AMERICAN UNIVERSITY OF BEIRUT

DEA-BASED ICT PERFORMANCE MEASUREMENT SYSTEM

by
ALI HUSSEIN EL MOUSSAOUI

A project
submitted in partial fulfillment of the requirements
for the degree of Master of Business Administration
to the Suliman S. Olayan School of Business
at the American University of Beirut

Beirut, Lebanon
September 2014

AMERICAN UNIVERSITY OF BEIRUT

DEA-BASED ICT PERFORMANCE MEASUREMENT SYSTEM

by

ALI HUSSEIN EL MOUSSAOUI

Approved by:

Dr. Ibrahim Osman, Professor
Suliman S. Olayan School of Business

First Reader

Imad Hoballah

Dr. Imad Hoballah
CEO, Telecom Regulatory Authority

Second Reader

Date of project presentation: September 19, 2014

AMERICAN UNIVERSITY OF BEIRUT

THESIS, DISSERTATION, PROJECT RELEASE FORM

Student Name: El Moussaoui (Last) Ali (First) Hussein (Middle)

○ Master's Thesis ☑ Master's Project ○ Doctoral Dissertation

☑ I authorize the American University of Beirut to: (a) reproduce hard or electronic copies of my thesis, dissertation, or project; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes.

☐ I authorize the American University of Beirut, **three years after the date of submitting my thesis, dissertation, or project,** to: (a) reproduce hard or electronic copies of it; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes.

Signature 1/10/2014 Date

ACKNOWLEDGMENT

I would like to thank Dr. Ibrahim Osman, for his guidance, inspiration and patience throughout the course of my project, without which this project would have been impossible.

Besides, I would like to thank Dr. Imad Hobballah for his encouragement and insightful comments.

I would also like to express my sincere gratitude to my wife for the support and encouragement rendered to me to undertake this project.

Above all, I am indebted to God for the strength and wisdom He's given me during this project.

AN ABSTRACT OF THE PROJECT OF

Ali Hussein El Moussaoui for Master of Business Administration
Major: Business Administration

Title: DEA-Based ICT Performance Measurement System

Recently, the world has been witnessing a growing diffusion process of Information and Communication Technology (ICT), but we can clearly spot different levels of access, use and skills of ICT among countries as well as within them. These differences cause ICT gap; thus decision and policy makers in many countries have been applying strategies targeting to the development of ICT. Consequently, measuring and analyzing of the digital divide among countries is of top importance for managers and researchers. Their main focus is to understand the causes driving ICT adoption, which in turn boost ICT development.

We developed an alternative approach for measuring ICT performance by applying Data Envelopment Analysis (DEA) using data from the International Telecommunications Union (ITU) as a sample of 139 economies. We compared the ICT Development Index (IDI) with our DEA efficiency score and found a high correlation between the two. Our findings suggest that both indices are consistent in their measurement of ICT performance. Using our new model, improvement targets and peer groups for each country can be identified.

CONTENTS

ILLUSTRATIONS

TABLES

CHAPTER I

INTRODUCTION

In our fast-growing information society, technology has had a profound effect on every aspect of society and individual's life. Importantly, two distinctive technologies: Information Technology (IT) and Communications Technology (CT) have gradually become integrated to form what we call today ICT (Information and Communications Technology). Coupled with the huge success and popularity of the Internet, the global society has now indisputably entered the era of ICT.

IT refers to software (operating systems, application tools, and software development), services (consulting, network and systems integration, hosting, data processing and other services), and hardware (computers, storage devices, printers, tablets and other peripherals). Communication Technology defines the telecommunications equipment through which information can be looked for and accessed such as phones, faxes, modems, routers, switches, transmission and computers. All these technologies together are called Information and Communication Technologies (ICTs). Therefore, there are three dimensions for ICTs: infrastructure (hardware), content (information produced, processed, stored, distributed or retrieved), and access (ownership, internet and e-literacy). From a dynamic perspective the three dimensions can reinforce one another. This is particularly relevant in network technologies such as Internet or telephone. Thus, ICTs change processes and play an important role in social and economic transformation. There are five roles that ICTs can play as driver of change: efficiency enhancing, transparency enhancing, control enhancing, network enhancing and innovation enhancing.

ICT is indeed a pre-requisite for countries' economic success. The ability of developing countries to thrive in global economy depends on the nations' objectives of ICT policies and their ability for proper implementation of such policies, as the latter has directly reached the heartland of the business life of the people. The advent of the new information technologies has opened many doors for socio-economic and political development in many countries.

The economic benefit of ICT is enormous, both as a growing industry and in terms of its influence on economic development. ICT is making the world a smaller place and creating new information highways, changing how people communicate, become informed or do business. In parallel, the social benefit is completely invaluable as it highlights several considerable advantages, including social interactions. Keeping in touch with friends and relatives is one of the major social benefits of ICT.

ICT, in its economic and social development role, is just a catalyst meant to aid national development. The benefits of ICT policies to a national economy should be measured as an input to other economic activities. More importantly, it should be considered as complementary to other sectors. ICT development is linked with and complements the development of industry, trade, farming, education, housing, health and financial institutions. It is the complementary role of ICT that makes it appropriate to link ICT planning to a national economic and social planning.

It is an inevitable fact that we can't manage what we don't measure. Unless we measure what is of interest, we don't know if it is getting better or worse. ICT

measurement is crucial for policy makers and regulators all over the world to track down the effect of the implied policies and to keep a close eye on the state of the industry relative to their peers.

Lately, we have been witnessing a growing diffusion process of ICT globally, but we can clearly spot different levels of access, use and skills of ICT among countries as well as within them. These differences cause ICT gap[2] thus decision and policy makers in many countries have been applying strategies targeting to the development of ICT. Consequently, measuring and analyzing of the digital divide among countries is of top importance for managers and researchers. Their main focus is to understand the causes driving ICT adoption, which in turn boost ICT development.

Since 2008, the International Telecom Union (ITU) has been publishing "*Measuring the Information Society (MIS)"* report on yearly basis. This report presents two benchmarking tools to monitor information society developments worldwide. The ICT Development Index (IDI) ranks countries' performance with regard to ICT infrastructure and uptake. The ICT Price Basket (IPB) tracks and compares the cost and affordability of ICT services globally. Combined, the IDI and the IPB, are powerful measures for benchmarking and explaining differences among countries and within regions when it comes to ICT developments.

On the other hand, the World Economic Forum uses the Network Readiness Index (NRI) published in "*The Global Information Technology Report*" to provide decision makers with a useful conceptual framework to evaluate the impact of ICTs at a

global level and to benchmark the ICT readiness and usage of their economies. The Networked Readiness Index measures performance of global economies in leveraging ICT to boost competitiveness and well-being.

The existing ICT measurement methods certainly provide useful indication with regards to member countries' readiness trends to embrace the information society, but none of them could:

- enlighten us about the impact of regulatory policy on the performance of an ICT sector
- identify the best practice performance benchmark (role model countries) to determine improvement targets for the less performing countries;
- provide monitoring tool to measure the impact of regulatory policies among other measures and their changes over time

To address the above shortcomings, we propose an alternative non-parametric technique based on Data Envelopment Analysis (DEA). DEA does not require the a priori specification of the functional form; but generates data-driven weights that allow for the generation of a relative aggregate efficiency score for each country. While the classical methods are based on statistical and econometric models, DEA uses the efficiency frontier approach. The DEA efficiency score measures the relative transformation efficiency of a country in terms of the effectiveness of production of multiple-output and outcomes over the efficiency of utilization of multiple-input resources. DEA was first introduced by Charnes *et al* (1978) and was in regulatory studies that motivated our investigation to the ICT domain.

In the next chapter we define and discuss the existing ICT evaluation measurement methods. Then, chapter 3 will present an analysis about the Lebanese ICT industry following the existing methods in ICT measurement defined in chapter 2. Chapter 4 describes the Data Envelopment Analysis (DEA) models and review DEA in ICT literature. Chapter 5 will highlight our contribution in ICT measurement and introduce the new DEA-based ICT measurement system. Finally, we will summarize all the findings in Chapter6.

CHAPTER II

EXISTING ICT EVALUATION MEASUREMNT METHODS

The Organization for Economic Co-operation and Development (OECD) led the developed world's effort for measuring the information society and to the establishment of the International Telecommunication Union (ITU) at the United Nations (UN) as a special agency for ICTs. ITU currently has a membership of 193 countries and over 700 private-sector entities and academic institutions. Recently, ITU has published and updated a list of Core ICT Indicators (Partnership, 2010) and a set of E-Government Indicators (Partnership, 2011a).

An ICT indicator is a statistic about the technological aspects of the information society; these indicators allow analysis of performance and predictions of future performance. Indicators have rigorous definitions which allow, among other things, for comparability among a large number of countries. The Partnership list of core 55 ICT Indicators are grouped into six categories (Partnership, 2010 and 2011a) essentially related to: ICT infrastructure and access (10 indicators), access to and use of ICT by households and individuals (13 indicators), use of ICT by businesses (12 indicators), ICT sector (4 indicators), ICT in education (9 indicators), and ICT in government (7 indicators). ITU is in charge of collecting data on ICT statistics through an annual questionnaire sent to official country contacts, usually the regulatory authority or the ministry in charge of ICT.

"Measuring the Information Society (MIS)" is a yearly report published by ITU. This report presents two benchmarking tools to monitor information society

developments worldwide. The ICT Development Index (IDI) ranks countries' performance with regard to ICT infrastructure and uptake. The ICT Price Basket (IPB) tracks and compares the cost and affordability of ICT services globally. Combined the IDI and the IPB are powerful measures for benchmarking and explaining differences among countries and within regions when it comes to ICT developments.

On the other hand, "The Global Information Technology Report (GITR)" is published yearly by the World Economic Forum. This report presents the Networked Readiness Index (NRI) which provides decision makers with a useful conceptual framework to evaluate the impact of ICTs at a global level and to benchmark the ICT readiness and usage of their economies. The Networked Readiness Index measures performance of global economies in leveraging ICT to boost competitiveness and well-being.

A. ICT Development Index

ITU has also introduced in 2009 the ICT Development Index (IDI) based on eight indicators related to ICT infrastructure and use, and three indicators borrowed from UNESCO related to adult literacy, secondary and tertiary education enrolment rates. The index measures the ICT development process through three sub-indices:

1- IDI Access sub-index reflects the level of networked infrastructure and access to ICT

2- IDI Use sub-index reflects the level of use of ICT in the society

3- IDI Skills sub-index reflects the outcome of effective ICT use

IDI is calculated based on the methodology shown in Fig.1

Fig.1 IDI Methodology

B. ICT Price Basket

ITU has also defined the ICT Price Basket index (IPB) (ITU, 2009a), with the objective of measuring the cost and affordability of the key ICT services: fixed telephony, mobile cellular (voice and SMS) and fixed broadband. The IPB has proved to be a useful benchmarking tool for the international comparison of ICT prices covering more than 160 countries.

IPB index is composed of three sub-baskets:

- Fixed-telephone sub-basket: represents the cost of local fixed residential telephone services. It includes the monthly subscription fee charged for subscribing to the public switched telephone network (PSTN), plus the cost of 30 local calls of three minutes each to the same (fixed) network (15 peak and 15 off-peak calls)
- Mobile-cellular sub-basket: represents the price of a standard monthly usage of mobile services, as determined by OECD. It includes 30 outgoing calls per month (on-net, off-net and to a fixed line, and for peak and off-peak periods) in predetermined ratios, plus 100 SMS messages.
- Fixed-broadband sub-basket: is calculated on the basis of the price of the monthly subscription to an entry-level fixed-broadband plan based on a monthly usage of 1 Gigabyte (GB).

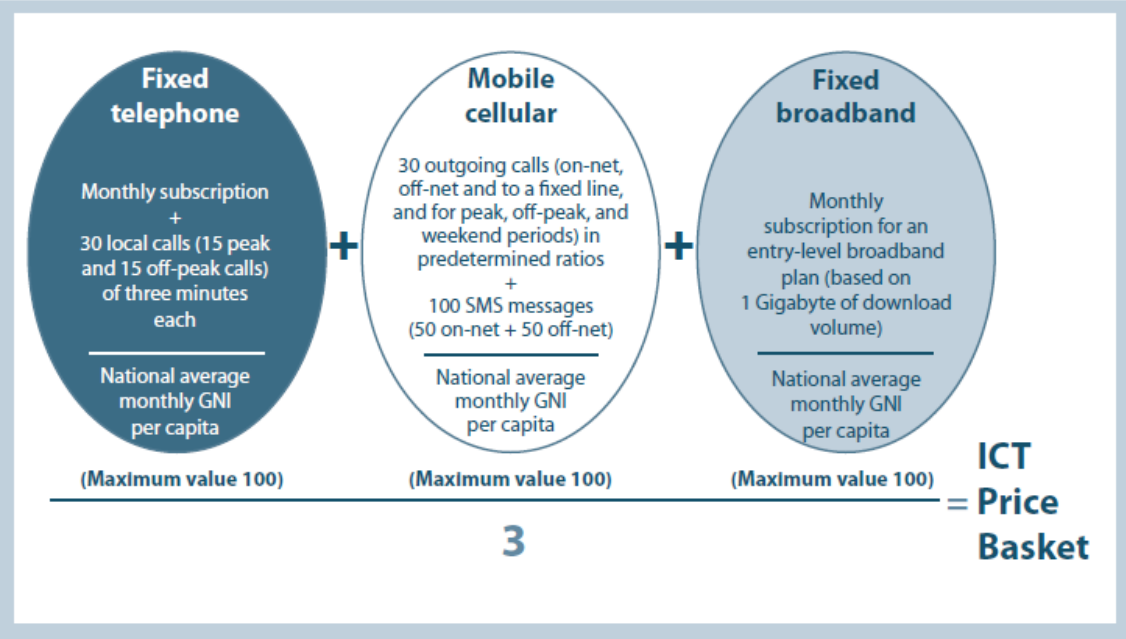

Fig.2 IPB Methodology

C. Networked Readiness Index

In partnership with INSEAD, the World Economic Forum has been publishing the *Global Information Technology Report (GITR)* since 2002. The Report monitors ICT advances over the last decade and raises awareness of the importance of ICT diffusion and usage for long-term competitiveness and societal well-being. This is reflected through the lens of the Networked Readiness Index (NRI) which comprises four sub-indexes:

- Environment sub-index: weighs the friendliness of a country's market and regulatory framework in supporting high levels of ICT uptake
- Readiness sub-index: measures the degree to which a society is prepared to make good use of an affordable ICT infrastructure and digital content
- Usage sub-index: assesses the individual efforts of the main social agents to increase their capacity to use ICT
- Impact sub-index: determines the economic and social impacts resulting from ICTs to boost competitiveness and well-being

The first three sub-indexes are considered the drivers that establish the conditions for the results of the last sub-index, ICT impacts. These four sub-indexes are divided into 10 pillars composed of 54 individual indicators in total, according to the structure shown in Fig.3.

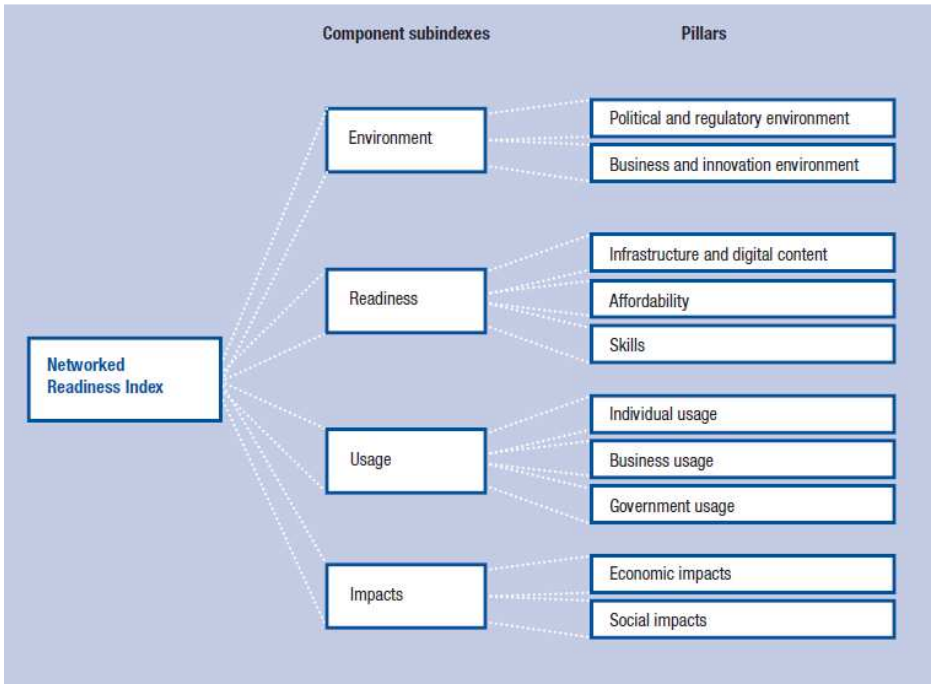

Fig. 3 NRI Structure

CHAPTER III

ICT in LEBANON

Since 2008, Lebanon's ICT has witnessed a giant leap in terms of growth and expansion. Lebanon has been observed among evolving ICT markets in the region as a result of the tech community booming due to this remarkable development. BankMed (Lebanese Bank) has recently released an ICT analysis report showing that the advancement of the ICT market has been driven by several factors including: rising incomes, falling device prices, enhancements to infrastructure, as well as enterprises and public sector modernization. Over the period 2008-2013, the ICT sector in Lebanon has shown a significant growth. Increasing broadband capacity, expanding internet speeds, recent investments in infrastructure and the young skilled labor force are the key factors behind this development.

According to the report, Lebanese economy is considered one of the most open economies in the region, due to the significant inflows of foreign direct investments (FDI) to Lebanon since 2006 with FDI-to-GDP exceeding 11% and FDI per capita at about USD 9,000. The improved openness has reflected positively on the quality to technology transfer as well as on workforce globalization. Consequently, the sector has attracted several multinational companies engaging in ICT investments in Lebanon. ANIMA investment network has recorded 18 new ICT partnerships and 10 new FDI projects during the period 2003-2012 in Lebanon. Moreover, top multinational ICT companies operate today in Lebanon including Cisco, Microsoft, Nokia Siemens, Sony Ericson, Alcatel-Lucent, ZTE and Huawei.

Although the ICT industry in Lebanon has grown with technological improvements, it has been constantly hindered by several inefficiencies including political motivation, lack of privatization, and insufficient competition due to Government control of major operators, networks and assets besides not implementing Law 431. Moreover, the sector exponential advancement is faced with a bottleneck created by low quality and poor coverage of infrastructure coupled with high costs. Furthermore, hindering the function of the Telecom Regulatory Authority (TRA), the deficient regulatory framework and the constant electricity outages are other challenges facing this advancement. We should also mention that Lebanon is subject to a large uncertainty due to destabilizing security issues. Finally, confidence in the Lebanese ICT industry is discouraged due to its vulnerability to cyber security threats.

As discussed earlier, Lebanon has made major progress on several ICT indicators. However, there is still a long way to go in order to catch up with leading countries in the region.

A. Lebanon's ICT Development Index

Lebanon ranked 52nd out of 155 countries with an IDI value of 5.37 in 2012, improving from 61st in the 2011. Lebanon scored the highest increase in IDI value during 2012 of 0.75 points. Regionally, Lebanon ranked 5th following Qatar (31st worldwide), UAE (33rd worldwide), Bahrain (39th worldwide), and Saudi Arabia (50th worldwide).

In 2011, Lebanon made a huge progress in its IDI Access sub-index that continued in 2012, with the sub-index moving from 5.34 in 2011 to 6.04 in 2012, resulting in an improvement in the country's ranking from 64th position to 55th position. This result was achieved due to the fact of the considerable expansion in international internet bandwidth which took place in Lebanon during 2011-2012. The ICT access and infrastructure improvement was translated into more intense use of services. This is evident in the remarkable progress recorded on the IDI Use sub-index. The IDI Use sub-index increased from 2.37 in 2011 to 3.54 in 2012. On the other hand, Lebanon stayed in the 56th rank for the IDI Skills sub-index during 2011 and 2012. This reflects the fact that the access and use of ICT has not yet resulted in effective outcomes.

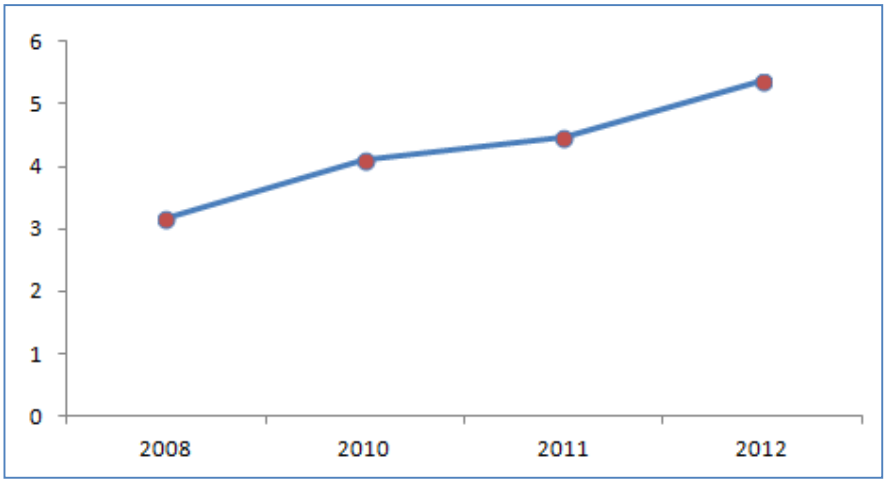

Fig.4 Lebanon's IDI progress

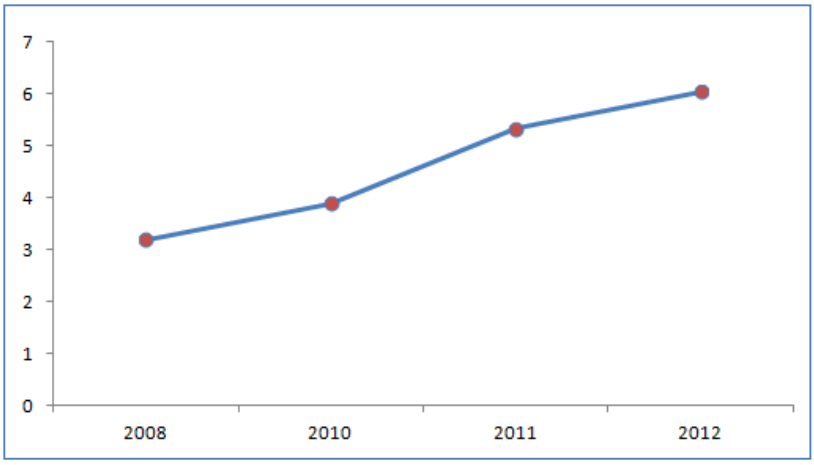

Fig.5 Lebanon's IDI Access

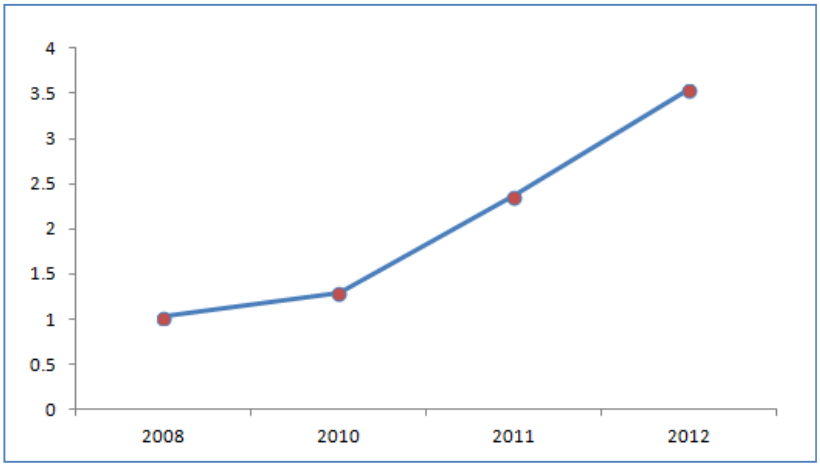

Fig.6 Lebanon's IDI Use

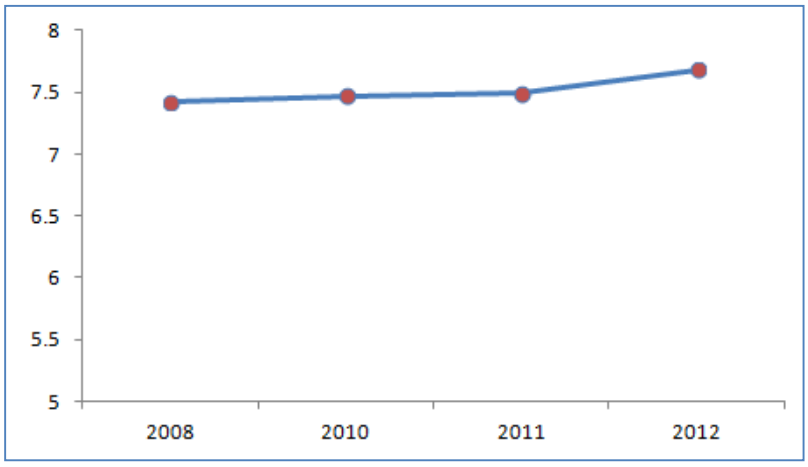

Fig.7 Lebanon's IDI Skills

A detailed assessment of the 11 indicators monitored reveals that Lebanon succeeded at achieving progress in some of these measures. The country's broadband market has seen a number of changes between 2011 and 2012, in particular with the introduction of wireless broadband, where wireless broadband penetration went up from 11% in 2011 to 26% in 2012. Likewise, fixed (wired)-broadband penetration more than doubled, from 5% in 2011 to 12% in 2012. Furthermore, the proportion of individuals with access to internet increased by three percentage points to 64%, while the proportion of individuals using the Internet climbed by nine percentage points to 61% in 2012. When it comes to telephone access, fixed-telephone subscriptions and mobile-cellular telephone subscriptions expanded to 20.5% and 93.2%, respectively

B. Lebanon's Networked Readiness Index

In 2012, Lebanon ranked 94th out of 144 countries on the Networked Readiness Index (NRI), moving one position up from 2011. In 2013, Lebanon improved its score but dropped 3 positions in the overall raking to the 97th position of 148 countries with a score of 3.64. Lebanon's score was lower than the Arab average of 4 and ranked 10, right behind Egypt (91st), but right ahead of Morocco (99th worldwide).

Table 1 NRI Arab States Ranking 2013

	Country	Score	Rank
1	Qatar	5.22	23
2	United Arab Emirates	5.20	24
3	Bahrain	4.86	29
4	Saudi Arabia	4.78	32
5	Oman	4.56	40
6	Jordan	4.36	44
7	Kuwait	3.96	72
8	Tunisia	3.77	87
9	Egypt	3.71	91
10	Lebanon	3.64	97
11	Morocco	3.61	99
12	Algeria	2.98	129

13	Libya	2.75	138
14	Yemen	2.73	140

The NRI sub-indices reveal the reason behind Lebanon's weaknesses in terms of ICT development. Lebanon ranked 81st on the Environment sub-index. Within this sub-index, although Lebanon ranked 48th on the business and innovation pillar, it lagged significantly in the political and regulatory pillar, ranking 142nd. When it comes to the Readiness sub-index, Lebanon's ICT readiness was at the 79th rank. Despite the high-skilled ICT workforce as indicated by the country's ranking of 45 on the skills pillar, the country ranked 99th on the affordability pillar indicating the high cost of ICT in Lebanon. Furthermore, on the Usage sub-index Lebanon ranked 90th, mainly due to the low 136th rank on government usage pillar which offset the 58th rank on individual usage pillar. As for the Impact sub-index, Lebanon came in 114th position worldwide, while ranking 101st on the economic impacts and 121st on the social impacts.

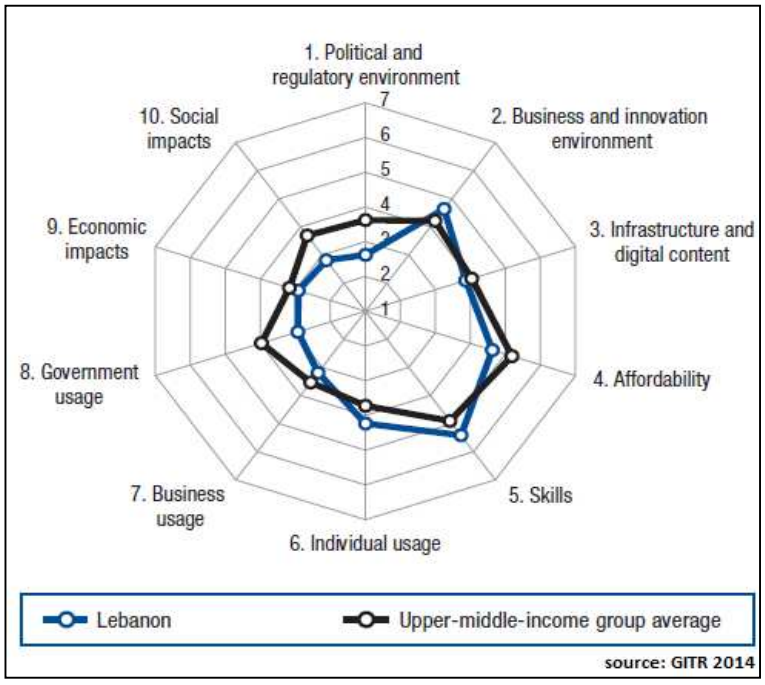

Fig. 8 Lebanon vs. Upper Middle income group NRI matrix

It is worth mentioning that, when compared to the upper-middle-income group, Lebanon's score exceeds the average score of the group in business and innovation environment pillar, skills pillar, and individual usage pillar. On the other hand, it still lags behind in the infrastructure and digital content pillar, the affordability pillar, and economic and social impact pillars. This means that despite the high ranking in capacity, innovation, and skills required for improving the ICT sector, the lack of sufficient infrastructure and regulations have so far hindered Lebanon's ICT development.

CHAPTER IV

DATA ENVELOPE ANALYSIS (DEA)

Data Envelope Analysis (DEA) is a non-parametric technique based on linear programming that was developed by Charnes et al. (1978) and Banker et al. (1989). It is used to measure the relative efficiency of several Decision Making Units (DMU) where several inputs and outputs are taken into account[2]. DMUs are organizations under observation such as hospitals, banks, schools or enterprises. Inputs and outputs of DMUs are compared by establishing a frontier of excellence and by evaluating efficiency relative to that frontier. Therefore, a DMU is qualified as efficient if no other DMU can produce more outputs by using an equal or smaller quantity of inputs, or if no other DMU can use fewer inputs to produce an equivalent or higher quantity of outputs. In any of either case, the DMU is located on the frontier of excellence else the DMU is qualified as inefficient.

There are several advantages to using DEA as a performance or efficiency evaluation method compared to parametric methods. DEA allows certain flexibility in the treatment of the inputs and the outputs as well as in the conversion of multiple inputs and outputs into an easy and comprehensible efficiency measure.

A. CCR Model

The first DEA model, and the one most extensively used in the literature, is that of Charnes et al. (1978). This model measures the relative technical efficiency ratio of a DMU by the sum of its weighted outputs to the sum of its weighted inputs. However, this ratio should not exceed one for any DMU in the study. It is formulated as follows:

$$\max h_i = \frac{\sum_{r=1}^{t} \mu_r y_{ir}}{\sum_{s=1}^{m} \upsilon_s x_{is}} \tag{1}$$

$$\frac{\sum_{r=1}^{t} \mu_r y_{jr}}{\sum_{s=1}^{m} \upsilon_s x_{js}} \leq 1, \quad j = 1, \ldots, n \tag{2}$$

$$\mu_r \upsilon_{js} \geq \varepsilon. \tag{3}$$

Note that n is the number of DMUs, t is the number of outputs, m is the number of inputs, x_{is} is the value of input s for DMU_i, y_{ir} is the value of output r for DMU_i, h_i is the efficiency ratio of DMU_i or company i, l_r is the relative importance of output r, t_s is the relative importance of input s and e is a small positive number. If the model [(1)–(3)] is fractional, using Charnes and Cooper (1962) we can solve it by maximizing the numerator of (1) and by fixing its denominator at 1. The new model [(4)–(7)] is known as CCR.

$$\max h_o = \sum_{r=1}^{t} \mu_r y_{ir} \tag{4}$$

$$\sum_{r=1}^{t} \mu_r y_{jjr} - \sum_{s=1}^{m} \upsilon_s x_{js} \leq 1, \quad j = 1, \ldots, n \tag{5}$$

$$\sum_{s=1}^{m} \upsilon_s x_{is} = 1, \tag{6}$$

$$\mu_r \upsilon_s \geq \varepsilon. \tag{7}$$

This model will answer the following question: by what proportion can all the inputs be reduced while maintaining the same level of outputs in order to make a unit efficient. In a similar way, the CCR oriented output model—which would be obtained if we minimize the denominator of (1) and fix its numerator at 1—would answer the following question: by what proportion can all the outputs be increased while maintaining the same level of input in order to make a unit efficient.

B. BCC Model

The CCR model assumes Constant Returns to Scale (CRS). The BCC model of Banker et al. (1984) assumes a Variable Return to Scale (VRS) by specifically adding a parameter to the numerator to capture Variable Returns to Scale (u_0). The efficiency ratios are then calculated by comparing only the same scale DMUs. The input-oriented BCC model takes the following form:

$$\max h_o = \sum_{r=1}^{t} \mu_r y_{iir} - u_o \tag{8}$$

$$\sum_{r=1}^{t} \mu_r y_{jjr} - \sum_{s=1}^{m} \upsilon_s x_{js} \leq 1, \quad j = 1, \ldots, n \tag{9}$$

$$\sum_{s=1}^{m} \upsilon_s x_{is} = 1, \tag{10}$$

$$\mu_r \upsilon_s \geq \varepsilon. \tag{11}$$

A DMU is efficient if h_o is equal to one and inefficient otherwise. In these models, the ratio h_o could be interpreted as the load factor of the resources. One of the advantages of DEA is to allow the identification and the quantification of the sources of inefficiencies

C. Literature Review

Sueyoshi (1994) applied DEA to compare the performance of public telecommunications operators (PTOs) in 24 member countries of the Organization for Economic Cooperation and Development (OECD) in 1987 where results showed that large and small PTO countries had attained higher efficiency. Majumdar (1998) used three different DEA models to investigate the patterns of resource utilization in the US telecommunications industry. Giokas and Pentzaropoulos (2000) estimated the regional

efficiency of PTOs in Greece using DEA approach and concluded that around 42% of surveyed units were efficient. Uri (2001) used DEA to investigate the effect of incentive regulation on the productivity of the telecommunication industries in the United States. Furthermore, another DEA model to investigate the quality of service for Brazilian local telephony was applied by Facanha and Resende (2004). Using a combined DEA and Analytic Hierarchy Process (AHP) technique, Giokas and Pentzaropoulos (2008) compared the performance of 30 telecom organizations in OECD member countries. Lam and Shiu (2008) also used DEA to measure the productivity of China's telecommunication sector at the provincial level. They showed that the operating environment is the main driver behind the differences in the efficiency scores. V. Kyriakidou (2013) used DEA to estimate DEA-opportunity index (DEA-OI), which is a useful tool for measuring progress in ICT. Findings of this alternative approach were in line with ICT-opportunity index that was developed by ITU (2005).

CHAPTER V

THE NEW DEA-BASED ICT MEASUREMNT MODEL

The collected data for indicators are either from administrative sources when available or through an opinion survey of selected panel of ICT experts. The associated analytical methods to generate indices are regression-based approaches with a priori specification of functional form and pre-fixed weights for indicators; they estimate average performances and trends from the aggregated data on indicators. The indicators may not have been developed from all stakeholders' perspectives. For instance, the recent report by (ESCWA, 2013) confirmed "the early insights regarding the ESWCA region's efforts in the e-government domain allowing many of its countries, essentially GCC, to occupy top spots in related international indices; however, it is still debatable if these services are effectively used by citizens". Moreover the ICT impact in the region is, to a significant extent, driven more by government ICT initiatives especially in rich GCC countries. There is still an additional challenge facing ESCWA countries, namely, how to stir demand and effective *use* of these ICT services to match government offerings. A best practice guideline to overcome such challenges requires benchmarking methodology and tools that cannot be generated from the current statistical methods that often drop best practice outliers of good performance.

From the above brief review, it is important to observe that neither IDI nor NRI could directly enlighten us about the impact of regulatory policy on the performance of the ICT sector. They certainly provide useful indication with regards to member countries' readiness trends to embrace the information society. They also fail to identify the benchmark for the best practice performance (role model countries) in order to

determine improvement targets for the less performing countries, and to provide monitoring tool to measure the impact of regulatory policies among others measure and their changes over time.

To address the above shortcomings in the ICT literature, an alternative non-parametric technique based on Data Envelopment Analysis (DEA) is proposed. DEA does not require the a priori specification of the functional form; and it also generates data-driven weights that allow for the generation of a relative aggregate efficiency score for each country. The DEA efficiency score measures the relative transformation efficiency of a country in terms of the effectiveness of production of multiple-output and outcomes over the efficiency of utilization of multiple-input resources.

In this project, we will use the BCC model because the assumption of VRS underlying the BCC model seems to be the most representative of ICTs performance. The marginal increase in output is not necessarily always equal to marginal increase in the input. Input might be kept at a certain fixed level while output is increasing. ICT performance might be influenced by many factors that are external and unrelated to the production process itself. Among these factors we can cite regulations and political stability, or lack thereof.

A. Sample Selection

For this project we benchmark the ICT performance of 128 countries in 2008, 124 countries in 2010, 122 countries in 2011 and 139 countries in 2012. Data for selected input and output variables is collected from ITU MIS Reports for years 2008, 2010, 2011

and 2012. Countries with IDI and IPB available data in the ITU reports were only selected.

B. Input and Output Variables

In order to calculate efficiency scores and determine the performance of the ICT sectors in study, we used eight variables in the form of inputs and outputs. The five input variables are: IDI access sub-index, IDI skills sub-index and the three IPB sub-baskets as a % of GNI per capita: fixed-telephone, mobile-cellular and fixed-broadband. The three output variables are the indicators of the IDI use sub-index: Percentage of individuals using the internet, fixed-broadband subscriptions per 100 inhabitants and mobile-broadband subscriptions per 100 inhabitants

Table 2 Summary of input and output variables

Variable	Description	Type
ACCESS	access sub-index	INPUT
SKILL	skill sub-index	INPUT
MOBILESB	mobile-cellular sub-basket	INPUT
BROADBANDSB	fixed-broadband sub-basket	INPUT
FIXEDSB	fixed-telephone sub-basket	INPUT
INTERNET	percentage of internet users	OUTPUT
BROADBAND	fixed-broadband subscriptions per 100 inhabitants	OUTPUT
MOBILE	active mobile-broadband subscription per 100 inhabitants	OUTPUT

The choice of input and output variables was based on our definition of ICT performance. Investments and expansion in ICT infrastructure coupled with skilled labor

that delivers affordable ICT services will drive higher rates of usage for ICT services for individuals, businesses and governments leading to a better socio-economic environment.

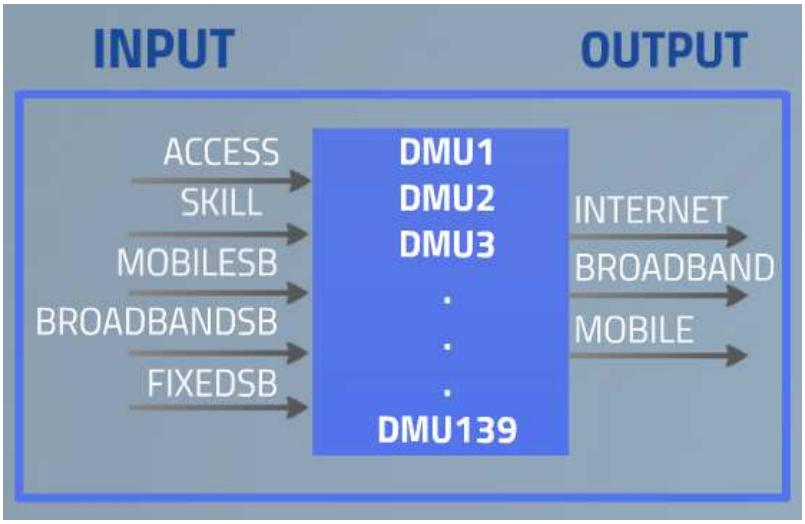

Fig. 9 DEA input/output variables

The price of ICT services has a significant impact on the demand for and spread of ICTs as stated by the economic theory. Prices strongly influence how many people are able and willing to subscribe to a service which is reflected as ICT usage. The concept of service affordability for consumers is useful for service providers, policy-makers and analysts in ascertaining the potential user base of ICTs and identifying limits on ICT uptake. A comparison between countries can help identify realistic price targets, as well as best practices, and highlight bottlenecks and shortcomings (MIS,2011). For these given reasons, our DEA model uses ICT price sub baskets for input and ICT usage for output.

We could have used more input variables by zooming into access and skills sub-indexes but this will leave us with relatively huge number on input variables. In order to investigate the perception of high prices of ICT in Lebanon, we zoomed into IPB and used its sub-baskets as input variables.

C. Countries Classification

According to the World Bank (http://www.worldbank.org) countries are divided in two groups, developed and developing. This classification is based on the income level. There are four categories of income level: high, upper-middle, low-middle and low. More specifically, for year 2012, high income is over 12,475$, upper-middle income between $4,036–12,475, low-middle income between $1,026–4,035 and a low income is less than 1025$. The classification is based on Gross National Income per capita in US dollars ($), a commonly used indicator which echoes social welfare and can be associated with the expected public and private actions for example, ICT investments and usage of telecommunication services.

The data available from 139 countries in 2012 for our study is divided as follows: 48 of them correspond to the high income group, 40 to the upper-middle income group, 32 to the low-middle income group and 19 to low income group. The countries belonging to the high income group are addressed as the developed countries, while those belonging to the other three groups are considered as the developing countries.

Developed countries are characterized by extensive infrastructures, urbanization and competence in science and technology. It can be easily stated that these countries have already reached ICT maturity. On the contrary, developing countries are at the beginning of their development process and there is still room for improvements.

D. Analysis and Discussion

In this project an output orientation has been selected first as it is believed that it would be fair to assume that, ICT regulators and policy makers usually attempt to maximize output from a given set of inputs rather than the converse. Then we ran an input oriented DEA to highlight the ICT services' high price perception in Lebanon. Both DEA models were based on BCC model.

1. Output-Oriented Technical Efficiency

Output-oriented technical efficiencies for years 2008 till 2012 are shown in Appendix A. In 2012, 18 out of 139 countries scored one (100% Efficient): Belarus, Cuba, Denmark, Finland, Hong Kong, Iceland, Iran, Korea, Luxembourg, Macao, Netherlands, Norway, Qatar, Singapore, Sweden, Switzerland, United Arab Emirates and United States. This means that these countries were operating on the best practice frontier as far as ICT policies are concerned in 2012. These countries were judiciously converting their inputs (ICT Access, ICT Skills and IPB) into Output (ICT Use). The average technical efficiency score across countries in 2012 works out to be 0.51. This means that 96% scaling up of output is required on an average by the ICT industry across countries to reach the best practice frontier.

Lebanon had shown a great progress in its output efficiency during the period 2008-2012. In 2011, Lebanon scored 0.55 on the output oriented technical efficiency occupying the 53rd position out of 122 countries. Lebanon scored 0.64 on the output oriented technical efficiency occupying the 51st position out of 139 countries for 2012 showing a 9% improvement from 2011 which is translated into 25% of scaling up of output. This puts Lebanon on the list of most dynamic countries who improved their

output efficiency from 2011 to 2012. Despite the fact that Lebanon is still lagging behind by 56% of the best practice frontier, it is ranked 6th on the list of the top 10 countries who made progress on output efficiency score from 2011 to 2012.

Table 3 Top 10 dynamic countries

	2012		2011		
	Score	Rank	Score	Rank	Change
Belarus	1.00	1	0.706	1	29%
South Africa	0.43	82	0.229	93	20%
Jamaica	0.48	72	0.332	82	15%
Hungary	0.75	39	0.625	46	12%
Dominican Republic	0.47	77	0.374	75	10%
Lebanon	0.64	51	0.547	53	9%
Colombia	0.51	67	0.425	68	9%
Egypt	0.46	78	0.375	74	8%
Moldova	0.48	73	0.400	71	8%
Argentina	0.58	56	0.503	61	8%

Only until 2011 that Lebanon has outperformed the Arab States average as well as the world average on ICT output efficiency. In 2012, Lebanon ranked 4th among 13 Arab countries lagging behind Qatar, UAE and Bahrain.

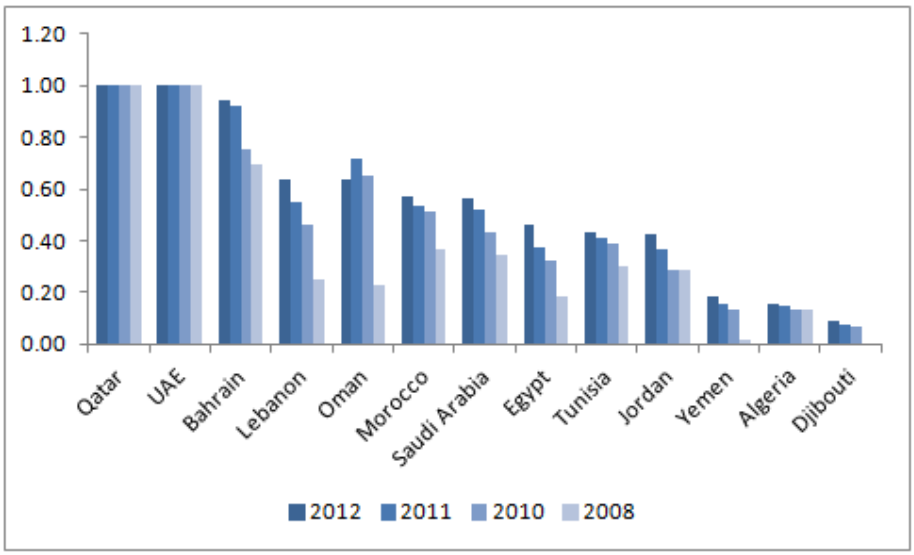

Fig. 10 Arab States Output Efficiency

Despite the fact the Lebanon is still lagging behind the average output efficiency of the developed countries (20% in 2012); Lebanon has shown a continuous and fast advancement in its ICT indicators since 2008. The developed countries average is at a stable level of 0.84 showing an advancement of 7% since 2008 while Lebanon score has increased by 39%. On the other hand, developing countries average has increased by 15% only.

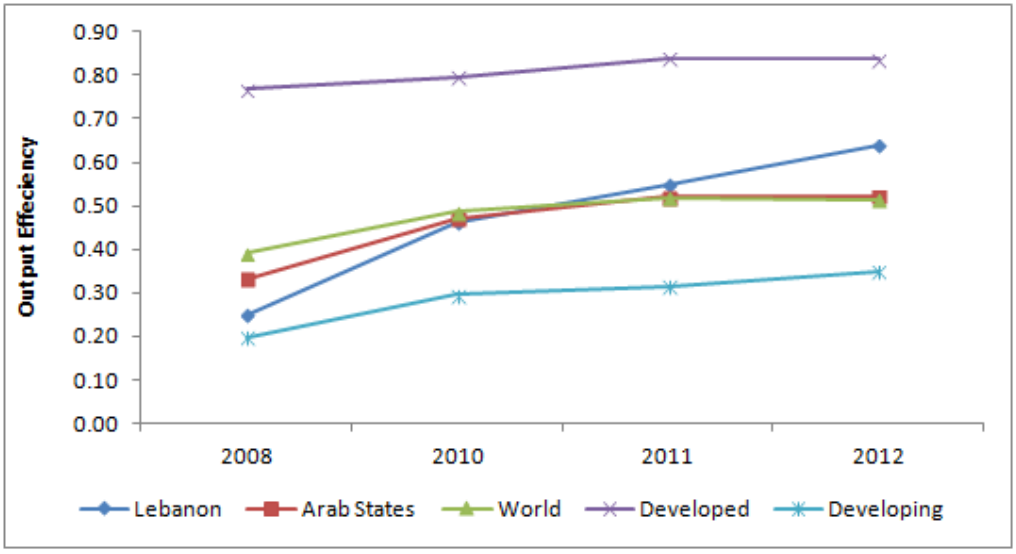

Fig. 11 Output Efficiency

Table 4 shows that the average output efficiency for the developed countries has reached a zone of stability while developing countries are still showing progressive growth. This is a reflection of the fact that there is still much room for improvement in the developing countries than developed countries specifically on ICT usage.

Table 4 Output Efficiency Comparison Table

	Output Efficiency			
	2008	2010	2011	2012
Lebanon	0.25	0.46	0.55	0.64
Arab States	0.33	0.47	0.52	0.52
World	0.39	0.49	0.52	0.51
Developed	0.77	0.80	0.84	0.84
Developing	0.20	0.30	0.32	0.35

Table 5 shows that Lebanon was positioned in 10th place among 91 developing countries for 2012 on ICT technical output efficiency.

Table 5 Top 10 Developing Courtiers

	Score	Rank
Belarus	1.00	1
Cuba	1.00	1
Iran	1.00	1
Malta	0.80	4
Hungary	0.75	5
Malaysia	0.69	6
Bosnia and Herzegovina	0.68	7
Venezuela	0.67	8
Macedonia	0.66	9
Lebanon	0.64	10

Lebanon was able to translate progress in ICT access and infrastructure into more intense use of services. Lebanon's broadband market has seen a number of changes between 2011 and 2012, especially with the introduction of wireless broadband. 3G was commercially launched in November 2011 by the two state-owned mobile operators, Touch and Alfa which resulted in an increase of wireless-broadband penetration from 11% in 2011 to 26% in 2012. Fixed-broadband penetration more than doubled, from 5% in 2011 to 12% in 2012. A new entry-level broadband plan was introduced by governmental decree in September 2011, lowering the cost of entry-level broadband by 70%. The price of this new package lies below the Arab States average, according to a study by the Lebanese Telecommunications Regulatory Authority (TRA). Internet usage has climbed to 61% in 2012, up from 52% in 2011.

The DEA-based system allows the identification of the best performers in the ICT and benchmarks the performance of other countries against theirs. This benchmarking enables a gap analysis between each country's performance and the performance frontier.

This gap analysis allows the identification of the causes of inefficiency in the country's performance through the projection of the country's performance on the performance frontier. For 2012, the DEA BCC-O model suggests Iceland as an ideal performer for Lebanon.

Lebanon is inefficient since its output efficiency score is way below 1 (0.64). The projection of Lebanon's performance on the performance frontier shows that its inefficiency comes from the usage of internet 56.86% lower, fixed-broadband 194.87% lower and wireless (mobile)-broadband 180.08%. More specifically, policy makers in Lebanon should set the following targets to ensure efficient performance of the country's ICT sector.

- Raise Internet usage from 61.2% to 96%
- Raise Fixed-Broadband usage from 11.7% to 34.5%
- Raise Mobile-Broadband usage from 25.6% to 71.7%

Table 6 Lebanon's Output Projections

INTERNET		**BROADBAND**		**MOBILE**	
Projection	Change(%)	Projection	Change(%)	Projection	Change(%)
96	56.86%	34.5	194.87%	71.7	180.08%

The targets might seem too aggressive but these targets should be put within a time frame while monitoring the progress during this period based on the newly applied policies.

2. Input-Oriented Technical Efficiency

Input-oriented technical efficiencies for years 2008 till 2012 are shown in Appendix B. In 2012, the same 18 output efficient countries scored one (100% Efficient): Belarus, Cuba, Denmark, Finland, Hong Kong, Iceland, Iran, Korea, Luxembourg, Macao,

Netherlands, Norway, Qatar, Singapore, Sweden, Switzerland, United Arab Emirates and United States. The average technical efficiency score across countries in 2012 works out to be 0.72. This means that 28% scaling down of input (resources) is required on an average by the ICT industry across countries to reach the best practice frontier.

In 2012, Lebanon ranked 66th out of 139 countries on input efficiency with a score of 0.78 showing no progress from 2011 where it ranked 60th out of 122 countries. Surprisingly, the Arab States' average is below the World's average while Lebanon's average is above the World's average but still lagging behind the developed countries' average by 14%.

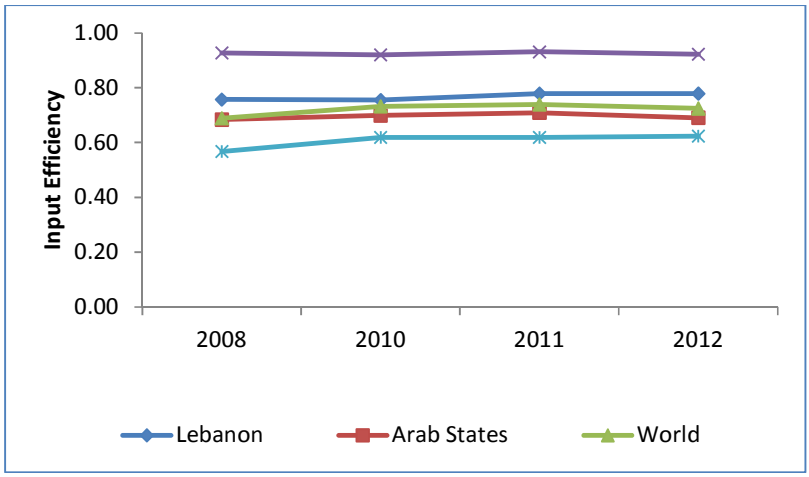

Fig. 12 Input Efficiency

Table 7 shows that the world average on input efficiency went down by 1% from 2011 to 2012. This decrease is related to the decrease of input efficiency of the developed countries while developing countries have shown a stable state on input efficiency.

Table 7 Input Efficiency Comparison

	Input Efficiency			
	2008	2010	2011	2012
Lebanon	0.76	0.76	0.78	0.78
Arab States	0.68	0.70	0.71	0.69
World	0.69	0.73	0.74	0.72
Developed	0.93	0.92	0.93	0.92
Developing	0.57	0.62	0.62	0.62

Despite the fact that the Arab State average has shown a 2% decrease from 2011 to 2012, Lebanon maintained the same level of input efficiency where it ranked 5th right behind the rich GCC countries and ahead of Jordan and Oman.

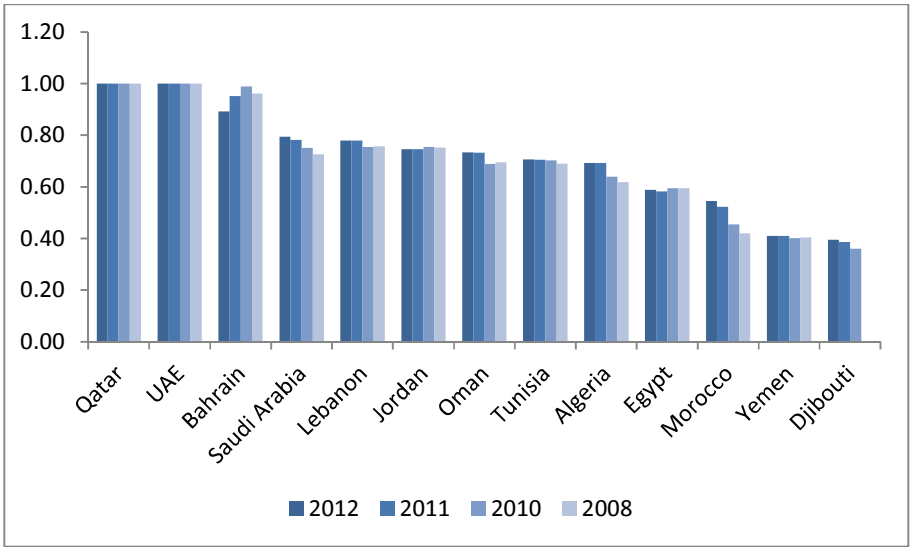

Fig. 13 Arab States Input Efficiency

For 2012, the DEA BCC-I model suggests Korea as an ideal performer for Lebanon. Lebanon is inefficient since its input efficiency score is below 1 (0.78). The projection of Lebanon's performance on the performance frontier shows that the cause of it inefficiency comes from the higher prices of Fixed-Telephone by 71.4% than Korea, Mobile by 85.2% and Broadband by 30.4%. More specifically, policy makers in Lebanon should set the following targets with a predefined time frame while monitoring its progress to ensure input efficiency of the country's ICT sector:

- Lower Fixed price basket from 1.4 to 0.4
- Lower Mobile price basket from 2.7 to 0.4
- Lower Broadband price basket from 2.3 to 1.6

Table 8 Lebanon's Input Projection

FIXEDSB		MOBILESB		BROADBANDPB	
Projection	Change(%)	Projection	Change(%)	Projection	Change(%)
0.40	-71.4%	0.40	-85.2%	1.60	-30.4%

E. Performance Matrix

Given the input and output oriented efficiencies we constructed a matrix of the upper-middle income countries where the axes of this matrix intersect at the average input (0.76) and output (0.51). The matrix defines four zones:

- **Zone A**: contains the group of countries with high efficiency score on both input and output efficiency scores. This group is consuming little resources and producing high output. Policy makers in these countries should keep an eye on the applied ICT policies and ensure that any change in ICT access and infrastructure should be reflected efficiently as ICT usage.
- **Zone B:** contains the group of countries that are performing above output average but below input average. Those countries are delivering high output meaning that ICT usage is high but consuming ICT resources (input) in higher proportions than peer countries. The current ICT regulations in these countries are targeted towards the use of ICT. More attention on the resources is required (proper allocation, expansion, bandwidth utilization, package offerings…).
- **Zone C:** contains the the group of countries that are performing above input average but below output average. Those countries are good in utilizing their ICT resources but producing less output than counter countries. Regulations in these countries are focused on managing the limited resources. An extra effort should be put into stimulating the ICT usage in these countries.

- **Zone D**: contains the group of countries that are performing below input and output averages, basically those countries are wasting resources and producing very little output. Those countries need new ICT regulatory framework that looks into managing ICT resources and stimulating its usage.

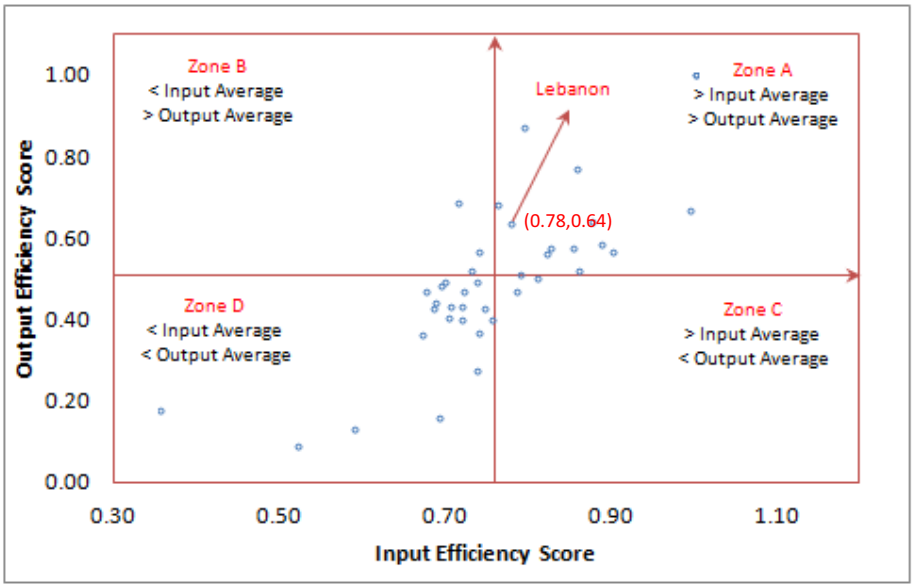

Fig .14 Upper Middle Income Group Performance Matrix

From the above matrix we notice that Lebanon belongs to Zone A which means that its ICT industry is performing above the upper-middle income countries average input and average output. Compared to its peers in zone A, Lebanon is performing much better on output than input. The table below shows the distribution of the upper-middle income countries per zone. Lebanon belongs to the top 38% ranked 16th on input and 8th on output.

Table 9 Performance Matrix Summary

	Count	Percentage
Zone A	15	38%
Zone B	3	8%
Zone C	3	8%
Zone D	19	48%

Table 10. Upper Middle Income Group Ranking

Country	Input Score	Output Score	Zone	Input rank	Output rank
Belarus	1.00	1.00	A	1	1
Macao	1.00	1.00	A	1	1
Venezuela	0.99	0.67	A	3	7
Russian	0.90	0.57	A	4	10
Argentina	0.89	0.58	A	5	9
Chile	0.88	0.64	A	6	8
Romania	0.86	0.52	A	7	16
Latvia	0.86	0.77	A	7	4
Uruguay	0.85	0.57	A	9	10
Bulgaria	0.82	0.57	A	10	10
Kazakhstan	0.82	0.56	A	10	15
Serbia	0.81	0.50	C	12	19
Antigua & Barbuda	0.79	0.87	A	13	3
Colombia	0.79	0.51	A	13	18
Turkey	0.79	0.47	C	13	23
Lebanon	0.78	0.64	A	16	8
Bosnia and Herzegovina	0.76	0.68	A	17	6
Peru	0.76	0.40	C	18	32
Jordan	0.75	0.43	D	19	27
Ecuador	0.74	0.37	D	20	34
Azerbaijan	0.74	0.57	B	20	10
St. Vincent	0.74	0.49	D	20	20
Thailand	0.74	0.28	D	20	36
Brazil	0.73	0.52	B	24	16
Panama	0.72	0.47	D	25	23
Mexico	0.72	0.40	D	25	32
Mauritius	0.72	0.43	D	25	27
Malaysia	0.71	0.69	B	28	5
Tunisia	0.71	0.43	D	28	27
Maldives	0.70	0.41	D	30	31
Seychelles	0.70	0.49	D	30	20
Jamaica	0.69	0.48	D	32	22
Algeria	0.69	0.16	D	32	38
China	0.69	0.44	D	32	26
South Africa	0.68	0.43	D	35	27
Dominican Rep.	0.68	0.47	D	35	23
Suriname	0.67	0.37	D	37	34
Botswana	0.59	0.13	D	38	39
Gabon	0.52	0.09	D	39	40
Angola	0.36	0.18	D	40	37

F. Old System vs. New System

We ran a correlation between the output efficiency score and the ITU IDI for 2012. The results showed a 92% correlation which proves that our new ICT performance evaluation DEA-based system is in line with the ITU evaluation. Lebanon ranked 51st out of 139 courtiers in both systems.

Table 11. Old vs New Rankings

Economy	IDI Rank	IDI Score	BCCO Rank	BCCO Score	Economy	IDI Rank	IDI Score	BCCO Rank	BCCO Score
Korea	1	8.57	1	1.00	Qatar	31	6.54	1	1.00
Sweden	2	8.45	1	1.00	Greece	32	6.45	48	0.66
Iceland	3	8.36	1	1.00	UAE	33	6.41	1	1.00
Denmark	4	8.35	1	1.00	Czech Republic	34	6.4	34	0.78
Finland	5	8.24	1	1.00	Latvia	35	6.36	36	0.77
Norway	6	8.13	1	1.00	Portugal	36	6.32	45	0.67
Netherlands	7	8	1	1.00	Poland	37	6.31	43	0.68
United Kingdom	8	7.98	19	0.96	Croatia	38	6.31	46	0.66
Luxembourg	9	7.93	1	1.00	Bahrain	39	6.30	21	0.94
Hong Kong	10	7.92	1	1.00	Russia	40	6.19	61	0.57
Australia	11	7.90	25	0.90	Belarus	41	6.11	1	1.00
Japan	12	7.82	26	0.88	Hungary	42	6.1	39	0.75
Switzerland	13	7.78	1	1.00	Slovakia	43	6.05	30	0.83
Macao	14	7.65	1	1.00	Cyprus	44	5.86	49	0.64
Singapore	15	7.65	1	1.00	Bulgaria	45	5.83	57	0.57
New Zealand	16	7.64	20	0.95	Uruguay	46	5.76	58	0.57
United States	17	7.53	1	1.00	Antigua & Barbuda	47	5.74	28	0.87
France	18	7.53	22	0.93	Kazakhstan	47	5.74	64	0.56
Germany	19	7.46	24	0.91	Saudi Arabia	49	5.69	63	0.57
Canada	20	7.38	23	0.91	Chile	50	5.46	50	0.64
Austria	21	7.36	29	0.85	Lebanon	51	5.37	51	0.64
Estonia	22	7.28	31	0.83	Oman	52	5.36	53	0.63
Ireland	23	7.25	32	0.83	Argentina	53	5.36	56	0.58
Malta	24	7.25	33	0.80	Romania	54	5.35	65	0.52
Belgium	25	7.16	27	0.88	Serbia	55	5.34	68	0.50
Israel	26	7.11	35	0.77	Macedonia	56	5.19	47	0.66
Spain	27	6.89	38	0.76	Brunei Darussalam	57	5.06	52	0.63
Slovenia	28	6.76	40	0.74	Malaysia	58	5.04	41	0.69
Barbados	29	6.65	37	0.76	Costa Rica	59	5.03	69	0.50
Italy	30	6.57	55	0.61	Azerbaijan	60	5.01	62	0.57

Economy	IDI Rank	IDI Score	BCCO Rank	BCCO Score	Economy	IDI Rank	IDI Score	BCCO Rank	BCCO Score
Brazil	61	5	66	0.52	Guyana	101	3.08	94	0.36
St. Vincent	62	4.81	70	0.49	Algeria	102	3.07	115	0.16
Seychelles	63	4.75	71	0.49	Sri Lanka	103	3.06	109	0.19
Moldova	64	4.74	73	0.48	Botswana	104	3	121	0.13
Trinidad & Tobago	65	4.73	54	0.62	Namibia	105	2.85	114	0.16
Bosnia &Herzegovina	66	4.71	42	0.68	Cuba	106	2.72	1	1.00
Turkey	67	4.64	76	0.47	Gabon	107	2.61	123	0.09
Ukraine	67	4.64	96	0.35	Ghana	108	2.6	106	0.20
Panama	69	4.61	75	0.47	Nicaragua	109	2.54	117	0.14
Georgia	70	4.59	74	0.47	Zimbabwe	110	2.52	108	0.20
Mauritius	71	4.55	80	0.43	Kenya	111	2.46	99	0.33
Maldives	72	4.53	86	0.41	Swaziland	112	2.44	105	0.22
Armenia	73	4.45	85	0.41	Bhutan	113	2.40	103	0.26
Jordan	74	4.22	82	0.43	Sudan	114	2.33	104	0.22
Colombia	75	4.2	67	0.51	Cambodia	115	2.3	129	0.05
China	76	4.18	79	0.44	India	116	2.21	120	0.13
Venezuela	77	4.17	44	0.67	Nigeria	117	2.18	98	0.34
Albania	78	4.11	60	0.57	Senegal	118	2.02	107	0.20
Ecuador	79	4.08	91	0.37	Solomon islands	119	1.97	125	0.07
Fiji	80	3.99	96	0.35	Lesotho	120	1.95	128	0.06
South Africa	81	3.95	82	0.43	Yemen	121	1.89	112	0.18
Mexico	81	3.95	87	0.40	Pakistan	122	1.83	122	0.10
Mongolia	83	3.92	110	0.19	Uganda	123	1.81	116	0.15
Egypt	84	3.85	78	0.46	Zambia	124	1.77	117	0.14
Suriname	85	3.84	92	0.37	Djibouti	124	1.77	124	0.09
Viet Nam	86	3.8	84	0.41	Mauritania	126	1.76	127	0.06
Iran	87	3.79	18	1.00	Bangladesh	127	1.73	126	0.07
Morocco	87	3.79	59	0.57	Côte d'Ivoire	128	1.7	134	0.02
Tunisia	89	3.7	80	0.43	Angola	129	1.68	113	0.18
Jamaica	90	3.68	72	0.48	Tanzania	130	1.65	119	0.14
Peru	90	3.68	88	0.40	Benin	131	1.6	132	0.04
Dominican Rep.	92	3.58	77	0.47	Mali	132	1.54	135	0.02
Thailand	93	3.54	101	0.28	Malawi	133	1.43	131	0.05
Cape Verde	94	3.53	93	0.36	Mozambique	134	1.31	130	0.05
Indonesia	95	3.43	111	0.19	Congo Dem Rep	134	1.31	137	0.02
Philippines	96	3.34	90	0.38	Madagascar	136	1.28	136	0.02
Bolivia	97	3.28	95	0.36	Ethiopia	137	1.24	138	0.02
El Salvador	98	3.25	102	0.27	Eritrea	138	1.2	139	0.01
Paraguay	99	3.21	100	0.28	Burkina Faso	139	1.18	133	0.04
Uzbekistan	100	3.12	89	0.38					

In addition, we ran Spearman's rank correlation defined by the following equation, where di is the difference between ranks and n is the total number of observations.

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

The results showed again a very strong correlation between the old and the new system with a score of 92.1%

G. The Effect of Institutional Environment on ICT Performance

The institutional environment is determined by the legal, regulatory, business and administrative framework within which individuals, firms, and governments interact to generate wealth. The quality of institutions has a strong bearing on competitiveness and growth. It influences investment decisions and the organization of production and plays a key role in the ways in which societies distribute the benefits and bear the costs of development strategies and policies.

The role of institutions goes beyond the legal framework. Government attitudes toward markets and freedoms and the efficiency of its operations are also very important: excessive bureaucracy and red tape, overregulation, corruption, dishonesty in dealing with public contracts, lack of transparency and trustworthiness, and political dependence of the judicial system impose significant economic costs to businesses and slow the process of economic development.

In order to verify if the quality of institutions would affect the performance of ICT, we added a new input to our BCC-O model. This input is the INSTITUTIONS indicator from the Global Competitiveness Report 2012 published by World Economic. Forum. This is a composed index that contains 21 indicators shown in Fig.16. Each country may score between 1 and 7 where 1 is the worst. Then we split countries into two groups based on INSTITUATIONS score: above average and below average where the average is 4.11. We assumed that countries with above average score have better quality of institutions.

A. Public institutions **75%**

1. Property rights 20%
   - 1.01 Property rights
   - 1.02 Intellectual property protection [1/2]

2. Ethics and corruption 20%
   - 1.03 Diversion of public funds
   - 1.04 Public trust of politicians
   - 1.05 Irregular payments and bribes

3. Undue influence 20%
   - 1.06 Judicial independence
   - 1.07 Favoritism in decisions of government officials

4. Government inefficiency 20%
   - 1.08 Wastefulness of government spending
   - 1.09 Burden of government regulation
   - 1.10 Efficiency of legal framework in settling disputes
   - 1.11 Efficiency of legal framework in challenging regulations
   - 1.12 Transparency of government policymaking

5. Security 20%
   - 1.13 Business costs of terrorism
   - 1.14 Business costs of crime and violence
   - 1.15 Organized crime
   - 1.16 Reliability of police services

B. Private institutions **25%**

1. Corporate ethics 50%
   - 1.17 Ethical behavior of firms

2. Accountability 50%
   - 1.18 Strength of auditing and reporting standards
   - 1.19 Efficacy of corporate boards
   - 1.20 Protection of minority shareholders' interests
   - 1.21 Strength of investor protection*

Fig. 16 Institutions Pillar

The average output efficiencies for the new and old models were calculated for both groups (Table12). The results were interesting. The countries with better institutions showed an increase in output efficiency by 2% on average while the second group showed a retraction of output efficiency by 2%. We can conclude that the advancement of ICT within a country might be hindered by the quality of its institutions.

Table 12 Output Efficiency Scores

	Above Average Institutions	Below Average Institutions
Old Score Average	0.74	0.41
New Score Average	0.76	0.39

Table 13 Countries with above average Institutions Index

DMU	Old Score	New Score	INSTITUTIONS	DMU	Old Score	New Score	INSTITUTIONS
Singapore	1.000	1.000	6.11	Chile	0.640	0.640	5.06
Sweden	1.000	1.000	6.06	Belgium	0.883	0.883	5.03
Finland	1.000	1.000	5.98	France	0.934	0.934	5
New Zealand	0.945	0.966	5.98	Estonia	0.833	0.833	4.99
Denmark	1.000	1.000	5.94	Malaysia	0.685	0.685	4.94
Switzerland	1.000	1.000	5.78	Botswana	0.145	0.145	4.87
Norway	1.000	1.000	5.74	Israel	0.772	0.772	4.81
Luxembourg	1.000	1.000	5.67	Brunei Darussalam	0.635	0.635	4.8
Hong Kong	1.000	1.000	5.63	Uruguay	0.574	0.574	4.8
Netherlands	1.000	1.000	5.61	Cyprus	0.642	0.642	4.76
Canada	0.911	0.911	5.57	Malta	0.023	0.801	4.69
Saudi Arabia	0.565	0.566	5.47	United States	1.000	1.000	4.64
Australia	0.941	0.941	5.39	Mauritius	0.056	0.431	4.54
Qatar	1.000	1.000	5.39	Namibia	0.231	0.231	4.5
United Kingdom	0.960	0.960	5.34	Jordan	0.427	0.427	4.38
Oman	0.634	0.634	5.33	South Africa	0.427	0.427	4.36
Bahrain	0.943	0.943	5.29	China	0.442	0.442	4.32
Barbados	0.764	0.765	5.29	Spain	0.757	0.757	4.27
Germany	0.908	0.908	5.27	Sri Lanka	0.192	0.192	4.23
Austria	0.850	0.850	5.24	Portugal	0.667	0.667	4.2
UAE	1.000	1.000	5.21	Poland	0.680	0.680	4.17
Ireland	0.827	0.827	5.19	Costa Rica	0.496	0.496	4.13
Japan	1.000	1.000	5.18	Cape Verde	0.361	0.361	4.11
Iceland	1.000	1.000	5.16				

Table 14 Countries with below average Institutions Index

DMU	Old Score	New Score	INSTITUTIONS	DMU	Old Score	New Score	INSTITUTIONS
Slovenia	0.744	0.744	4.08	Greece	0.655	0.655	3.52
Malawi	0.046	0.046	4.05	Uganda	0.153	0.153	3.5
Albania	0.570	0.570	4.01	Zimbabwe	0.238	0.238	3.5
Ethiopia	0.016	0.016	4	Romania	0.521	0.521	3.49
Morocco	0.232	0.573	3.98	Colombia	0.510	0.510	3.47
Georgia	0.474	0.474	3.97	Slovakia	0.833	0.833	3.46
Ghana	0.270	0.270	3.96	Mexico	0.431	0.400	3.44
Zambia	0.141	0.141	3.9	Mozambique	0.573	0.050	3.39
Korea	1.000	1.000	3.89	Moldova	0.400	0.482	3.38
Latvia	0.771	0.771	3.87	Mali	0.405	0.023	3.36
Thailand	0.276	0.276	3.85	Pakistan	0.104	0.104	3.36
Azerbaijan	0.568	0.568	3.84	Bosnia Herzegovina	0.681	0.681	3.32
India	0.131	0.131	3.84	Bulgaria	0.574	0.574	3.32
Indonesia	0.255	0.255	3.81	Bangladesh	0.066	0.066	3.31
Hungary	0.750	0.750	3.79	Lesotho	0.078	0.078	3.31
Iran	0.999	0.999	3.79	Nigeria	0.343	0.343	3.31
Egypt	0.459	0.459	3.78	Kenya	0.334	0.334	3.3
Panama	0.471	0.471	3.76	Lebanon	0.637	0.637	3.26
Swaziland	0.217	0.217	3.73	Philippines	0.377	0.377	3.22
Brazil	0.519	0.519	3.72	El Salvador	0.266	0.266	3.21
Senegal	0.200	0.200	3.7	Mongolia	0.482	0.232	3.21
Cambodia	0.059	0.059	3.69	Serbia	0.504	0.504	3.15
Turkey	0.470	0.470	3.69	Bolivia	0.356	0.356	3.14
Trinidad & Tobago	0.621	0.621	3.67	Mauritania	0.801	0.056	3.14
Armenia	0.408	0.408	3.65	Algeria	0.158	0.158	3.11
Czech	0.781	0.781	3.65	Dominican Rep.	0.469	0.469	3.11
Jamaica	0.484	0.484	3.63	Ecuador	0.366	0.366	3.11
Tanzania	0.136	0.136	3.63	Russian	0.572	0.572	3.08
Viet Nam	0.411	0.411	3.63	Nicaragua	0.141	0.141	3.06
Italy	0.610	0.610	3.61	Ukraine	0.351	0.351	2.98
Croatia	0.660	0.660	3.59	Paraguay	0.282	0.282	2.96
Suriname	0.365	0.365	3.59	Argentina	0.584	0.584	2.93
Benin	0.040	0.040	3.58	Madagascar	0.022	0.022	2.93
Burkina Faso	0.039	0.039	3.58	Côte d'Ivoire	0.025	0.025	2.87
Guyana	0.357	0.357	3.55	Yemen	0.181	0.181	2.58
Kazakhstan	0.561	0.561	3.54	Venezuela	1.000	1.000	2.42
Peru	0.398	0.398	3.54				

CHAPTER VI

CONCLUSION

In this project we presented a new system to evaluate the performance of ICT sectors worldwide. The new system is DEA-based that uses the efficiency frontiers approach rather than the classical statistical and econometric based approach. DEA does not require the a priori specification of the functional form; and generates data-driven weights that allow for the generation of a relative aggregate efficiency score for each country.

This new ICT evaluation system was able to enlighten us about the impact of applied regulatory policies on the performance of an ICT sector. Moreover, we were able to identify the benchmark for best practice performance for Lebanon ICT sector which can lead the country's policymakers to determine improvement targets. In addition, the DEA-based system was able to provide a monitoring tool to measure the impact of regulatory policies among other measures and their changes over time.

The ITU evaluation system, the IDI, doesn't include price of services but rather have it in a separate index. Our new DEA-based evaluation system embeds and integrates price in the performance evaluation as we consider the price of ICT services is an integral part of ICT access. Technically, we have merged the indicators of both ITU indexes (IDI & IPB) into one DEA-based model to evaluate ICT performance.

Our results came in line with the ITU MIS report for 2012 with a 92% correlation. Lebanon has ranked in the 51st place in both systems showing a dynamic

performance between 2011 and 2012. The advantages of the new DEA-based evaluation system are the insights that we could tell about sources of inefficiencies and targets of improvement that the old system cannot tell. Some countries had major differences in their rankings and scores between the old and the new system; this is a call for future research which might enlighten us about new insights regarding the differences between the two models.

We were able to identify two role model countries for Lebanon's ICT: Iceland for output oriented performance and Korea for input oriented performance. Sources of input inefficiencies come from the higher prices of Fixed-Telephone by 71.4% than Korea, Mobile by 85.2% and Broadband by 30.4%. Lebanon's performance on the output performance frontier shows that the cause of its inefficiency comes from the lower usage of internet by 56.86% than Iceland, fixed-broadband by 194.87% and wireless (mobile)-broadband by 180.08%. Finally, we showed that the advancement of ICT within a country might be hindered by the quality of its institutions. Future research can re-run the same model based on different income levels and/or geographic locations, thus identifying different role model countries and targets of improvement.

There are important policy implications that can be drawn from our observed results to help policymakers craft effective ICT policies. Governments can use the results to **identify** their positions in the global and regional ICT, **realize** their strengths and weaknesses, and **take** the right measures to boost their productive capacity and ICT use.

APPENDIX I

OUTPUT ORIENTED EFFICIENCY

DMU	2012	2011	2010	2008	DMU	2012	2011	2010	2008
Albania	0.57	0.52	0.47	0.26	Costa Rica	0.50	0.44	0.38	0.36
Algeria	0.16	0.15	0.13	0.13	Côte d'Ivoire	0.02	0.02	0.02	0.04
Angola	0.18			0.03	Croatia	0.66	0.74	0.63	0.58
Antigua & Barbuda	0.87	0.86	0.84		Cuba	1.00	1.00	1.00	
Argentina	0.58	0.50	0.42	0.31	Cyprus	0.64	0.62	0.58	0.47
Armenia	0.41			0.07	Czech	0.78	0.77	0.73	0.66
Australia	0.90	0.84	0.80	0.94	Denmark	1.00	1.00	1.00	1.00
Austria	0.85	0.86	0.80	0.84	Djibouti	0.09	0.07	0.07	
Azerbaijan	0.57	0.53	0.48	0.31	Dominican Rep.	0.47	0.37	0.33	0.24
Bahrain	0.94	0.92	0.75	0.69	Ecuador	0.37	0.33	0.31	0.33
Bangladesh	0.07			0.00	Egypt	0.46	0.37	0.32	0.19
Barbados	0.76	0.76	0.74		El Salvador	0.27	0.19	0.17	0.12
Belarus	1.00	0.71	0.61		Eritrea	0.01	0.07		
Belgium	0.88	0.89	0.89	0.78	Estonia	0.83	0.81	0.78	0.74
Benin	0.04	0.04	0.03	0.02	Ethiopia	0.02	0.01	0.01	0.00
Bhutan	0.26	0.22	0.14	0.07	Fiji	0.35	0.29	0.21	0.13
Bolivia	0.36	0.32	0.24	0.12	Finland	1.00	1.00	1.00	1.00
Bosnia and Herzegovina	0.68	0.63	0.55	0.38	France	0.93	0.93	0.89	0.77
Botswana	0.13	0.07	0.06	0.07	Gabon	0.09			
Brazil	0.52	0.47	0.43	0.42	Georgia	0.47		0.29	0.27
Brunei Darussalam	0.63	0.59	0.59		Germany	0.91	0.89	0.88	0.86
Bulgaria	0.57	0.54	0.49	0.40	Ghana	0.20	0.18	0.13	0.05
Burkina Faso	0.04	0.03	0.03	0.01	Greece	0.66	0.65	0.64	0.76
Cambodia	0.05	0.03	0.01	0.01	Guyana	0.36	0.34	0.31	
Canada	0.91	0.88	0.88	0.92	Hong Kong	1.00	1.00	1.00	1.00
Cape Verde	0.36	0.34	0.32	0.23	Hungary	0.75	0.63	0.57	0.66
Chile	0.64	0.57	0.47		Iceland	1.00	1.00	1.00	1.00
China	0.44	0.40	0.36	0.25	India	0.13	0.11	0.08	
Colombia	0.51	0.43	0.38	0.43	Indonesia	0.19	0.21	0.15	0.09
Congo Dem Rep	0.02				Iran	1.00			1.00

DMU	2012	2011	2010	2008	DMU	2012	2011	2010	2008
Ireland	0.83	0.82	0.79	0.73	Poland	0.68	0.69	0.68	0.55
Israel	0.77	1.00	0.99		Portugal	0.67	0.59	0.55	0.54
Italy	0.61	0.61	0.59	0.80	Qatar	1.00	1.00	1.00	
Jamaica	0.48	0.33	0.29	0.63	Romania	0.52		0.42	0.35
Japan	0.88	0.92	0.94	1.00	Russia	0.57	0.54	0.47	0.35
Jordan	0.43	0.37	0.29	0.29	Saudi Arabia	0.57		0.43	0.35
Kazakhstan	0.56	0.51	0.36		Senegal	0.20	0.18	0.17	0.09
Kenya	0.33	0.29	0.15	0.10	Serbia	0.50	0.45	0.43	0.38
Korea	1.00	1.00	1.00	1.00	Seychelles	0.49	0.45	0.43	0.45
Latvia	0.77	0.75	0.72	0.67	Singapore	1.00	1.00	1.00	1.00
Lebanon	0.64	0.55	0.46	0.25	Slovakia	0.83	0.78	0.80	0.74
Lesotho	0.06				Slovenia	0.74	0.77	0.79	0.67
Luxembourg	1.00	1.00	1.00	1.00	Solomon Islands	0.07			
Macao	1.00	1.00	1.00	0.80	South Africa	0.43	0.23	0.20	0.10
Macedonia	0.66			0.46	Spain	0.76	0.72	0.69	0.69
Madagascar	0.02	0.02	0.02	0.02	Sri Lanka	0.19	0.16	0.13	0.07
Malawi	0.05				St. Vincent	0.49			
Malaysia	0.69	0.64	0.59	0.62	Sudan	0.22			
Maldives	0.41	0.36	0.30	0.26	Suriname	0.37			
Mali	0.02	0.02	0.02	0.02	Swaziland	0.22	0.19	0.12	0.08
Malta	0.80	0.77	0.74	0.60	Sweden	1.00	1.00	1.00	1.00
Mauritania	0.06	0.05	0.04	0.03	Switzerland	1.00	1.00	1.00	1.00
Mauritius	0.43	0.37	0.30	0.25	Tanzania	0.14	0.13	0.12	0.01
Mexico	0.40	0.38	0.33	0.24	Thailand	0.28	0.25	0.24	0.26
Moldova	0.48	0.40	0.34	0.26	Trinidad & Tobago	0.62	0.58	0.51	0.21
Mongolia	0.19				Tunisia	0.43	0.41	0.39	0.30
Morocco	0.57	0.54	0.52	0.37	Turkey	0.47	0.44	0.42	
Mozambique	0.05	0.05	0.04	0.02	Uganda	0.15	0.14	0.13	0.09
Namibia	0.16	0.13	0.12	0.06	Ukraine	0.35	0.32	0.25	0.12
Netherlands	1.00	1.00	1.00	0.98	United Arab Emirates	1.00	1.00	1.00	1.00
New Zealand	0.95	0.92	0.89	0.87	United Kingdom	0.96	0.95	0.86	0.87
Nicaragua	0.14	0.11	0.11	0.04	United States	1.00	1.00	1.00	1.00
Nigeria	0.34	0.30	0.25	0.18	Uruguay	0.57	0.54	0.49	0.44
Norway	1.00	1.00	1.00	0.99	Uzbekistan	0.38	0.32	0.22	
Oman	0.63	0.72	0.65	0.23	Venezuela	0.67	1.00	1.00	0.29
Pakistan	0.10	0.09	0.08	0.12	Vietnam	0.41	0.37	0.32	0.26
Panama	0.47	0.45	0.42	0.30	Yemen	0.18	0.16	0.13	0.02
Paraguay	0.28	0.25	0.21	0.16	Zambia	0.14	0.12	0.11	0.06
Peru	0.40	0.38	0.37	0.27	Zimbabwe	0.20	0.17	0.12	

APPENDIX II

INPUT ORIENTED EFFICIENCY

DMU	2012	2011	2010	2008	DMU	2012	2011	2010	2008
Albania	0.78	0.78	0.69	0.72	Cyprus	0.84	0.85	0.83	0.85
Algeria	0.69	0.69	0.64	0.62	Czech	0.86	0.86	0.89	0.86
Angola	0.36			0.31	Denmark	1.00	1.00	1.00	1.00
Antigua & Barbuda	0.79	0.79	0.77		Djibouti	0.40	0.39	0.36	
Argentina	0.89	0.89	0.85	0.85	Dominican Rep.	0.68	0.68	0.67	0.67
Armenia	0.81			0.80	Ecuador	0.74	0.74	0.70	0.70
Australia	0.94	0.95	0.94	0.97	Egypt	0.59	0.58	0.59	0.59
Austria	0.96	0.96	0.91	0.90	El Salvador	0.60	0.60	0.58	0.58
Azerbaijan	0.74	0.74	0.73	0.72	Eritrea	0.35	0.35	0.89	
Bahrain	0.89	0.95	0.99	0.96	Estonia	0.89	0.89		0.89
Bangladesh	0.42			0.36	Ethiopia	0.28	0.28	0.23	0.23
Barbados	0.88	0.88	0.84		Fiji	0.84	0.84	0.64	0.65
Belarus	1.00	0.99	0.97		Finland	1.00	1.00	1.00	1.00
Belgium	0.96	0.97	0.97	0.92	France	0.96	0.94	0.91	0.90
Benin	0.31	0.31	0.30	0.30	Gabon	0.52			
Bhutan	0.46	0.44	0.41	0.39	Georgia	0.73		0.76	0.76
Bolivia	0.71	0.71	0.70	0.71	Germany	0.95	0.95	0.94	0.97
Bosnia and Herzegovina	0.76	0.76	0.76	0.75	Ghana	0.48	0.48	0.45	0.43
Botswana	0.59	0.59	0.59	0.59	Greece	0.97	0.98	0.99	0.99
Brazil	0.73	0.73	0.77	0.76	Guyana	0.64	0.64	0.71	
Brunei Darussalam	0.78	0.80	0.81		Hong Kong	1.00	1.00	1.00	1.00
Bulgaria	0.82	0.82	0.82	0.81	Hungary	0.87	0.87	0.91	0.89
Burkina Faso	0.21	0.20	0.20	0.19	Iceland	1.00	1.00	1.00	1.00
Cambodia	0.45	0.45	0.44	0.42	India	0.49	0.49	0.47	
Canada	0.93	0.95	0.95	0.96	Indonesia	0.67	0.67	0.66	0.64
Cape Verde	0.66	0.66	0.61	0.61	Iran	1.00			1.00
Chile	0.88	0.88	0.84		Ireland	0.93	0.93	0.91	0.91
China	0.69	0.69	0.66	0.66	Israel	0.90	1.00	1.00	
Colombia	0.79	0.79	0.76	0.74	Italy	0.91	0.92	0.92	0.94
Congo Dem Rep	0.39				Jamaica	0.69	0.69	0.68	0.69
Costa Rica	0.81	0.81	0.74	0.72	Japan	0.95	0.95	0.95	1.00
Côte d'Ivoire	0.32	0.32	0.32	0.31	Jordan	0.75	0.75	0.76	0.75
Croatia	0.84	0.84	0.85	0.83	Kazakhstan	0.82	0.83	0.84	0.51
Cuba	1.00	1.00	1.00		Kenya	0.46	0.46	0.51	1.00

DMU	2012	2011	2010	2008	DMU	2012	2011	2010	2008
Korea	1.00	1.00	1.00	0.44	Russia	0.90	0.90	0.90	0.89
Latvia	0.86	0.86	0.90	0.91	Saudi Arabia	0.80		0.75	0.73
Lebanon	0.78	0.78	0.76	0.76	Senegal	0.34	0.34	0.31	0.27
Lesotho	0.43				Serbia	0.81	0.81	0.80	0.81
Luxembourg	1.00	1.00	1.00	1.00	Seychelles	0.70	0.66	0.65	0.66
Macao	1.00	1.00	1.00	0.94	Singapore	1.00	1.00	1.00	1.00
Macedonia	0.74			0.75	Slovakia	0.82	0.82	0.86	0.83
Madagascar	0.34	0.34	0.34	0.33	Slovenia	0.96	0.96	0.99	0.96
Malawi	0.33				Solomon Islands	0.49			
Malaysia	0.71	0.70	0.66	0.67	South Africa	0.68	0.68	0.67	0.67
Maldives	0.70	0.69	0.66	0.63	Spain	0.95	0.95	0.91	0.91
Mali	0.28	0.27	0.24	0.23	Sri Lanka	0.70	0.70	0.62	0.62
Malta	0.91	0.91	0.86	0.84	St Vincent	0.74			
Mauritania	0.31	0.31	0.29	0.29	Sudan	0.39			
Mauritius	0.72	0.72	0.69	0.69	Suriname	0.67			
Mexico	0.72	0.72	0.72	0.71	Swaziland	0.52	0.52	0.50	0.49
Moldova	0.83	0.76	0.76	0.77	Sweden	1.00	1.00	1.00	1.00
Mongolia	0.83			0.73	Switzerland	1.00	1.00	1.00	1.00
Morocco	0.54	0.52	0.46	0.42	Tanzania	0.36	0.34	0.34	0.34
Mozambique	0.27	0.28	0.28	0.27	Thailand	0.74	0.74	0.73	0.72
Namibia	0.51	0.51	0.55	0.56	Trinidad & Tobago	0.71	0.71	0.71	0.70
Netherlands	1.00	1.00	1.00	0.98	Tunisia	0.71	0.70	0.70	0.69
New Zealand	0.96	0.95	0.95	0.94	Turkey	0.79	0.78	0.73	
Nicaragua	0.56	0.56	0.56	0.56	Uganda	0.37	0.37	0.35	0.34
Nigeria	0.36	0.36	0.34	0.35	Ukraine	0.93	0.93	0.95	0.93
Norway	1.00	1.00	1.00	1.00	United Arab Emirates	1.00	1.00	1.00	1.00
Oman	0.73	0.73	0.69	0.69	United Kingdom	0.99	0.99	0.95	0.95
Pakistan	0.33	0.33	0.32	0.32	United States	1.00	1.00	1.00	1.00
Panama	0.72	0.72	0.71	0.71	Uruguay	0.85	0.85	0.87	0.85
Paraguay	0.66	0.66	0.65	0.64	Uzbekistan	0.70	0.70	0.70	
Peru	0.76	0.76	0.73	0.73	Venezuela	0.99	1.00	1.00	0.87
Philippines	0.70	0.70	0.69	0.70	Viet Nam	0.66	0.66	0.58	0.58
Poland	0.91	0.91	0.92	0.91	Yemen	0.41	0.41	0.40	0.40
Portugal	0.88	0.88	0.87	0.87	Zambia	0.37	0.37	0.40	0.41
Qatar	1.00	1.00	1.00		Zimbabwe	0.44	0.44	0.46	
Romania	0.86		0.87	0.87					

BIOGRAPHY

Charnes, Cooper, W, and Rhodes, E., (1978). Measuring the efficiency of decision making units. *European Journal of Operation Research, 2(6): 429-444.*

D. Parker (1999). The Performance of BAA before and after Privatisation: A DEA Study. *Journal of Transport Economics and Policy, Vol. 33, No. 2 (May, 1999), pp. 133-145*

ESCWA. 2011a. Regional Profile of the Information Society in Western Asia, 2011. Available at http://isper.escwa.un.org/ISProfiles/RegionalProfiles/tabid/65/language/en-US/Default.aspx.

Giokas, D.I. and Pentzaropoulos, G.C. (2000), "Evaluating productive efficiency intelecommunications: evidence from Greece", *Telecommunications Policy, Vol. 24, pp. 781-94.*

Giokas, D.I. and Pentzaropoulos, G.C. (2008), "Efficiency ranking of the OECD member states in the area of telecommunications: a composite AHP/DEA study", *Telecommunications Policy, Vol. 32, pp. 672-85.*

ICT-UN-ESCWA (2013). Impact of e-services on socio-economic development in the Arab region, ICT Division, UN-ESCWA Report 2013, United Nations, New York, 2013.

ITU. 2009. Manual for measuring ICT access and use by households and individuals; 2009 Edition. Available at http://www.itu.int/ITU-D/ict/publications/hhmanual/2009/index.html

ITU. 2012a. ICT Adoption and Prospects in the Arab Region, 2012. Available at http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-AR-2012-PDF-E.pdf

ITU. 2012b. Measuring the Information Society, 2012. Available at http://www.itu.int/ITU-D/ict/publications/idi/index.html

ITU. 2012c. Impact of Broadband on the Economy. Broadband Series. April 2012. Available at http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-AR-2012-PDF-E.pdf

Lam, P.L. and Shiu, A. (2008), "Productivity analysis of the telecommunications sector in China",*Telecommunications Policy, Vol. 32, pp. 559-71*.

Majumdar, S.K. (1997), "Modularity and productivity assessing the impact of digital technology in the US telecommunications industry", *Technological Forecasting and Social Change,Vol. 56, pp. 61-75.*

M. Resende (2000). Regulatory Regimes and Efficiency in US Local Telephony. *Oxford Economic Papers, Vol. 52, No. 3 (Jul., 2000), pp. 447-470*

ESCWA, 2011b. Information Society Measurements: Building a Common Benchmarking Model for the ESCWA Region. 2011. Available at http://www.escwa.un.org/information/publication/edit/upload/E_ESCWA_ICTD_11_1_e.pdf

OECD. 2011. OECD Guide to Measuring the Information Society 2011. OECD Publishing. Available at http://browse.oecdbookshop.org/oecd/pdfs/free/9311021e.pdf

Partnership on Measuring ICT for Development (Partnership). 2010. ICT Core Indicators 2010. Available at http://www.itu.int/ITU-D/ict/partnership/index.html

Partnership. 2011a. Framework for a set of E-Government Indicators. Geneva. Available at http://www.itu.int/ITU-D/ict/partnership/index.html

Partnership. 2011b. Measuring the WSIS Targets: A statistical framework. Geneva. Available at http://www.itu.int/ITU-D/ict/partnership/index.html

Resende, M. (2008), "Efficiency measurement and regulation in US telecommunications:a robustness analysis", *International Journal of Production Economics, Vol. 114, pp. 205-18.*

Uri, N.D. (2001), "Changing productive efficiency in telecommunications in the United States", *International Journal of Production Economics, Vol. 72, pp. 121-37.*

Varoudakis, C.M. Rossotto (2002). Regulatory reform and performance in telecommunications: unrealized potential in the MENA countries. *Telecommunications Policy 28 (2004) 59–78*

World Bank's Independent Evaluation Group (IEG). 2011. Capturing Technology for Development: An Evaluation of World Bank Group Activities in Information and Communications Technologies. Available at http://ieg.worldbankgroup.org/content/ieg/en/home/reports/ict.html

Vagia Kyriakidou (2012). Assessment of information and communications technology maturity level 2012. *Telecommunications Policy37 (2013) 48–62*

World Economic Forum (2013). The Global Competitiveness Report 2012–2013. Available at http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf

World Economic Forum (2013). The Global Information Technology Report 2013. Available at http://www3.weforum.org/docs/WEF_GlobalInformationTechnology_Report_2013.pdf