (0.44) 22 (0.51) 24 (0.05)
21.LGB S.A.L.	10 (0.05) 18 (0.11) 24 (0.06)	2 (0.04) 8 (0.77) 18 (0.19)
22.MEAB S.A.L.	18 (0.01) 24 (0.12)	3
23.NECB S.A.L.	1	0
24.SGBL S.A.L.	8	5

Table 17 : Benchmarks in 2013

b.2 Comparisons

2008-2011

2008 was a tragedy for the global banking sector. Severe losses were incurred by banks worldwide and several inefficiencies were revealed in their operations. The CCR results of the Lebanese banks under study somewhat worsened. Average efficiency decreased

from 0.919 in 2008 to 0.905 in 2011 and the number of fully efficient banks decreased from 9 to 4. As for the dispersion of the efficiency scores, it slightly declined since the coefficient of variation decreased from 0.086 in 2008 to 0.084 in 2011. The least CCR efficient bank in 2011 was Banque Bemo S.A.L. It obtained a score of 0.762, lower than the minimum CCR score of 0.784 recorded by Banque de L'Industrie et du Travail S.A.L. in 2008. The BCC average efficiency slightly increased from 0.936 in 2008 to 0.940 in 2011. Dispersion diminished as the coefficient of variation decreased from 0.075 in 2008 to 0.063 in 2011. The minimum efficiency score decreased from 0.801 to 0.780 and the number of fully efficient banks decreased from 11 to 6.

2011-2013

The Arab spring erupted in 2011 and Lebanon's economy has been suffering from its negative spillovers. However, this phenomenon didn't seem to have much impact on the efficiency of the Lebanese banks under study. As previously mentioned, 2013 was the most efficient year as indicated by the CCR and BCC models. Average efficiency, the minimum efficiency score and the number of fully efficient banks increased for both models from 2011 to 2013. The coefficient of variation decreased from 0.084 in 2011 to 0.073 in 2013 for the CCR model, and it slightly increased from 0.063 in 2011 to 0.066 in 2013 for the BCC model.

Paired Difference Test

To test whether this worsening/improvement of the efficiency of Lebanese banks during these 2 turbulent periods is significant, a Wilcoxon matched pairs signed rank test is performed. The test is conducted using IBM SPSS Statistics Version 22 following the below steps:

1. Load the CCR and BCC efficiency scores for the whole study period in an SPSS worksheet
2. Go to the "Analyze" menu
3. Select "Non-Parametric Tests"

4. Select "Legacy Dialogs"

5. Click on "2 Related Samples"

6. Arrange the variables in pairs as indicated by Figure 24 (C=CCR, B=BCC, Y=Year)

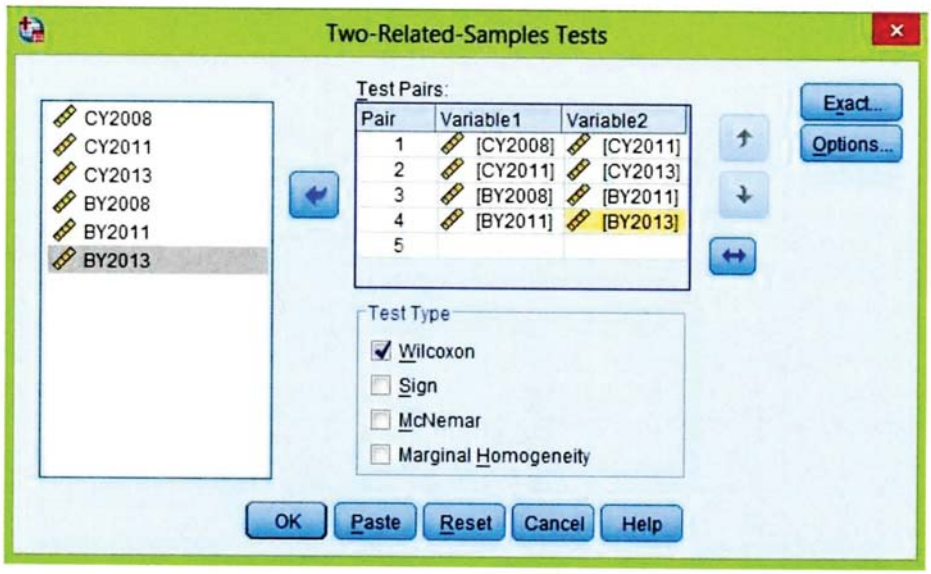

Figure 24 : Input for the Wilcoxon Matched Pairs Signed Rank Test

7. Make sure the "Wilcoxon" test type is selected
8. Click on "OK"

9. We obtain the ranks in table 16 and the P-values in table 17

Table 18 provides interesting results to evaluate the trend of the CCR or BCC efficiencies for two measurement periods. For example, the trend of BCC scores from the year 2008 to 2011 can be analyzed by first looking at column N. We observe that 10 banks witnessed a decrease in their BCC efficiency scores and that would constitute a negative rank, 9 banks witnessed an increase which is counted as a positive rank and 5 banks saw no changes. The mean of positive ranks was 11.17 which is greater than the mean for the negative ranks of 8.95. This indicates that there is a trend for BCC efficiency scores to increase from 2008 to 2011.

		N	Mean Rank	Sum of Ranks
CCR2011 - CCR2008	Negative Ranks	10	12.85	128.50
	Positive Ranks	10	8.15	81.50
	Ties	4		
	Total	24		
CCR2013 - CCR2011	Negative Ranks	6	5.67	34.00
	Positive Ranks	14	12.57	176.00
	Ties	4		
	Total	24		
BCC2011 - BCC2008	Negative Ranks	10	8.95	89.50
	Positive Ranks	9	11.17	100.50
	Ties	5		
	Total	24		
BCC2013 - BCC2011	Negative Ranks	5	7.70	38.50
	Positive Ranks	13	10.19	132.50
	Ties	6[l]		
	Total	24		

Table 18 : Ranks

To confirm if that is the case, we look at the p-value calculated for the BCC scores for the years 2008 and 2011 presented in table 19. It is equal to 0.825 which is greater than our chosen α of 0.05. Therefore the null hypothesis is not rejected and it can be concluded that there is no significant difference in the BCC efficiency scores for 2008 and 2011.

	CCR		BCC	
	2008-2011	2011-2013	2008-2011	2011-2013
P-value	0.380	0.008	0.825	0.041

Table 19 : Wilcoxon Matched Pairs Signed Rank Test P-values

The same analysis can be repeated for the CCR scores in 2008 and 2011. Since the p-value $0.380 > \alpha$, it can be concluded that no significant difference exists for the CCR

efficiency scores. Therefore the efficiency of Lebanese banks didn't change significantly in the aftermath of the financial crisis.

As for the years 2011 and 2013, the p-value for the CCR results is $0.008 < \alpha$, thus the null hypothesis is rejected and it can be concluded that there is a significant difference in the efficiency scores between these two years. Analysis of the ranking shows that the trend for the CCR scores is increasing. The p-value for the BCC results is $0.041 < \alpha$, allowing us to conclude again that a significant difference exists in the efficiency score and according to the rankings, the trend for the BCC scores is increasing. Therefore, the efficiency of Lebanese banks increased significantly after the eruption of the Arab spring.

c. Super-Efficiency : A&P Model Results and Comparison With Key Ratios

As stated in chapter 3, this study implements the A&P, a radial super-efficiency approach, to rank the banks. The A&P model could be executed using EMS as follows:

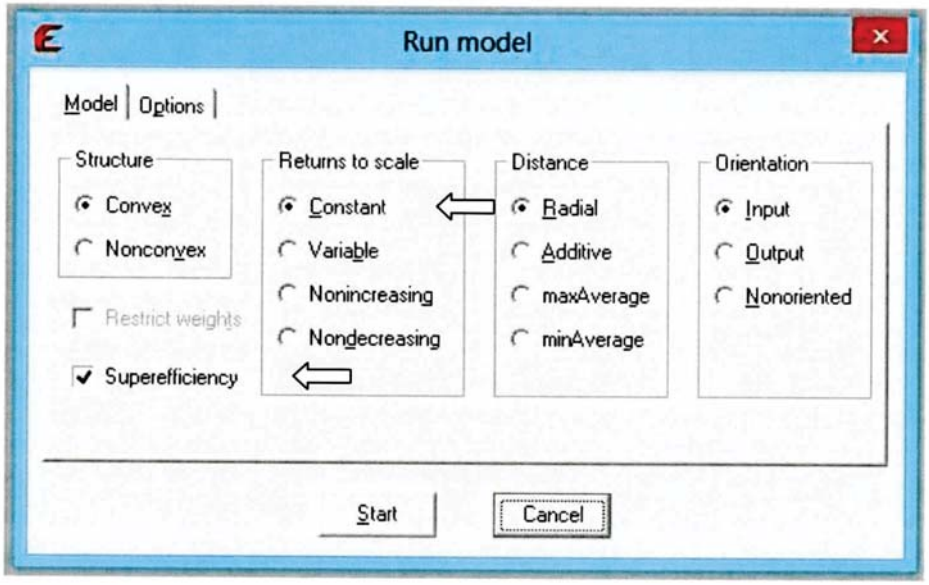

Figure 25 : A&P Model

The obtained scores and the rankings are presented in table 20.

Ranking	DMU	A&P Score
1	IBL Bank S.A.L.	**2.082**
2	BankMed S.A.L.	**1.451**
3	Banque Pharaon et Chiha S.A.L.	**1.160**
4	Near East Commercial Bank S.A.L.	**1.154**
5	Bank Audi S.A.L.	**1.052**
6	BLOM Bank S.A.L.	**1.037**
7	SGBL S.A.L.	**1.020**
8	B.L.C Bank S.A.L..	**1.007**
9	Bank of Beirut S.A.L.	**1.005**
10	Banque Libano-Francaise S.A.L.	0.992
11	Fransabank S.A.L	0.968
12	MEAB S.A.L.	0.960
13	Lebanon and Gulf Bank S.A.L.	0.947
14	Byblos Bank S.A.L.	0.939
15	Jammal trust Bank S.A.L.	0.922
16	First National Bank S.A.L.	0.908
17	Fenicia Bank S.A.L.	0.908
18	BBAC S.A.L.	0.899
19	Credit Libanais S.A.L.	0.888
20	Banque Bemo S.A.L.	0.861
21	CreditBank S.A.L.	0.854
22	Lebanese Swiss Bank S.A.L.	0.837
23	BSL Bank S.A.L.	0.802
24	BIT S.A.L.	0.791

Table 20 : A&P Scores and Banks Ranking in 2013

After the calculation of the A&P scores, a correlation analysis was conducted to find if a clear pattern exists between the scores and some key ratios that represent the most important aspects of banks performance. Table 21 lists these ratios with their respective values for each bank in 2013. We observe that Bank Audi was the bank with the highest total assets value, BBAC had the highest LLR on DLs/DLs, BSL Bank had the lowest loans to deposits ratio, NECB recorded the highest capital adequacy ratio, Pharaon et Chiha was the bank with the highest ROAA and IBL had the lowest cost/income ratio.

Bank	A&P Scores	Total Assets (USD Million)	Loan Loss Reserves on DLs/DLs (%)	Loans to Deposits (%)	Capital Adequacy Ratio (As Provided by Banks)	ROAA (%)	Cost/ Income (%)
IBL Bank	2.082	4,747.71	85.65	21.18	10.22	1.18	36.13
BankMed	1.451	13,790.40	77.27	40.64	14.01	0.97	61.91
Pharaon et Chiha	1.160	299.52	75.17	38.06	15.73	1.67	55.17
NECB	1.154	397.32	84.96	27.50	21.28	0.22	83.54
Bank Audi	1.052	36,191.28	64.25	47.42	12.09	0.90	56.04
BLOM Bank	1.037	26,148.65	74.70	28.11	16.83	1.38	37.05
SGBL	1.020	13,010.96	79.52	30.45	12.52	1.13	44.64
B.L.C Bank	1.007	5,133.99	74.39	43.64	14.47	0.82	73.86
BOB	1.005	13,616.87	85.75	36.81	13.79	1.16	47.33
BLF	0.992	11,031.69	91.06	38.82	13.13	0.94	47.13
Fransabank	0.968	16,964.39	75.57	37.48	14.72	0.98	52.55
MEAB	0.960	1,683.27	84.08	71.19	10.41	0.93	42.79
LGB	0.947	2,715.53	68.78	44.78	13.25	0.88	43.22
Byblos Bank	0.939	18,485.09	82.96	30.59	16.11	0.88	46.86
JTB	0.922	826.07	90.84	45.07	11.29	0.73	76.63
FNB	0.908	3,547.88	87.14	30.19	10.42	0.74	58.68
Fenicia Bank	0.908	1,393.33	69.37	31.87	14.04	1.02	50.14
BBAC	0.899	5,107.29	97.28	29.70	13.51	0.87	54.04
Credit Libanais	0.888	8,359.70	70.00	36.31	16.63	0.84	57.52
Bemo	0.861	1,484.63	93.71	50.30	14.50	0.43	69.29
CreditBank	0.854	2,643.20	42.69	56.94	11.04	0.75	67.45
LSB	0.837	1,501.88	92.27	23.64	18.53	1.00	53.49
BSL Bank	0.802	1,018.71	96.57	19.98	13.53	0.70	68.79
BIT	0.791	724.45	92.07	34.29	15.60	0.08	95.52

Table 21 : Key Ratios in 2013

Table 21 also represents the Excel table used to calculate the correlation coefficients. The Excel function used for this purpose is "=PEARSON(array1,array2)" where array 1 includes the column of the A&P scores and array 2 includes the column of the intended ratio. The obtained correlation coefficients are presented in table 22. The results show a weak correlation between the A&P scores and all the ratios under study. Therefore no clear association can be concluded between these ratios representing the different aspects of bank performance and the efficiency scores calculated using the DEA A&P model.

	Total Assets	Loan Loss Reserves on DLs/DLs	Loans to Deposits	Capital Adequacy Ratio	ROAA	Cost/ Income
A&P Score	0.11	-0.02	-0.22	-0.19	0.34	-0.33

Table 22 : Pearson Correlation Coefficients

Furthermore, as shown in table 23, a difference exists between the rankings obtained from the A&P results and the rankings obtained from the key performance ratios.

Bank	A&P	Total Assets	Loan Loss Reserves on DLs/DLs	Loans to Deposits	Capital Adequacy Ratio	ROAA	Cost/ Income
IBL Bank S.A.L.	1	12	10	2	24	3	1
BankMed S.A.L.	2	5	15	17	12	9	17
Pharaon et Chiha S.A.L.	3	24	17	15	6	1	13
NECB S.A.L.	4	23	11	4	1	23	23
Bank Audi S.A.L.	5	1	23	21	19	12	14
BLOM Bank S.A.L.	6	2	18	5	3	2	2
SGBL S.A.L.	7	7	14	8	18	5	5
B.L.C Bank S.A.L..	8	10	19	18	10	17	21
Bank of Beirut S.A.L.	9	6	9	13	13	4	8
BLF S.A.L.	10	8	6	16	17	10	7
Fransabank S.A.L	11	4	16	14	8	8	10
MEAB S.A.L.	12	16	12	24	23	11	3
LGB S.A.L.	13	14	22	19	16	13	4
Byblos Bank S.A.L.	14	3	13	9	5	14	6
JTB S.A.L.	15	21	7	20	20	20	22
FNB S.A.L.	16	13	8	7	22	19	16
Fenicia Bank S.A.L.	17	19	21	10	11	6	9
BBAC S.A.L.	18	11	1	6	15	15	12
Credit Libanais S.A.L.	19	9	20	12	4	16	15
Banque Bemo S.A.L.	20	18	3	22	9	22	20

CreditBank S.A.L.	21	15	24	23	21	18	18
LSB S.A.L.	22	17	4	3	2	7	11
BSL Bank S.A.L.	23	20	2	1	14	21	19
BIT S.A.L.	24	22	5	11	7	24	24

Table 23 : Comparison of Rankings

The preceding investigation shows that analyzing these widely used key ratios is not enough to assess a bank's efficiency and performance. Utilizing DEA is more effective, since it converts the multiple input and output measures used by each bank into one single measure of efficiency.

5.3 Malmquist TFP Index

Since this study deals with panel data, it is possible to calculate the Malmquist TFP index to evaluate the productivity change of banks from 2008 to 2011 and from 2011 to 2013. DEAP is chosen to perform the calculations following a procedure similar to the one explained in 5.2.b.1:

1. Create 3 notepad documents: one for the data, another for the instruction and one empty document for the output.

2. The file containing the data should contain only numbers. It should include all the values of the outputs and the inputs for the three years under study in the following form:

```
128990944.6 9829115.755 34    526   86633458.04 }
                                                  } 2008
1147155510  238569972.8 143   4200  724150201.7 }

233391429.5 35272905.47 52    898   149564698.5 }
                                                  } 2011
1364492319  437539789.1 154   4560  841625342.6 }

300440095.5 21199873.3  56    961   183009769.8 }
                                                  } 2013
1807143715  398049998   189   5894  1151746245  }
```

3. The instruction file should be as follows (The bold text is only for the purpose of explanation and should not be included in the instruction file):

`Malmdta.txt`	**(Data file name)**
`Malmout.txt`	**(Output file name)**
`24`	**(Number of DMUs)**
`3`	**(Number of time periods)**
`2`	**(Number of outputs)**
`3`	**(Number of inputs)**
`0`	**(0=Input and 1=Output oriented)**
`0`	**(0=Constant Returns to Scale, 1=Variable Returns to Scale)**
`2`	**0=DEA(Multi-Stage), 1=Cost-DEA, 2=Malmquist-DEA, 3=DEA (1-Stage), 4=DEA(2-Stage)**

4. Once the three files are ready, open the DEAP DOS document, write the instruction file name then click on enter to save the results in the output file.

Table 24 presents the geometric means for total factor productivity change (TFPCH) , technical efficiency change (TEC), technological change (TC), pure efficiency change (PEC) and scale efficiency change (SEC) of the banks under study, for the two time periods and for the whole study period. TFPCH is decomposed into TEC and TC. TEC is further divided into PEC and SEC.

Years	TEC	TC	PEC	SEC	TFPCH
2008-2011	0.985	1.093	1.006	0.980	1.077
2011-2013	1.036	1.012	1.016	1.019	1.048
Mean of Study Period	1.010	1.052	1.011	0.999	1.063

Table 24 : Malmquist Index Summary of Geometric Means

Productivity improved from 2008 to 2011 by 7.7%. This improvement was due to a TC of 9.3% which managed to offset a TEC of -1.5%. The negative TEC was caused by a SEC of -2% and PEC of 0.6%. As to productivity change from 2011 to 2013, it was also positive reaching 4.8%. Although less than the productivity witnessed in the previous

period, all the efficiencies have improved from 2011 to 2013 as all their values were greater than 1.

On average, the productivity of banks improved by 6.3%. This development was due to a 5.2% TC and a 1% TEC. In other words, the results suggest an improvement in the boundary of production overtime (progress in technology), and a small movement of banks towards the frontiers (improvement in managerial efficiency). The decomposition of TEC reveals that 1.1% PEC and -0.1% SEC contributed to the obtained 1% TEC score. Therefore the improvement in managerial ability to minimize inputs and maximize outputs (PEC) contributed to the increase in technical efficiency by offsetting the worsening in managerial ability to choose the optimum scale of production (SEC).

To allow a bank specific analysis, table 25 presents the geometric means over the study period of the Malmquist TFP index and its constituents for each bank. Interestingly, IBL bank recorded the highest productivity change of 27.7%, which made it the leader in terms of efficiency and productivity. The 27.7% increase in productivity, was due in its entirety to a progress in technology at the bank. Lebanon and Gulf bank followed IBL in the TFPCH ranking since its productivity improved by 21.4%. LGB's managerial efficiency and technology improved since it witnessed a TEC of 8.7% and TC of 11.7%. The main contributor to TEC was the PEC of 7%, while the SEC of 1.6% was less significant.

As for the banks that recorded a decrease in productivity, they are Banque Bemo, Banque Libano-Francaise, BLOM Bank and Lebanese Swiss Bank. The result is surprising for BLOM which was revealed by our previous analysis as fully efficient for the three years under study. Further investigation shows that BLOM needs to invest more in technology since its productivity regress is due to a -6.7% TC. Banque Bemo and Lebanese Swiss Bank were facing managerial efficiency problems despite their investments in technology. As for Banque Libano-Francaise, it was suffering from managerial efficiency and innovation problems.

Bank	TEC	TC	PEC	SEC	TFPCH
B.L.C Bank S.A.L..	1.054	1.021	1.052	1.002	1.076
Bank Audi S.A.L.	1.000	1.146	1.000	1.000	1.146
Bank of Beirut S.A.L.	1.000	1.034	1.000	1.000	1.034
BankMed S.A.L.	1.000	1.069	1.000	1.000	1.069
Banque Bemo S.A.L.	0.928	1.077	0.982	0.945	0.999
Banque de L'industrie et du Travail S.A.L.	1.004	1.037	1.012	0.992	1.041
Banque Libano-Francaise S.A.L.	0.996	0.979	0.997	0.999	0.975
Banque Pharaon et Chiha S.A.L.	1.000	1.053	1.000	1.000	1.053
BBAC S.A.L.	1.033	1.005	1.029	1.004	1.039
BLOM Bank S.A.L.	1.000	0.993	1.000	1.000	0.993
BSL Bank S.A.L.	0.992	1.028	0.985	1.007	1.019
Byblos Bank S.A.L.	0.995	1.050	1.026	0.969	1.044
Credit Libanais S.A.L.	0.999	1.018	0.999	1.000	1.017
CreditBank S.A.L.	1.015	1.037	1.025	0.990	1.053
Fenicia Bank S.A.L.	0.993	1.019	0.995	0.998	1.012
First National Bank S.A.L.	1.045	0.997	1.042	1.003	1.042
Fransabank S.A.L	1.009	1.012	1.013	0.996	1.021
IBL Bank S.A.L.	1.000	1.277	1.000	1.000	**1.277**
Jammal trust Bank S.A.L.	1.035	1.047	1.072	0.965	1.084
Lebanese Swiss Bank S.A.L.	0.973	1.025	0.970	1.003	0.997
Lebanon and Gulf Bank S.A.L.	1.087	1.117	1.070	1.016	1.214
MEAB S.A.L.	1.080	1.052	1.000	1.080	1.136
Near East Commercial Bank S.A.L.	1.015	1.154	1.000	1.015	1.171
Societe Generale de Banque au Liban S.A.L.	1.000	1.043	1.000	1.000	1.043

Table 25 : Malmquist Index Summary of Firm Means

5.4 Conclusion

This chapter presented and analyzed the outcome of implementing DEA and the additional methodologies previously elaborated. The results showed that the CCR and BCC efficiencies were high for the three years under study. Moreover, they revealed that 2013 witnessed the highest efficiency levels when compared to 2008 and 2011. To further investigate the sources of inefficiency in 2013, scale efficiencies were computed. It was found that, on average, PTE contributes more than SE to overall technical inefficiency. Additionally, it was determined that 6 of the scale inefficient banks were operating at DRS, while 9 were operating at IRS.

The comparison of the scores obtained in 2008 and 2011 revealed a decrease in the average CCR efficiency, and an increase in the average BCC efficiency. However, both movements were not significant as determined by the Wilcoxon matched pairs signed rank test at an alpha of 5%. On the other hand, comparing the scores of 2011 and 2013 showed a significant improvement of the average CCR and BCC efficiencies.

In order to rank the efficient banks, the A&P model was implemented and IBL Bank was determined to be the most efficient. The A&P scores were later compared to some key ratios of banks performance, and it was found that no apparent relationship exists between them. Finally, the Malmquist TFP index was executed and its results showed that the productivity of banks improved by 6.3% from 2008 to 2013.

CHAPTER 6

Conclusion

6.1 Introduction

This chapter concludes the thesis and represents a brief summary of the findings. It also highlights the limitations and suggests some recommendations for future improvements.

6.2 Summary

The recent subprime crisis resulted in huge losses for banks worldwide and revealed several inefficiencies in their operations. Consequently, in the aftermath of the crisis, efficiency measurement became of great importance to direct banks toward overcoming short and long run challenges.

Lebanese banks were shielded from the effects of the crisis. However they are subject to the resulting regulations and stringent capital requirements, therefore they need to adopt more efficient operating models and to monitor the efficiency of their activities.

Despite the importance of periodically measuring the efficiency of Lebanese commercial banks, studies remain limited in this context. In fact, previous studies covered periods up to 2009, and therefore do not reflect the current condition of the industry.

For this purpose, this study implemented the Data Envelopment Analysis (DEA), a non-stochastic, non-parametric, linear programming (LP) based method aiming at measuring the relative efficiency of Lebanese commercial banks in 2008, 2011 and 2013.

6.3 Discussion of Main Results

The CCR and BCC Data Envelopment Analysis (DEA) models were implemented to measure the relative efficiency of Lebanese commercial banks in 2008, 2011 and 2013. The yearly average efficiencies obtained using both models were relatively high, which reflects the competitive nature of the banking industry in Lebanon driving banks to operate as efficiently as possible. According to these two models, the year 2013 witnessed the best efficiency levels when compared to the years under study. Average CCR and BCC efficiencies were respectively 0.937 and 0.956 in 2013, the highest compared to 2008 and 2011.

Scale efficiency (SE) and returns to scale were also determined for 2013. Results indicated that PTE, which reveals managerial efficiency in utilizing inputs in order to maximize outputs, contributes more to overall inefficiency than SE, which reflects the ability of management to choose the optimum scale of production. Among the scale inefficient banks, two cases were identified. 6 banks were operating at decreasing returns to scale (DRS), above their optimal scale size, and therefore they need to downsize to reach their optimal scale, and 9 banks were operating at increasing returns to scale (IRS), below their optimal scale size, and consequently they should expand their scale of operations.

In order to study the changes in the efficiency of Lebanese commercial banks after the outbreak of the global financial crisis and the eruption of the Arab spring, we compared and examined the DEA scores of 2008-2011 and 2011-2013. It was found that the average CCR efficiency worsened, while the average BCC efficiency improved from 2008 to 2011. However, the worsening and improvement were not significant as determined by the Wilcoxon matched pairs signed rank test at an alpha of 5%. On the other hand, when comparing the scores of 2011 and 2013, increases in both the average CCR and BCC efficiencies were noticed. The increases were determined to be significant by the Wilcoxon matched pairs signed rank test at an alpha of 5%.

The A&P Super-Efficiency model was implemented to rank the efficient banks. It showed that IBL was the best performing among the efficient banks with a score of

2.082. The obtained A&P scores were also compared to 6 key ratios of bank performance, and it was concluded that no clear association exists between them.

Finally, the Malmquist TFP index was implemented to evaluate the productivity change of banks. It was found that productivity advanced on average by 6.3% from 2008 to 2013. This improvement was due to a 5.2% progress in technology and a 1% enhancement in managerial efficiency. The 1% improvement in managerial efficiency was decomposed into a 1.1% increase in managerial ability to minimize inputs and maximize outputs, and a -0.1% worsening in managerial ability to choose the optimum scale of production.

Improvements

In addition to measuring the relative efficiencies of DMUs and specifying the sources of inefficiency, DEA offers the advantage of suggesting improvements to increase the efficiency scores. Two approaches could be implemented for this purpose: the input oriented and the output oriented. The input orientation orders DEA to reduce the inputs as much as possible without decreasing outputs. It is employed when the inputs are controllable and the aim of the DEA exercise is to save costs. As for the output orientation, it instructs DEA to increase outputs as much as possible without increasing inputs. It is selected when the objective is to raise productivity without raising the resource base.

We have opted in our study to implement the input orientation since banks have better control over their inputs. Before we proceed with the suggested improvements, it is worth noting that it is possible to find slacks in inputs and outputs. Even under the input oriented approach, potential improvements in DEA might include an increase in one or more of the outputs while decreasing the inputs. Such output slacks represent outputs that are under-produced. Similarly, using the output oriented approach, the results may suggest increasing outputs and decreasing one or more inputs. These input slacks depict over-utilized inputs.

Table 26 presents the improvements suggested by DEA for the year 2013 under the BCC approach. They were obtained in the same output file generated by DEAP in the previous

chapter to determine returns to scale. The target values for the efficient banks are not included since they are the same as the actual values.

Regarding the improvements related to the outputs, we notice that total interest income presents no slacks for any of the inefficient banks. Therefore it is not an under-produced output in any of them. Alternatively, total non-interest income presents slacks for 10 inefficient banks. Consequently, it is an under-produced output in these banks and they should invest more efforts in diversifying their sources of income.

As for the inputs, they should all be decreased to reach the optimal efficiency levels. The reduction of total interest expense could be achieved by cutting the amount of deposits or decreasing the interest rates given on deposits. Targets for the number of branches and employees were kept in decimals since they can indicate hiring part time employees, or setting up ATMs instead of branches.

1-Banque Bemo	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	60972380.10	0	0	60972380.10
Total Non-Interest Income	9272936.65	0	3604737.49	12877674.14
Total Interest Expense	41883454.73	-1525012.51	0	40358442.22
Number of Branches	10	-0.36	0	9.64
Number of Employees	262	-9.54	-50.04	202.42

2-Banque de L'Industrie et du Travail	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	37562031.18	0	0	37562031.18
Total Non-Interest Income	2375974.13	0	4993960.86	7369934.98
Total Interest Expense	25049066	-4494424.96	0	20554641.04
Number of Branches	13	-2.33	0	10.67
Number of Employees	242	-43.42	-0.96	197.62

3-Banque Libano-Francaise	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	496750790	0	0	496750790
Total Non-Interest Income	82350013.27	0	0	82350013.27
Total Interest Expense	332762936.70	-2159155.11	0	330603781.59
Number of Branches	62	-0.40	0	61.60
Number of Employees	1308	-8.49	0	1299.51

4-BBAC	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	247343833.50	0	0	247343833.5
Total Non-Interest Income	37833975.46	0	0	37833975.46
Total Interest Expense	169388319.70	-16795544.69		152592775
Number of Branches	41	-4.07	-0.828	36.11
Number of Employees	870	-86.26	0	783.74

5-BSL Bank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	49820563.18	0	0	49820563.18
Total Non-Interest Income	6651896.52	0	1543339.24	8195235.75
Total Interest Expense	35147217.25	-6923374.64	0	28223842.62
Number of Branches	18	-3.55	-4.16	10.30
Number of Employees	261	-51.41	0	209.59

6-Credit Libanais	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	441587634.50	0	0	441587634.50
Total Non-Interest Income	57605767.16	0	9374938.65	66980705.81
Total Interest Expense	304743651.70	-33870798.20	0	270872853.50
Number of Branches	70	-7.78	0	62.22
Number of Employees	1591	-176.83	0	1414.17

7-CreditBank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	161022250.10	0	0	161022250.10
Total Non-Interest Income	23354595.69	0	8107592.76	31462188.45
Total Interest Expense	108099411.60	-12898136.14	0	95201275.46
Number of Branches	33	-3.94	0	29.06
Number of Employees	869	-103.69	-110.06	655.25

8-Fenicia Bank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	69115507.13	0	0	69115507.13
Total Non-Interest Income	9285219.24	0	1309639.04	10594858.28
Total Interest Expense	46375501.16	-3265303.90	0	43110197.26
Number of Branches	17	-1.20	-3.68	12.12
Number of Employees	247	-17.39	0	229.61

9-First National Bank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	185203407.60	0	0	185203407.60
Total Non-Interest Income	12921632.50	0	24830394.92	37752027.42
Total Interest Expense	130781624.50	-8899919.66	0	121881704.84
Number of Branches	24	-1.63	0	22.37
Number of Employees	600	-40.83	0	559.17

10-Fransabank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	912772963.80	0	0	912772963.80
Total Non-Interest Income	97582727.03	0	79291397.07	176874124.10
Total Interest Expense	565138863	-14017164.41	0	551121698.59
Number of Branches	154	-3.82	-37.26	112.92
Number of Employees	3265	-80.98	-34.05	3149.97

11-Lebanese Swiss Bank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	79047184.74	0	0	79047184.74
Total Non-Interest Income	9378738.31	0	2383527.07	11762265.38
Total Interest Expense	58962687.89	-8086416.11	0	50876271.78
Number of Branches	18	-2.47	-2.71	12.82
Number of Employees	282	-38.68	0	243.33

12-Lebanon and Gulf Bank	Original Value	Radial Movement	Slack Movement	Projected Value
Total Interest Income	140799999.30	0	0	140799999.30
Total Non-Interest Income	20644455.06	0	9739573.82	30384028.88
Total Interest Expense	98500683.25	-1455575.58	0	97045107.67
Number of Branches	17	-0.25	0	16.75
Number of Employees	409	-6.04	-2.80	400.16

Table 26 : Improvements 2013

6.4 Limitations of the Study

One of the limitations of this study consist in the accuracy of the published data for banks. The results are highly sensitive if huge discrepancies are found in the collected data.

Another limitation lies in the fundamentals of the methodology used. Despite its strengths and advantages, DEA presents several drawbacks:

- It assumes that all DMUs are homogenous which might not always be the case
- It is a non-parametric methodology which makes statistical hypothesis tests difficult to conduct.

- Units deemed efficient determine the efficiency frontier and the efficiency scores of the units enveloped by the frontier. Therefore DEA is an extreme point technique and the calculated efficiency scores are highly sensitive to small errors.

- The calculated efficiency scores are also sensitive to the selected inputs and outputs. A different set of input and output factors could yield different results.

- DEA measures the relative efficiency and not the absolute efficiency of a DMU. It determines how well the DMU is operating compared to its peers and not to a theoretical maximum.

- Since DEA scores are obtained after running a series of LP problems, it is not easy to explain intuitively its process for the case of multiple inputs or outputs. Therefore, an audience with little to no background in LP may not consider DEA transparent. In general, the management of an organization for which DEA scores are computed may find it difficult to understand its results and may favor less complex techniques.

- One of DEA's features is that it assigns weights to the input and output factors. The weights can be predetermined or they can be calculated by the technique itself. To maximize the measurement accuracy, it is preferable for weights to be set in advance. For example if bank policy makers view non-interest income as more desirable than net interest income, then the proper constraints can be set up in the linear program. However weight restrictions require a lot of information which are sometimes hard to obtain. That is why, for the purpose of this study, we opted to allow the weighting to be done by DEA itself.

6.5 Recommendations

Since DEA implementations on the banking sector are still limited in the Lebanese context, this study could be taken further in several ways. A parametric efficiency measure (TFA or DFA) can be added to compare its results with those of DEA. It is also

possible to build a linear regression based on DEA results to forecast the performance of banks. Additionally, it is interesting to examine different kinds of efficiency such as revenue and profit efficiencies, instead of technical efficiency. Conducting a window analysis is also feasible in our case. Window analysis focuses on the changes in efficiency overtime. Specifically, a DMU's performance in a certain period is contrasted with its performance in other periods in addition to the performance of other DMUs.

Instead of building a multi-stage DEA model, one can alternatively opt to build a two-stage DEA model to measure efficiency of Lebanese commercial banks. Two-stage models are interesting applications of DEA in which DMUs may consist of subunits or represent two-stage processes. A particular subset of such processes is those in which all the outputs from the first stage are the only inputs to the second stage. One can also choose to conduct a Network Data Envelopment Analysis (NDEA) study on Lebanese commercial banks. This approach allows management to spot the specific sources of inefficiency embedded in interactions among various banks departments. Various performance evaluation methods such as multivariate statistical analysis, analytic hierarchy process, grey relational analysis and balanced scorecard can also be implemented to allow an analysis of the efficiency of the Lebanese banking sector from a different perspective.

Efficiency measurement is of crucial importance in the Lebanese banking sector and it is not something to be taken for granted. Lebanese banks are the major creditors of the government and they are the backbone of the economy. Failure to confirm that they are operating profitably and efficiently could lead the country to a debt or economic crisis. Another concern that arises in this context is the riskiness of Lebanese banks. Monitoring the riskiness of banks is as important as measuring their efficiency, therefore studies for risk modeling and assessment are needed for Lebanese banks. Value at risk (VaR) is an effective method that can be also implemented for this purpose.

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