Measuring the Impacts of Electricity System Deregulation in Developing Countries

Pieter Herbert Griffioen

UPV Master's Program: Energy Technology for Sustainable Development

UPV Supervisor: Avgerinopoulos, Georgios

UPV Tutor: Álvarez, Carlos

KTH Master's Program: Sustainable Energy Engineering

KTH Examiner: Howells, Mark

KTH Supervisor: Howells, Mark

Date: 07.07.2017

Acknowledgements

First of all, I would like to thank professor José Miguel Corberán Salvador, director of the IIE institute, for his patience with my lack of organizational skills and unfailing readiness to answer any questions I had.

I wish to express my sincere thanks to my supervisor at the Royal Institute of Technology, M. Sc. Georgios Avgerinopoulos, for contributing very constructive comments and ideas throughout the entire writing process. His excellent supervision and helpful suggestions have been very valuable for the quality of this thesis. I am also grateful to assistant professor Manuel Alcázar Ortega for taking the time to examine my research proposal and offer his supportive comments. I would also like to thank professor Carlos Álvarez for reading this thesis and being my official tutor at the Universitat Politècnica de València despite his busy schedule.

At this point, I would like to thank my parents for their wise discipline, unceasing encouragement and unfailing love. Without their upbringing, I would never have reached where I am now. Accompanying me throughout most of my Master's degree and especially during my stay in Stockholm were Stefan and Ingrid Haus, faithful friends who taught me how to persevere in times of stress and focus on life's important matters. Furthermore, I would like to thank Hendrik Schaldach, without whom the long working hours would have been much more tedious and a lot less fun. Moreover, I am grateful to my fiancée, Elodie Francart, who showed me that there are more important things to life than writing a thesis and is the reason for the stressful yet joyful time towards the end. Further thanks goes to my beloved brother and friend, Daniel Griffioen, who proofread and edited the final version of this thesis: Thank you!

Last and most importantly, I want to take the opportunity to thank God for the mental capabilities and good health he has blessed me with and were necessary to complete my Master's degree concluding with this thesis.

Abstract

This thesis is concerned with analyzing the impacts of electricity system deregulation in developing countries. A heterogenous group of countries i.e. Turkey, Chile, India, Ghana and Iran are chosen as case-studies whereas the Sectoral Indicator of Regulatory Reform: Electricity (SIRRE) methodology provided by the OECD is selected to quantify deregulation and calculate the sub-indicators. Furthermore, seven impact indicators are defined, namely, the Shannon's diversity index, energy intensity, energy use, electric power T&D losses, access to electricity and the corruption perception index. Using multiple linear regression, the impacts of the SIRRE sub-indicators on the impact parameters are calculated and statistical significance is (dis)proven. In the second phase of the methodology, control variables are added to increase the robustness of the results and render them more realistic. Finally, the obtained results are first separately discussed for each country before they are compared for all analyzed countries to derive universally applicable conclusions and policy recommendations for all developing countries. This thesis found that deregulating the electricity sector of a developing country decreases its energy intensity and electric T&D losses while at the same time increases its electrification rate. Electricity sector reforms are therefore suggested as a method for combatting problems inherent in many developing countries such as frequent blackouts, insufficient funds for capacity expansions and high T&D as well as non-technical losses.

Keywords: Deregulation impacts, Energy sector, Electricity reforms, Developing countries, Sectoral Indicator of Regulatory Reform: Electricity, Multiple Linear Regression

Resumen

Esta tesis trata de analizar los impactos de la desregulación del sistema eléctrico en los países en desarrollo. Un grupo heterogéneo de países, en concreto, Turquía, Chile, India, Ghana e Irán, han sido seleccionados como casos de estudio representativos, y se ha escogido la metodología de Indicador Sectorial de Reforma Regulatoria: Electricidad (SIRRE), proporcionada por la OCDE, para cuantificar la desregulación y calcular los subindicadores. Adicionalmente, se definen siete indicadores de impacto, a saber, el índice de diversidad de Shannon, la intensidad energética, el uso de energía, las pérdidas de T y D de energía eléctrica, el acceso a la electricidad y el índice de percepción de corrupción. Mediante la regresión lineal múltiple, se calculan los impactos de los subindicadores SIRRE sobre los parámetros de impacto y se demuestra la significación estadística. En la segunda fase de la metodología se agregan variables de control para aumentar la robustez de los resultados y hacerlos más realistas. Por último, los resultados obtenidos se discuten primero por separado para cada país antes de que se comparen para todos los países analizados para obtener conclusiones y recomendaciones de política universalmente aplicables para todos los países en desarrollo. Esta tesis concluye que la desregulación del sector eléctrico de un país en desarrollo disminuye su intensidad energética y las pérdidas eléctricas de T y D, al tiempo que aumenta su tasa de electrificación. Por consiguiente, se sugieren reformas del sector eléctrico como un método para combatir los problemas inherentes a muchos países en desarrollo, como los frecuentes apagones, la insuficiencia de fondos para el aumento de la capacidad y las elevadas pérdidas de T y D, así como las pérdidas no técnicas.

Palabras clave: Impacto de la desregulación, Sector energético, Reforma del Sector eléctrico, Países en vías de desarrollo, Indicador Sectorial de la Reforma Regulatoria: Electricidad, Regresión lineal múltiple.

Sammanfattning

Denna examensarbete handlar om att analysera effekterna av avreglering av elsystem i utvecklingsländer. En heterogen grupp av länder, Turkiet, Chile, Indien, Ghana och Iran, väljs som fallstudier, medan den Sektorindikator för regelreformer: El (SIRRE) -metod som tillhandahålls av OECD väljs för att kvantifiera avreglering och beräkna delindikatorerna. Dessutom definieras sju effektindikatorer, nämligen Shannon diversitetsindex, energiintensitet, energianvändning, Elöverföring och distributionsförluster, eltillgång och korruptionsperspektivindex. Genom att använda multipel linjär regression beräknas effekterna av SIRRE-delindikatorerna på effektparametrarna och statistisk signifikans (dis)bevisas. I metodens andra fas läggs kontrollvariabler till för att öka resultatenes robusthet och göra dem mer realistiska. Slutligen diskuteras de erhållna resultaten först separat för varje land innan de jämförs för alla analyserade länder för att ta fram allmänt tillämpliga slutsatser och politiska rekommendationer för alla utvecklingsländer. Avhandlingen konstaterade att avreglering av el-sektorn i ett utvecklingsland minskar sin energiintensitet och elöverföring och distributionsförluster samtidigt som den ökar sin elektrifieringsgrad. Reformerna inom elsektorn föreslås därför som en metod för att bekämpa problem som är inneboende i många utvecklingsländer, som frekvent strömavbrott, otillräckliga finansiella medel för kapacitetsutökningar och höga elöverföring och distributionsförluster såväl som icke-tekniska förluster.

Nyckelord: Dereguleringspåverkan, Energisektorn, Elreformer, Utvecklingsländer, Sektorindikator för regelreformer: El, Multipla linjär regression

Resum

Esta tesi tracta d'analitzar els impactes de la desregulació del sistema elèctric en els països en desenvolupament. Un grup heterogeni de països, en concret, Turquia, Xile, Índia, Ghana i Iran, han sigut seleccionats com a casos d'estudi representatius, i s'ha triat la metodologia d'Indicador Sectorial de Reforma Reguladora: Electricitat (SIRRE) , proporcionada per l'OCDE, per a quantificar la desregulació i calcular els subindicadors. Addicionalment, es definixen set indicadors d'impacte, a saber, l'índex de diversitat de Shannon, la intensitat energètica, l'ús d'energia, les pèrdues de T'i D d'energia elèctrica, l'accés a l'electricitat i l'índex de percepció de corrupció. Per mitjà de la regressió lineal múltiple, es calculen els impactes dels subindicadors SIRRE sobre els paràmetres d'impacte i es demostra la significació estadística. En la segona fase de la metodologia s'agreguen variables de control per a augmentar la robustesa i fer-los més realistes. Finalment, els resultats obtinguts es discutixen primer per separat per a cada país abans de que es comparen per a tots els països analitzats per a obtindre conclusions i recomanacions de política universalment aplicables per a tots els països en desenvolupament. Esta tesi conclou que la desregulació del sector elèctric d'un país en desenvolupament disminuïx la seua intensitat energètica i les pèrdues elèctriques de T'i D, alhora que augmenta la seua taxa d'electrificació. Per consegüent, se suggerixen reformes del sector elèctric com un mètode per a combatre els problemes inherents a molts països en desenvolupament com les freqüents apagades, la insuficiència de fons per a l'augment de la capacitat i les elevades pèrdues de T'i D, així com les pèrdues no tècniques.

Paraules clau: Impacte de la desregulació, Sector energètic, Reforma del Sector elèctric, Països en via de desenvolupament, Indicador Sectorial de la Reforma Reguladora: Electricitat, Regressió lineal múltiple.

Table of Contents

Abstract....3
Resumen....3
Sammanfattning....4
Resum....4
1 List of Abbreviations....7
2 Introduction....9
2.1 Background....10
2.2 Objectives....11
2.3 Motivation....12
2.4 Scope and Thesis Limitations....13
2.5 Organization of Thesis....15
3 Literature Review....16
4 Methodology....19
4.1 Sectoral Indicator of Regulatory Reform: Electricity....19
4.2 Impact Indicators....22
4.2.1 Shannon's (Energy) Diversity Index....22
4.2.2 Energy Intensity....23
4.2.3 Energy Use....23
4.2.4 Net Energy Imports....24
4.2.5 Electric Power Transmission and Distribution Losses....24
4.2.6 Access to Electricity....25
4.2.7 Corruption Perception Index....26
4.3 Control Variables....27
4.4 Multiple Linear Regression and Econometrics....29
4.5 Country Choice Defense....31
5 Case Studies....33
5.1 Turkey....33
5.1.1 Brief Country Description and Electricity System History....33
5.1.2 Indicator Analysis and Results....34
5.1.3 Derived New Knowledge and Discussion of Results....41
5.2 Chile....43
5.2.1 Brief Country Description and Electricity System History....43
5.2.2 Indicator Analysis and Results....44
5.2.3 Derived New Knowledge and Discussion of Results....51
5.3 India....53
5.3.1 Brief Country Description and Electricity System History....53

5.3.2 Indicator Analysis and Results 54
5.3.3 Derived New Knowledge and Discussion of Results 63
5.4 Ghana 65
5.4.1 Brief Country Description and Electricity System History 65
5.4.2 Indicator Analysis and Results 66
5.4.3 Derived New Knowledge and Discussion of Results 75
5.5 Iran 78
5.5.1 Brief Country Description and Electricity System History 78
5.5.2 Indicator Analysis and Results 79
5.5.3 Derived New Knowledge and Discussion of Results 87
6 Comparison and Discussion of Results 90
7 Conclusion and Recommendations 95
8 Outlook and Suggested Future Work 98
9 Appendix A: Impact Indicators 100
10 Appendix B: Control Variables 105
11 List of Figures 110
12 List of Tables 111
13 List of Equations 113
Bibliography 114

1 List of Abbreviations

BOO	Build Operate Transfer
BOT	Build-Own-Operate
CEA	Central Electricity Authority
CELAC	Community of Latin American and Caribbean States
CNE	Comisión Nacional de Energía
DES	Deregulation of the Electricity Sector
EC	Energy Commission
ECG	Electricity Corporation of Ghana
EDL	Electricité Du Liban
e.g.	for example (Latin: exempli gratia)
ENDESA	Empresa Nacional de Electricidad S.A.
EPDK	Enerji Piyasası Düzenleme Kurumu
et al.	and others (Latin: et alia)
ETCR	Regulation in Energy, Transportation and Communications
EUAS	Elektrik Üretim A.Ş.
GDP	Gross Domestic Product
GridCo	Ghana Grid Company
GWh	Gigawatt-hour
HDI	Human Development Index
i.e.	that is (Latin: id est)
IEA	International Energy Agency
IGMC	Iran Grid Management Company
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt-hour
MENA	Middle East and North Africa
MOSES	Model of Short-term Energy Security
MW	Megawatt
NED	Northern Electricity Department
NEDCo	Northern Electricity Distribution Company
NMR	Regulation in Non-Manufacturing sectors
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries

PPP	Purchasing Power Parity
PSRP	Power Sector Reform Programme
PURC	Public Utilities Regulatory Commission
PV	photovoltaic
REC	Regional Electricity Company
RPO	Renewable Power Obligation
R&D	Research and Development
SDI	Shannon Diversity Index
SEBs	State Electricity Boards
SEC	Superintendencia de Electricidad y Combustibles
SERC	State Electricity Regulatory Commission
SIC	Sistema Interconectado Central
SING	Sistema Interconectado del Norte Grande
SIRRE	Sectoral Indicator of Regulatory Reform: Electricity
TEIAS	Türkiye Elektrik İletim A.Ş.
TETAS	Türkiye Elektrik Ticaret ve Taahhüt A.Ş.
TOOR	Transfer of Operating Rights
TPES	Total Primary Energy Supply
T&D	Transmission and Distribution
UNASUR	Union of South American Nations
VRA	Volta River Authority

2 Introduction

How many Lebanese does it take to change a lightbulb? No one cares, there's no electricity anyway! The painful truth of this joke is the motivation behind this thesis.

An electricity system is the sum of all components, actors, utilities and networks that work together for the purpose of supplying customers with generated or imported power through a transmission and distribution electrical grid. An electrical system has many unique characteristics when compared to other national systems. Some of these special features include the non-storability of electricity, the need to balance the frequency equilibrium over a wide range of geographic locations, physical transmission constraints and the difference between the ramp-up rate and synchronization time, which all contribute to the difficulty of deregulation and the establishment of electricity markets in this sector [1].

In developing countries, the lack of reliable electricity is often a stumbling block on the path to increasing human development and economic growth. In many countries, the electricity system is entirely owned and regulated by the government, either directly through a ministry or through a wholly state-owned company. Due to the public ownership of the electricity system, the often high ensuing public debt and the lack of financial resources, the operation, maintenance and expansion of the system infrastructure is often a heavy burden on the government. This frequently leads to the failure of the electricity system, which manifests itself through blackouts, incapability of installing new capacity and high amounts of T&D and non-technical losses. [2]

What is meant with the term "deregulation"? This is no trivial question and is answered differently throughout the studied literature. It could mean the implementation of a market design that transforms an electricity sector dominated by regulated, vertically integrated and state-owned utilities into one that relies on competition to deliver generated power and retail services [3]. Similarly, deregulation is defined as the transition process from model 1, i.e. a regulated natural monopoly, to model 4, which includes competition in the wholesale and retail markets [2]. A similar definition is implied by the authors of the OECD methodology [4], in which they state that deregulation is the removal of badly designed regulation in product markets and the reduction of state involvement in business sectors, thereby making it easier for entrepreneurs to create and expand firms and facilitating the entry of foreign products and firms. It is noteworthy that these authors state that deregulation does not necessarily mean an absolute lack of control or so called "laissez faire" through the total abolishment of all restrictions or regulations, but could simply mean replacing them with better designed legislation to enhance competition. On the other hand, electricity sector specific deregulation is limited to the competitive wholesale market and retail segments, while structural, regulatory and market design reforms are excluded from the definition [5]. It is explicitly stated, that the term "deregulation" cannot simply characterize the attributes of the most successful electricity sector reforms, which are the privatization of state-owned enterprises, vertical and horizontal restructuring to facilitate competition and mitigate potential self-dealing and cross-subsidization problems, good wholesale market designs that allow efficient competition and entry of generators and at least for industrial customers retail competition [5].

For this thesis, the definition of deregulation is directly linked to the methodology adopted for quantifying it, where "deregulation" refers to the transition process from a score of 6 to a score of 0 for the different SIRRE sub-indicators.[1] Firstly for entry regulation, deregulation involves increasing third-party access to the electricity transmission grid, establishing a liberalized wholesale electricity market and decreasing minimum consumption thresholds for customers to be able to choose their electricity supplier. Secondly, deregulation involves privatization through the decrease of market shares owned by the government in the largest firm in the electricity sector segment[2] and thereby transferring power and management responsibilities into private hands. Furthermore, deregulation is the transitory process of vertical separation of the electricity

[1] The SIRRE sub-indicators include entry regulation, public ownership, vertical integration and market structure.
[2] The electricity sector segments include generation, transmission, distribution and supply. Sometimes import is included as an electricity sector segment.

sector segments from not existing, to accounting separation, to legal separation and finally to ownership separation. Lastly, deregulation involves decreasing the market share of the largest company in generation, import and supply of electricity. However, no electricity system can be fully deregulated, but most are found between the two extremes of full regulation and complete deregulation, which is why a scale must be used to measure how regulated or deregulated an electricity system is.

By looking at past experiences of countries that have deregulated their electricity sectors, it is clear that the reforms can have big impacts on the energy sector, economy, society and future policies of the country. Caution must be taken and lessons learned from the bad examples, while the good examples pave the way for other deregulation reforms. Deregulation of economic sectors and privatization in general are established methods for combatting inefficiencies inherent in developing country government bodies that could contain certain undesired effects. The deregulation of the electricity sector is no exception, but is vital for further development and the alleviation of the numerous problems plaguing the electricity sector of developing countries explained above, but have the potential to mask unforeseen problems.

All of the above leads to the conclusion that a quantitative analysis of the impacts electricity sector deregulation have is imperative. A distinction is needed for observed effects that are simply due to the general development of the country and effects that are caused by the introduced reforms. The discussion of the results in such an analysis contains two types of information: warnings of undesired impacts of deregulation on the one hand and possible potential positive impacts on the other. Both are important for offering high-quality advice and making recommendations to key policy makers in order for them to make discerning decisions depending on the priorities of their country's agenda. Although perfect competition and an entirely deregulated electricity market are impossible, policy makers should do their best in this imperfect world [5].

2.1 Background

Electricity has ceased being a luxury good available for a lucky few, but has become an existential part of our lives, key to providing necessary human healthcare as well as economic growth. On the other hand, the lack of access to electricity has severe negative effects on the education, wealth and most importantly health of the affected population. The world electrification rate may be increasing, but it must still be accelerated by all possible means. The deregulation of the electricity sector is thought to do this.

Although electricity sector reforms have been strongly promoted by the World Bank and subsidized with financial resources, many policy makers of developing countries are still hesitant about introducing reforms in their own country. Furthermore, despite the fact that sector reforms were proven to be successful in several countries since they were first introduced in Chile in 1982, there are other examples, such as the deregulation of California in the early 2000's, that show fiascos devastating for the energy system as well as for the economy. They show that the deregulation of the electricity sector cannot be successful if the policy makers simply want the World Bank's financial resources. Political determination is key to successful enforcement of the reforms in the form of passed regulations or law amendments.

Many electricity systems in developing countries are in poor shape and in dire need of restructuring due to the plethora of existing problems. An example the author would like to draw attention to is the Colombian electricity system. Prior to the country's electricity sector deregulation, Colombia was plagued by a series of brownouts and blackouts that resulted in significant GDP losses. The relationship between electricity cuts and GDP loss was significant, seeing as even a very small outage can have severe effects on the economy. Even the uncertainty of a power outage creates the necessity of back-up generation units that are expensive in operation and maintenance even if they are not operated regularly. Furthermore, the state-owned vertically integrated power utility was unable to finance new capacity installations. Finally, the inefficiency of the system as well as the high non-technical losses aggravated the situation of the Colombian electricity system. For the case of Colombia and many others, deregulation of the sector was the solution to many of the system's problems. [6]

Turkey, Chile, India, Ghana and Iran have all started deregulating their electricity sector with various degrees of success. Each deregulation process is unique and new knowledge can be obtained from analyzing it. Turkey is a regional power today, starting electricity sector reforms in the early 2000's and enforcing the restructure of the sector arguably successfully. The SIRRE sub-indicators do not show a linear behavior, making the analysis of the Turkish power sector fascinating.

As for Chile, it is the show-off country when it comes to electricity reforms, since it was the first country to deregulate and has had considerable success in the process. Today, it is considered to have one of the most deregulated energy systems in the world. Chile leads South America in terms of human development, GDP/capita and democratic rule as well as other development indicators.

India is characterized by its mammoth population and therefore huge electricity system that is impossible to manage with one company. Even before sector reforms, this responsibility was held by regional electricity companies. The country's increasing human development and growing economy have led to a significant increase in energy demand that is satisfied by an increasingly diverse fuel mix and energy imports. India has the highest population of unelectrified households and one of the most inefficient T&D grids in the world. It is no wonder that access to electricity and a decrease in energy intensity are main priorities on the minds of Indian policy makers.

Up until the late 1990's, Ghana relied solely on hydropower to satisfy the electricity demand of the population. With increased electric consumption per capita and electrification rate, the installed hydro power capacity became insufficient to meet the demand. This forced Ghana to search for creative solutions to this conundrum and have led the country to enforce electricity sector reforms, more or less successfully. With the help of the World Bank financing reforms in different economic sectors, Ghana has grown from a developing country to a regional power in West Africa and from a net energy importer to an exporter of energy.

Iran has an abundance of energy resources, which makes it a unique country whose analysis is expected to bring forth interesting results. The enormous subsidies on electricity provided by the government distorted the real price of the cost of electricity generation for decades. This led Iran to be one of the worst energy efficient countries in the world. With the increasing number and wealth of the population, the national energy demand is rising rapidly, leaving less energy resources available for export, a revenue source urgently needed by an economically sanctioned country like Iran.

Whatever the background of the analyzed countries, electricity sector reforms always bring about drastic changes to the sector, economy and society. The quantitative correlation description of the impacts of these reforms on the population is therefore the main goal of this thesis.

2.2 Objectives

Past experiences and available literature shows that it is generally a good idea and practice to deregulate the energy system. In the past, electricity reforms have often been tainted by failures, nevertheless the overall trend is to move from a regulated monopoly to a deregulated free-market. Especially for developing countries, this could prove to be crucial, as many are desperately in need of financial capital to expand their capacity installations to satisfy the increasing energy demand. It is hoped that deregulatory reforms offer a solution by attracting financial resources from private companies.

Moreover, it would be easy to claim the impact of electricity sector reforms on a certain indicator by merely stating that in the years where the reform took place, the corresponding effects were witnessed. However, the quantitative analysis pursued in this research paper is intended to strengthen the argument for electricity sector reforms by proving its statistical significance and mathematical correlation with the improvements in the impact indicators. Even more importantly, the significance of the specific SIRRE sub-indicator and the corresponding coefficient value are deduced, which is key for future predictions and analogy comparisons. The lack of a quantitative analysis would be devastating to this area of research.

The final objective this thesis pursues is to offer policy makers of developing countries a manual to inform them what awaits them in case they decide to deregulate their electricity sector. This is done by analyzing a very heterogeneous group of countries so that analogies to a similar developing country in terms of population, geographic location or natural energy resources can be easily made. By abstracting the obtained results, conclusions and policy recommendations can be reached for each of the case-studies. In order to achieve this final goal, multiple previous steps are necessary first.

To begin with, the scope has to be limited by deciding what impacts of the electricity reforms the author wants to analyze. Secondly, the control variables corresponding with each impact indicator have to be defined. Thereafter, the analyzed countries have to be chosen and the data for all the impact indicators and control variables brought together from different sources, e.g. the World Bank, different ministries, the OECD in addition to other literature. Of course, all the data must be complete for the timeline in question for all the analyzed countries. At this point, the quantitative analysis can begin using the MLR methodology explained in detail later. It is hoped that the impact of electricity system deregulation can be quantitatively proven to exist and the specific impact indicators also precisely measured. After both MLR methodology phases are completed, the obtained results are then discussed and possible conclusions and policy recommendations extracted, which brings the reader back to the stated final objective of this thesis.

2.3 Motivation

Lebanon gained independence from the French colonial masters on November 22, 1943, thereby becoming their own nation. Ever since its birth, the Lebanese Republic has been plagued by a myriad of crises, hardships and wars, which are some of the reasons for the failing electricity sector. The current state of the electricity system is inefficient, corrupt and financially insolvent but it is important to note that a country in political turmoil and instability does not have electrical efficiency as its number one priority – understandably. [7]

In 1964, Electricité du Liban (EDL) was established for the purpose of generating, transmitting and distributing electrical energy in Lebanon. It is their stated mission to do this "up to the highest possible quality standards and in compliance with the laws and regulations of the Lebanese republic. EDL strives to play a beneficial and constructive role [by] supporting and promoting economic growth and social development in Lebanon and is strongly committed to offering all its customers fast, dependable and courteous services in a transparent manner." [8] The afore-quoted statement found on the EDL website sounds like a joke to anyone who has experienced the numerous power-cuts that plague the Lebanese electricity system.

During the Lebanese civil war (1975-1990), much of the electricity system infrastructure (generation, transmission and distribution units) was destroyed. After the war ended, the energy demand increased drastically and EDL was not capable of providing the financial resources for the urgently needed new capacity installations. Frequent electricity outages have been a problem ever since and are portrayed in Figure 2.1 for the timeline of 2009-2014.

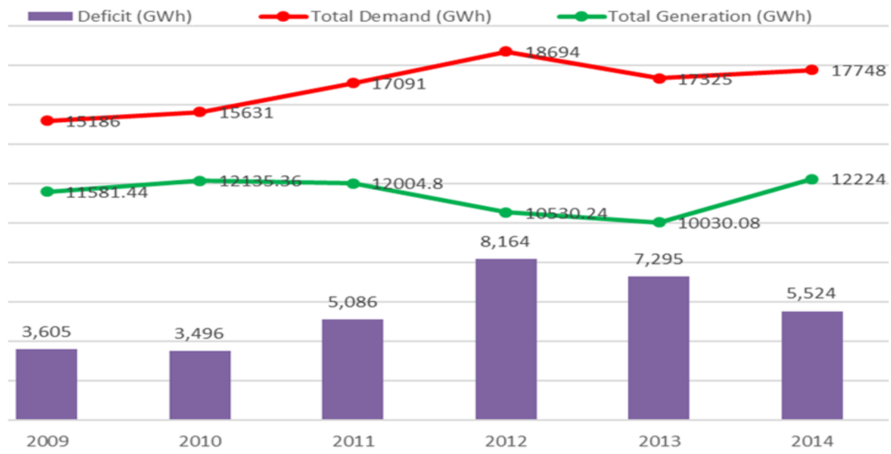

Figure 2.1 Lebanese Electricity Generation, Demand and Deficit, source [9]

Growing up in Lebanon, I experienced first-hand the detrimental effects of a strictly regulated electricity sector. EDL is kept busy trying to operate and maintain the already failing existing energetic facilities, while the situation has continued to deteriorate with the time and today the electricity cuts off for 4 hours every 4 hours, meaning that electricity is only available about half of the time, at best. Although the population is highly educated, it ranks among the lowest countries in terms of public management. This is especially drastic in the case of the quality of electricity supply, where Lebanon ranks 143rd out of 144 countries according to the World Economic Forum 2014-2015. [7] I believe that deregulation is the answer to the Lebanese electricity problem and that a successful transition to a deregulated system would also help battle the corruption that is economically crippling the country. If this thesis is successful, it could prove to be a key kick-off for the deregulation process.

To summarize, the main causes for an urgently needed change in the Lebanese electricity system are first and foremost the blackouts that bring about significant GDP losses. [9] This is politically unacceptable for a country that prides itself as being the "Switzerland of the Middle East". Secondly, government-owned EDL cannot fight the increasing blackouts due to its incapability of financing new capacity expansions. Lastly, the Lebanese electricity system is increasingly inefficient and runs large amounts of T&D as well as non-technical losses, exacerbating the financial problems[3]. [10], [11]

2.4 Scope and Thesis Limitations

The first step in significantly contributing to an area of research is setting the system boundaries. This thesis is no exception. An energy system is defined by the Intergovernmental Panel on Climate Change (IPCC) as "all components related to the production, conversion, delivery, and use of energy" [12]. However, the term "energy" is still very ambiguous and can contain electricity, heat and even transport. When the term "energy system" is used, it mainly refers to the electricity system and the natural gas distribution network. The deregulation process is complex enough already and so to limit the scope of this thesis, it will suffice to analyze the electricity system. Therefore, whenever the term "energy system" is used, it will only be referring to the electricity system unless otherwise specified. The IPCC definition will be modified and the new definition for this thesis will be "all components related to the production, conversion, delivery, and use of electricity".

In order to further narrow the scope of this thesis, renewable energy generation will not be specifically analyzed with its own impact indicator. This is due to the fact that non-conventional power generation technologies are very expensive and do not follow the rule of free market economy. Their exceptional status is due to their higher price; they would never survive in pure capitalism but have to rely on subsidies to

[3] The problems of the Lebanese electricity sector are nearly identical to those of Colombia that have been successfully alleviated by electricity sector reforms. [13]

economically compete. These subsidies are provided by governments, where regulation is implied by definition. The author is aware of the decreasing price trend of renewable energy technologies and their increased economic competitiveness. However, since sustainable energy technologies are less pronounced in developing countries (excluding hydro) and to limit the scope, they will not be analyzed with a separate impact indicator within this thesis.

The impacts of electricity system deregulation will be analyzed using seven impact indicators by searching for correlative relationships between the variable sets. The analyzed impact indicators are presented in Table 2-1 below and the impacts are limited to only these seven indicators.

Number	Impact Indicator
1	Shannon's (Energy) Diversity Index
2	Energy Intensity
3	Energy Use
4	Net Energy Imports
5	Electric Power T&D Losses
6	Access to Electricity
7	Corruption Perception Index

Table 2-1 Impact Indicators

It would have been advantageous to analyze more impacts, however, this was not done, so as to limit the scope. Previous studies have already analyzed some impacts of electricity system deregulation. Asane-Otoo [13] e.g., analyzed the impact of electricity reforms on GHG emissions in OECD countries. Therefore, although data for Methane, Nitrous Oxide and Carbon Dioxide emissions in the energy sector are provided by the World Bank [14] for all the years of interest, an analysis thereof would not contribute any new insight to the world of research knowledge.

The impact of electricity sector deregulation on the capacity utilization[4] was not analyzed in this thesis. Although data was provided for Turkey, Chile and Iran by the ministries responsible for the electricity sector, this was not the case for India and Ghana, which is why this impact indicator was discarded. Likewise, the *investment in energy with private participation* development indicator provided by the World Bank [14] was intended to be used as a control variable for the analysis, however lack of sufficient data for all the analyzed case-studies during the entire timeline rendered this impossible.

All impacts of the deregulation of the electricity system on the politics, economy, society and energy system of the respective country was intended to be measured. However, this was not possible and a limitation of the scope and a clear definition of the system boundaries was necessary. The impact indicators displayed in Table 2-1 above are the boundaries of this thesis. Economic indicators left out include the money supply, interest rate, and the purchasing power parity (PPP). Other discarded indicators describing the society include the GINI coefficient, which measures the wealth or income disparity and inequality in a country, the HDI, and the subjective life satisfaction index. The contribution of the electricity sector to the GDP of the country (% of GDP), the value lost due to electrical outages and the electricity price are all indicators dispensed of, while describing the energy system. The most common reason for indicator rejection was the lack of available data for all countries for the entirety of the analyzed timeline.

The Multiple Linear Regression (MLR) methodology used in this thesis and described in detail later has one major drawback. This drawback is namely that with the empirical model used it cannot be clearly defined

[4] Capacity utilization is measured in % and is defined as the gross power generation divided by the total installed capacity times the hours in a year.

what the impacts of deregulation are and what the drivers are. That is arguably the number one setback of this thesis.

Throughout this thesis, the terms "electricity sector deregulation", "electricity market reform", "electricity system restructure" or "electricity system reforms" are used interchangeably to mean implementation of a market design that transforms an electricity sector dominated by regulated, vertically integrated and state-owned utilities into one that relies on competition to deliver generated power and retail services. [3]

Finally, it is often not clear whether A is the cause or the effect of B. This is most certainly the case when considering electricity market reform. The simple example of the corruption index suffices to elaborate on this point. The results of [15] show that the level of democracy and corruption in a country are significantly correlated with how far electricity reforms have gone in that country. At the same time, the World Bank regards privatization (in this case electricity market deregulation) as a solution to rent-seeking behavior of corrupt officials. Catch-22! Deregulation should be implemented to fight corruption, while the presence of corruption inhibits deregulation.

2.5 Organization of Thesis

This thesis proceeds as follows. Chapter 2 provides a general introduction to the analyzed topic. This is done by giving background information on the problem in addition to defining the objectives, motivation and scope of this thesis. The next section provides a literature review on the deregulation of electricity systems in general. Thereafter, chapter 4 presents the methodological framework and describes the sectoral indicator for regulatory reform of electricity as well as the impact indicators and control variables. That chapter concludes with a defense of the country selection process. Chapter 5 is the core of this thesis and is devoted to briefly describing each of the five analyzed countries before presenting and subsequently explaining and discussing the obtained results for each country separately. Chapter 6 compares and contrasts the obtained results for all analyzed countries while explaining and discussing the observed phenomena. Chapter 7 reviews the most important attained conclusions and offers recommendations to policy makers wishing to deregulate their electricity sector. The last chapter highlights the shortcomings of this thesis and addresses possible future research paths.

3 Literature Review

The economic forces of markets have been of particular interest to researchers this past century since *the Great Depression* in 1929-1932. The electricity system as a market has lagged behind other markets in terms of deregulation which only started in 1982, Chile. [16] This is due to a variety of reasons such as physical bottlenecks in the transmission system and geographical restrictions. The electricity system is unique in the sense that the market must always be balanced, i.e. supply needs to match demand perfectly for the electric grid to function and maintain a nearly constant frequency. This poses a challenge for deregulation to take place since it must be done slowly and step-wise to ensure reliable deliverance of energy. Historically, strict regulation has been the default since the emergence of electricity grids in order to control these unique challenges in the system. Deregulation is therefore challenging the decade-old status quo, with the repercussions felt clearly throughout the whole system. Although deregulation of electricity systems commenced only 35 years ago, very different experiences have been encountered ranging from complete fiascos to extraordinary successes. This has sparked a great interest in the effects and impacts of different deregulation methods resulting in a large amount of research and available literature on this subject.

The main two books that have emerged regarding this topic hold almost the same title, namely *Electricity Market Reform(s)*. The difference in attitude between [17] and [2] concerning the Electricity Market Reform is compelling although both books were written around the same time and analyze many of the same countries. While Belyaev [2] is very pessimistic and regards the entire concept of deregulation as a big mistake, Sioshansi and Pfaffenberger [17] are more optimistic and maintain the idea that deregulation is theoretically *and* practically a good idea. Although there are many lessons to be learned from the bad examples, where deregulation has exacerbated the situation such as in California (prior to 2006), many good examples exist that can be followed such as in the UK and the Nordpool market existing in the Baltic and Scandinavian countries.

Belyaev [2] makes a number of bold statements, which include that "in the electric power industry it is impossible in principle to organize spot markets", that in competitive electricity markets, export ceases to be mutually effective, and that competitive electricity markets only benefit the electricity producers while the consumers have to deal with the increased prices, deficits and blackouts. Furthermore, he [2] believes that competition in the wholesale (and retail) markets is worse than a regulated natural monopoly or a single buyer market. This thesis will seek to refute the above-mentioned statements and prove that the pros of electricity market deregulation outweigh its cons.

Littlechild [18] suggests that for electricity reform to be successful, it must reflect a sound understanding of market dynamics. Broad agreement on the basic prerequisites has been achieved through decades of experience, analysis and research. However, there is still room for debate on the relative roles of deregulation. Therefore, he [18] has brought forth a "textbook model" for restructuring and competition. This includes 10 components such as privatization, vertical separation[5] and horizontal restructuring[6] to name only the first three. Naturally, this author stresses the importance of the self-proclaimed textbook model and claims its broad success where it has been followed and the existence of problems where it has not. Although the aim of this thesis is not to create a textbook model, abstract causalities will be defined (which will be/and) summarized to form a set of cause-effect statements.

Joskow [5] summarizes many of his research results under *lessons learnt* in bullet format, one of which is "Electricity sector reform appears to be a continuing process of improvement, but a process of continuing reforms of the reforms has both potential benefits and potential costs". This summary of the most important results in bullet points will be utilized similarly in the following thesis.

The deregulation of the Argentinean and Colombian electricity systems were analyzed by Dyner, et al. [6], who point out that the state-owned utilities ran high operational losses, provided poor services, suffered

[5] Vertical separation of a regulated monopoly facilitates competition and regulation.
[6] Horizontal restructuring creates an adequate number of competing generators and suppliers.

high non-technical losses and lacked the financial resources for new capacity investments. These are the exact problems that usually plague regulated markets in developing countries and provide the necessary incentives for a shift towards a deregulated market.

Erdogdu [15] analyzes why some countries have undergone the process of deregulation while others are still lagging behind. He does this by examining a myriad of countries in addition to states in the USA while considering multiple economic and political indicators. However, instead of taking the approach of analyzing a large number of countries and their current instantaneous regulation/deregulation level, this thesis will evaluate a small number of countries over a large time-period, thus capturing the entire process of market deregulation. This way, it is hoped, more insight can be gained on the nature of the reform process and the direct impacts thereof.

Apart from analyzing the electricity deregulation in California, Razeghi et al. [19] highlight the difference between electricity and other commodities that are traded in open markets. This difference demands a lot of attention and requires caution to be taken in order to learn from the mistakes of deregulation processes in other countries.

Craig [20] and Knittel [21] wish to know why policy makers deregulate electricity systems. It is found that the Interest Group Theory (that groups hoping to gain from deregulation lobby for regulatory changes) is backed by stronger evidence than the Public Interest Theory (that regulatory changes are undertaken to benefit society). Craig and Savage [22] find that the market restructuring initiatives to introduce competition have increased the efficiency of the investor-owned plants that stem from organizational and technological changes within the plant. Through this efficiency increase, society benefits from a massive reduction of greenhouse gas emissions. However, the evidence was restricted to the USA and the situation is expected to be very different in developing countries and requires further research.

Although Kaserman et al. [23], Kroszner and Strahan [24] and Gal et al. [25] analyze different market sectors, the insights gained on the political and economic effects of deregulation hold true for the electricity sector as well. The interests of the different parties involved in the deregulation process and the effects thereof are described in detail in these works.

Considine and Kleit [26] explain the basics of electricity market reforms and clearly prove their importance and the need for restructuring the sector. They do this by listing the different forms of deregulation and describing wholesale markets and customer choices. Most importantly, they argue that a regulated system has numerous structural deficits such as providing poor incentives for cost-reduction and reducing customer choices. With the introduction of a competitive market, substantial gains for society can be achieved.

The changes in China's energy sector are best described by Wu [27], who further analyzes the implications for trade, energy consumption prediction, production and regulation policy.

While Nakada [28] analyzes the impact of deregulation in an energy market on R&D activities for new energy technology when climate policy is implemented, this is not particularly relevant in our study since developing countries are usually not on the cutting-edge of research activities. In general, they copy or buy existing knowledge and technology from more developed countries while struggling to operate and maintain their own system adequately. However, the conclusion that the impact of deregulation depends on the number of energy suppliers in the economy is key – although obvious.

Van Koten and Ortmann [29] experimentally investigate the effects of introducing a forward market and conclude that the behavioral remedy of introducing such a market in concentrated markets with two or three competitors is an effective solution for countering single market power. They further suggest that making the EU forward electricity market more transparent would increase competition.

The key message of Clements et al. [30] is that market participants will behave in a strategic way by means of bidding and rebidding, which has undesired consequences on the market unless some regulatory issues are put in place to counter these measures.

A regular and secure supply of electricity is key for every country hoping to ensure quality of life to its citizens. As Afful-Dadzie et al. [31] highlight, dedicating a small portion of a nation's GDP to capacity investment is definitely worthwhile since shortfalls in electricity provision cost Ghana 1.5% of its GDP in 2007. While they [31] deal with the methodology of capacity installation under budget-constraint in developing countries, this thesis will deal with market deregulation and how it positively influences the ability of capacity installation by enhancing competition. In their own words: "Market deregulation […] is a good future direction and practical extension of this paper."

The electricity reforms in Argentina are analyzed by Nagayama and Kashiwagi [32] and include certain points that developing countries are advised to follow in order to achieve successful deregulation. In particular, they describe privatization techniques used for state-owned power companies, that establish conditions for promoting infrastructure development and a fair and healthy competitive environment.

Swisher, McAlphin [33] and Asane-Otoo [13] perform an empirical study on the effect of deregulation policies on GHG emissions in OECD countries. For his empirical analysis, the latter uses data provided by the OECD [34] which will be similarly used for this thesis. However, in contrast to Asane-Otoo [13] who analyzes a myriad of countries in their present state, this study will focus on a smaller number of countries and their development along the timeline of their deregulation. Furthermore, not only will the GHG emissions be analyzed, but also other indicators like energy efficiency, as well as political and economic pointers. Although some of the analyzed countries in this work have available SIRRE sub-indicator data provided by the OECD [34], others do not and so the same methodology will be adopted and the same questions asked to obtain it the missing data.

A review of the electricity sector reform in 5 countries in the Middle East and North Africa (MENA) region has been carried out by Dyllick-Brenzinger and Finger [35]. Apart from briefly reviewing the past deregulation reforms in the observed countries, this thesis will furthermore analyze the impacts these reforms had. So, instead of being a merely descriptive work, the focus will be more analytical and data will be used for empirical analysis.

Electricity deregulation has faced a lot of opposition in the past decade, especially when certain problems were encountered that the deregulation of the electricity system created. Multiple examples are summarized by Slocum [36] and Woo et al. [3] that include problems such as complicated market design, market power abuse, stranded cost, unequal benefit distribution to name but a few. They offer their work as a warning for countries considering to deregulate their electricity market and advise them to carefully consider all the possible obstacles hindering success.

In conclusion, plenty of literature exists regarding electricity sector deregulation and the opinions thereon differ greatly depending on the experienced results. However, today it is a fact that most industrialized countries have deregulated systems, whereas a regulated monopoly is the predominate state in developing countries. There are many benefits associated with electricity sector deregulation as well as many problems that can be avoided with careful implementation of reforms. The deregulation of market sectors in general is usually initiated by political will but can be obstructed by many factors such as corruption and focused lobbying. Deregulation has numerous effects and impacts on the economy, politics and society when it is implemented.

As seen from the multiple cited sources, the issue of energy system deregulation and its following impacts on a country is not a novel or innovative area of research. However, the idea of comparing the undergone deregulation process in several countries by using qualitative and quantitative analyzes, thereby obtaining relationships between impact indicators and electricity sector deregulation sub-indicators is new. Furthermore, a final comparison and contrast with the aim of abstracting principles and applying them to a case study for the sake of predicting future developments is innovative and subsequently the interest of this thesis.

4 Methodology

For a complete understanding of the impacts of electricity sector deregulation in developing countries, a comprehensive and extensive methodology was indispensable. Not only a qualitative but also a quantitative approach was desired to be able to analyze "real" data and derive conclusions and policy recommendations as well as deduce links and relationships that appear counter-intuitive at first glance. It would have been possible to analyze the current situations of many countries and draw conclusions from the differences as was done by Asane-Otoo, who analyzed the electricity reform impact of GHG emissions. [13] It was decided however, to only analyze a few countries and look at their deregulation process over time. Although the countries are small in number, this should prove to be very illuminating and expressive if diverse countries are chosen.

First and foremost, the degree of deregulation in the electricity sector needed to be quantified. This has been done by introducing the *Sectoral Indicator of regulatory reform: Electricity* with the help of the OECD methodology further elaborated on below. Thereafter, the list of indicators was determined which will be the way to analyze the actual impacts of electricity deregulation in the respective countries. Subsequently, control variables needed to be defined for each indicator to get a more realistic picture of the causes affecting those indicators. Then, with the required variables available, correlations were deduced and the impacts of electricity sector deregulation analyzed with the help of the Multiple Linear Regression tool. In the first phase of the methodology, this was done only with the SIRRE sub-indicators. The inclusion of the control variables into the MLR equation is defined as the second methodology phase. After obtaining the results in form of equations with coefficients describing the impacts, they were discussed and explained. Finally, from the obtained results, conclusions were inferred and policy recommendations drawn for each country separately before comparing and contrasting the results to deduce universally applicable altruisms for all developing countries.

4.1 Sectoral Indicator of Regulatory Reform: Electricity

Quantifying regulation and policy measures can be especially tricky and is not a trivial problem. The methodology adopted in this thesis will be the one proposed by the OECD in 2006 [34] and revised in 2013 [4]. However, complete data is only available for most OECD countries and a few non-OECD countries. This poses a further problem, since not all analyzed case-studies have available data. The questions asked to obtain this data will be regarded and the same procedure will be applied if data is lacking by answering the same questions independently, using other sources. This way, the data will be complemented for the countries of interest and can be used homogenously when analyzing the correlation of other factors.

The OECD has proposed a methodology for calculating the indicators of regulation in non-manufacturing sectors (NMR). These indicators measure regulation at the sectoral level for seven networks (i.e. electricity, gas, air, road, rail, post and telecom). These indicators are further aggregated into one indicator of regulation in energy, transportation and communications (ETCR), illustrated in Figure 4.1. This ETCR indicator is of little interest in this thesis due to the addition of unwanted indicators. However, the sectoral indicator of regulatory reform for electricity (SIRRE) is in contrast of significant importance. As can be seen in Figure 4.1, this indicator is subdivided into entry regulation, public ownership, vertical integration and market structure.

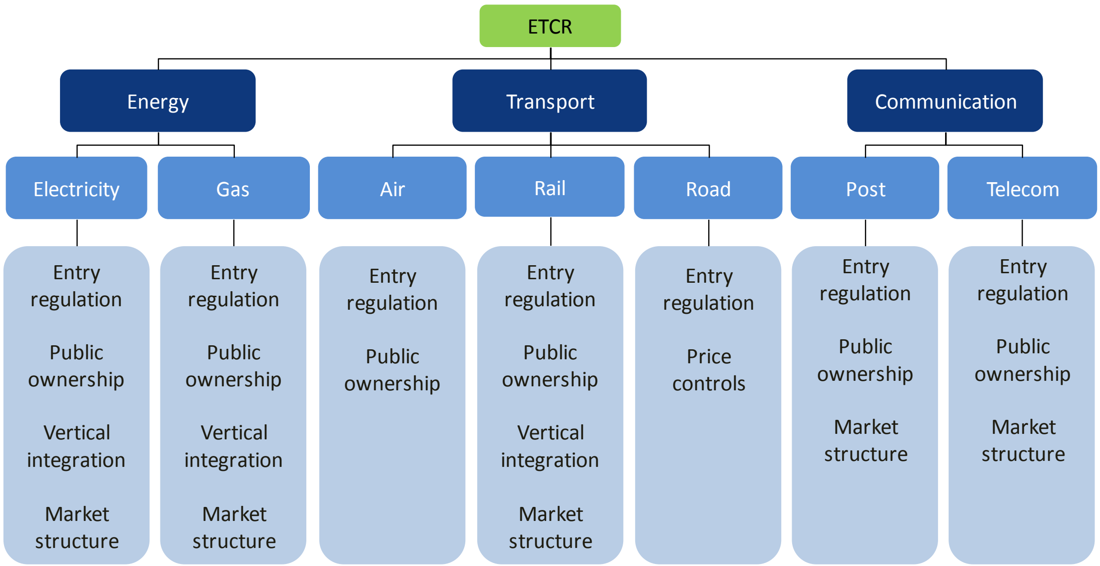

Figure 4.1 OECD Methodology for Calculation of ETCR Indicator, source [4]

For the countries where the information in the OECD database is lacking, the methodology proposed by the OECD and illustrated in Figure 4.2 is used. The questions are certainly not trivial and easy to answer, since it is not always clear to know when exactly (i.e. in which year) a reform took place, a certain policy came into effect or more importantly a law amendment was enforced.

Sectoral Indicator of regulatory reform: Electricity

	Topic weight a_i	Question weight b_j	Coding of data						Question number
Entry regulation	1/4								
How are the terms and conditions of third party access (TPA) to the electricity transmission grid determined?		1/3	regulated TPA 0		negotiated TPA 3		no TPA 6		Q1.4.1
Is there a liberalised wholesale market for electricity (a wholesale pool)?		1/3		yes 0			no 6		Q1.4.2
What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier ?		1/3	no minimum consumption threshold 0	<=250 1	between 251 and 500 2	between 501 and 1000 3	> 1000 4	no consumer choice 6	Q1.4.3a
Public ownership	1/4								
What is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector?[1]		1	% of shares owned by government / 100 * 6						Q1.1.1a
Vertical Integration	1/4								
What is the degree of vertical separation between a certain segment of the electricity sector and other segments of the industry?[1]		1	ownership separation 0	legal separation 3		accounting separation 4.5		no separation 6	Q1.2.1
Market structure	1/4								
What is the market share of the largest company in the electricity industry?[2]		1	smaller than 50% 0		between 50 and 90% 3		greater than 90% 6		Q1.2.2
Country scores (0-6)			$\Sigma_i a_i \Sigma_j b_j \text{ answer}_{ij}$						

1. Simple average over 4 segments: generation/import, transmission, distribution and supply.
2. Simple average over 2 segments: generation/import and supply.

Figure 4.2 OECD Methodology for Calculation of the Sectoral Indicator of Regulatory Reform: Electricity, source [4]

Apart from the questions to be answered in Figure 4.2, the following questions in Table 4-1 elaborate and further expand on each question, thereby clarifying the answers by further subdivision. The process of answering them is long and tiresome but is rewarded with valuable quantifiable data that is needed to proceed with the next step of the analysis.

Code	Question text 2013	Indicator
PO.Q1	Do national, state or provincial governments hold equity stakes in the largest firm in the sector? - Electricity generation	Public ownership
PO.Q2	Do national, state or provincial governments hold equity stakes in the largest firm in the sector? - Electricity import	Public ownership
PO.Q3	Do national, state or provincial governments hold equity stakes in the largest firm in the sector? - Electricity transmission	Public ownership
PO.Q4	Do national, state or provincial governments hold equity stakes in the largest firm in the sector? - Electricity distribution	Public ownership
PO.Q5	Do national, state or provincial governments hold equity stakes in the largest firm in the sector? - Electricity supply	Public ownership
PO.Q6	If the answer is yes, what is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector? - Electricity generation	Public ownership
PO.Q7	If the answer is yes, what is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector? - Electricity import	Public ownership
PO.Q8	If the answer is yes, what is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector? - Electricity transmission	Public ownership
PO.Q9	If the answer is yes, what is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector? - Electricity distribution	Public ownership
PO.Q10	If the answer is yes, what is the percentage of shares owned, either directly or indirectly, by the government in the largest firm in the sector? - Electricity supply	Public ownership
VI.Q1	What is the nature of vertical separation from other segments of the industry? - Electricity generation	Vertical integration
VI.Q2	What is the nature of vertical separation from other segments of the industry? - Electricity import	Vertical integration
VI.Q3	What is the nature of vertical separation from other segments of the industry? - Electricity transmission	Vertical integration
VI.Q4	What is the nature of vertical separation from other segments of the industry? - Electricity distribution	Vertical integration
VI.Q5	What is the nature of vertical separation from other segments of the industry? - Electricity supply	Vertical integration
MS.Q1	What is the market share of the largest company in the sector? - Electricity generation	Market structure
MS.Q2	What is the market share of the largest company in the sector? - Electricity import	Market structure
MS.Q3	What is the market share of the largest company in the sector? - Electricity supply	Market structure
ER.Q1	How are the terms and conditions of third-party access (TPA) to the electricity transmission grid determined?	Entry regulation
ER.Q2	Is there a liberalised wholesale market for electricity (a wholesale pool)?	Entry regulation

ER.Q3	Can consumers choose their electricity supplier?	Entry regulation
ER.Q4	If yes, what is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier (in GWh/year)?	Entry regulation

Table 4-1 Sector Regulation (NMR) Methodology: Electricity, source [37]

4.2 Impact Indicators

It is of interest in this thesis to analyze the impacts of energy reforms in developing countries. Certain indicators have been chosen in order to perform a quantified analysis of these specific impacts. Below, a brief description can be found of each indicator and a short justification for its use in this work.

4.2.1 Shannon's (Energy) Diversity Index

The Shannon's Diversity Index (SDI) is no different from other diversity indices in that it is a quantitative measure that reflects how many different types there are in a dataset. This simultaneously considers how evenly the entities are distributed among the abundance of the types. [38] The SDI can be calculated with the help of the equation below. The variables are explained in Table 4-2 below.

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

Equation 4-1 Shannon's Diversity Index

If all types in the dataset of interest are equally common, then all p_i values are equal to 1/S and the Shannon value becomes equal to ln (S). If the abundances of the types increase in inequality and certain types become more common than others, the geometric mean of the p_i values increases too, thereby decreasing H, the Shannon Diversity Index. If one type dominates and makes the other types rare, the Shannon Index approaches 0. In the extreme case of only having one type in the dataset, H = 0 and there is no uncertainty in predicting the type of the next randomly chosen entity. [38], [39]

Variable	Explanation
H	Shannon's Diversity Index
S	Total number of electricity generating fuel sources
$\boldsymbol{p_i}$	Proportion of S made up of the *i*-th power plant type
$\mathbf{E_H}$	Equitability (evenness)

Table 4-2 Shannon's Diversity Index Variable Explanation

Thus, the SDI will be used to measure the diversity of the fuel sources used for electricity generation. Six fuel sources will be taken into consideration (i.e. coal, hydroelectric, natural gas, nuclear, oil and finally renewables excluding hydroelectric). The data for the percentages of electricity generation sources is taken from The World Bank Development Indicators, see [14]. It is evident that not all analyzed countries make us of these previously mentioned electricity generating fuel sources and therefore the variable S will not be equal to 6 all the time but can change for one country over the years as well. This does not affect the SDI for mathematical reasons, but plays an important role on the equitability, E_H, which can be calculated using the equation below.

$$E_H = \frac{H}{H_{max}} = \frac{H}{\ln S}$$

Equation 4-2 Equitability (Evenness)

It is important to note that the Equitability assumes a value between 0 and 1, with 1 being complete evenness and 0 being complete dominance of one fuel source. [39]

The aim of using the SDI as an indicator for electricity system deregulation is to analyze the effect on the diversity of the electricity generation technologies. Although the energy mix might be more influenced by political will than anything else, based on previous experience it is expected that deregulation still has an impact in this sector. As with the following indicators, control variables will be added to the equation in order to provide a more realistic, contextual and comprehensive view of the impact of the actual deregulation process.

4.2.2 Energy Intensity

The energy intensity of a country describes how energy efficient its economy is. It is an indicator that measures how well a kWh of energy is transformed into a GDP $. A high energy intensity indicates a high cost of converting energy into GDP with the opposite being true for low energy intensity. Several factors influence the energy intensity of a country, of which the climate and the standard of living are the most important. The energy intensity mainly depends on the amount of heating or cooling a typical household in that country needs, but is also affected by the number of appliances consuming energy and their frequency of use. [40]

It cannot be directly said that a causal relationship exists between a high GDP per capita and lower energy intensity. Industrialized countries such as countries within the G7 boast a very high GDP per capita while being relatively energy efficient due to the tremendous amounts of energy they consume in comparison to less-developed countries. The latter consume very little energy due to their low standard of living and can therefore be considered energy efficient but at the same time show a meager GDP per capita score. However, there are many nations whose energy intensity lies between these two extremes and an apparent trend is not evident. [40]

The author wishes to express his intent to deduce the impact of electricity sector deregulation precisely on the energy intensity of the country in question. The indicator will be the Energy Intensity and is measured in MJ/$2011 PPP GDP for all analyzed countries in order to obtain comparable values. This data is provided by [14] for the countries of interest. Furthermore, it is noteworthy that the analyzed energy intensity applies to the level of primary energy, i.e. an energy form that is found in nature and has not yet been subject to any kind of transformation process (e.g. coal, oil, natural gas, hydro).

It must be indicated that the number of observations was only 24 since the timeline under inspection was constricted to 1990-2013. This was done due to the fact that historical data for the time 1975-1990 was missing for the impact indicator of energy intensity level of primary energy (MJ/$2011 PPP GDP).

4.2.3 Energy Use

The indicator of energy use, measured in kg of oil equivalent per capita is dependent on several other variables. Two phenomena are currently working against each other, which is the reason that the Total Primary Energy Supply (TPES) of Germany e.g. has remained nearly constant over the past decade. The first phenomenon is that the more a nation develops, the more machines and appliances per capita exist that use energy to function such as cars, washing machines, televisions, etc. which increases the TPES of that country. On the other hand, the more a nation develops, the more efficient the technologies it implements become, with a car using 5 liters of fuel for 100 km instead of 10 liters for example.

Therefore, it will be interesting to analyze the energy use per capita and see if the electricity sector deregulation has had any impact thereupon. The impact is expected to be minimal since electricity does not constitute the major energy use, but is merely one of many energy sectors such as transport, industry, and heating. Nonetheless, this indicator will be analyzed, as interesting results might still shake old prejudices. Other factors influence energy use much more such as the average commuting distance to work, the climate of the country, and the level of development. These factors will be taken into consideration as much as possible during the analysis.

The main reason for analyzing the energy use is that the countries under consideration are developing countries with a significantly rising energy use during the period of electricity regulatory reform. For developing countries, an increase in energy use is often correlated with an increase in development and therefore of interest in this piece of research. It will further be analyzed what else influences the energy use of a country under development. This will be done by adding control variables that give deep insight into relationships between influencing variables and energy use.

4.2.4 Net Energy Imports

The International Energy Agency (IEA) defines energy security as "the uninterrupted availability of energy sources at an affordable price". [41] Energy security ranks high on the political agenda of European governments. This is no different for most countries that are net energy importers and especially for industrialized countries whose GDP mainly comes from product export. The value lost due to electrical outages is rampant in developing countries and is responsible for great GDP deficits. The historical oil price crises showed just how susceptible OECD countries are in matters such as energy security and the availability of energy sources *at an affordable price.*

It is for this reason that countries try to diversify their energy mix through a process that has been explained in detail before and depicted using another indicator, namely the Shannon's Diversity Index. Not only does a country strive to diversify its energy sources, but more importantly it seeks to rely on different energy suppliers. In a case of emergency where the main supplier of an energy source falls away, a country wants to be sure that its supply of energy can be secured from other sources and no interruption of energy source delivery can take place. "Countries will go to war in order to secure their safe flow of energy resources." [42]

Countries that have little or no own energy sources are therefore in an awkward position and dependent on the countries from which they import their energy. They will seek to lower this dependency and enhance their energy security. In the case of Turkey e.g., it is a stated goal to diversify energy supply routes and source countries, increase the share of renewable and nuclear sources in the energy mix and take significant steps to increase energy efficiency. [43] In conclusion, it is of particular interest to understand the impact of electricity sector deregulation on energy security, especially in net energy-importing developing countries. This is done practically with the indicator of net energy imports and is calculated as a percentage of the energy use.

The existence of the IEA Model of Short-term Energy Security (MOSES) [44] is known to the author. However, due to the relative novelty of this work yet in progress and the lack of reliable experience using this indicator, there are grounds for suspicion, which is why this indicator was not chosen for this thesis. Furthermore, the relative complex methodology and lack of data for the analyzed countries has forced the use of net energy imports as an indicator for energy security instead of the MOSES indicator developed by the IEA. It is noteworthy that the net energy imports will be taken into consideration since it is perceivable that a country may alternately export and import energy during different times of the year. This indicator will be measured in percentage of the energy use and as always, control variables will be used for obtaining realistic results.

4.2.5 Electric Power Transmission and Distribution Losses

The uniqueness of the electricity grid is that supply and demand must be in perfect balance to ensure the safety and the reliability of the system, i.e. stable frequency. In old-fashioned electricity systems, which are the predominant kind today, electricity is generated in power plants and then transported using high-voltage transmission lines. Then, transformers lower the voltage for the purpose of further transportation using the distribution grid, which is the final step before the electricity reaches the different households. A simplification of the discussed system is illustrated in Figure 4.3.

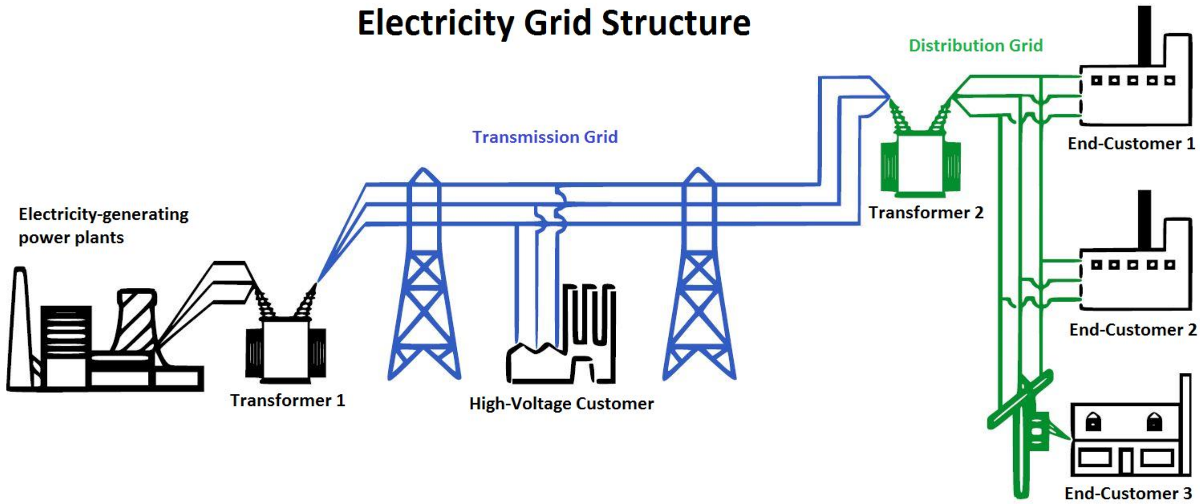

Figure 4.3 Electricity Grid Structure, adapted from [45]

The importance of an efficient electricity system is evident. The higher the losses during the transmission and distribution (T&D) process are, the less energy is finally delivered to the customers and/or the more fuel is used in the power plants to deliver the same amount of electricity. The electric power T&D losses are an indicator for the efficiency of the electric grid and are measured as a percentage of the electrical output. It is not yet entirely clear what the influence of the electricity sector deregulation has on the grid efficiency. A liberalized market could have the effect of economic competition which could help decrease the losses and increase efficiency. However, if e.g. only the generation sector is deregulated and competition is introduced, it could have negative influences on the T&D sector since policies could be unclear and the market situation not properly (de)regulated.

The author is fully aware that in many developing countries, the old-fashioned electric grid approach cannot be applied since many parts of the country might not have access to the grid. With the increase of renewable energy technologies, stand-alone electrification projects are increasing exponentially in developing countries. Solar photovoltaic (PV), wind, biomass and micro-hydro power generation have the needed capacity to power small micro-grids that are not connected to the national grid but provide electricity for the local population. It is not within the scope of this thesis to analyze the impacts of the national electricity system deregulation on the disconnected micro-grids. However, this effect will be included in the electric power T&D losses indicator in the form of the access to electricity control variable.

4.2.6 Access to Electricity

Modern electrical services are crucial to the human well-being and a nation's economy. Still today, 1.2 billion people are without access to electricity i.e. 17% of the global population, although mild improvements have taken place in the last few years due to rural electrification projects. [46] This sparked the SE4ALL initiative, one of the sustainable development goals (SDGs) which aims to secure affordable, reliable, sustainable and modern energy for all by 2030. [47]

Since the percentage of the population with access to electricity, i.e. the electrification rate, is a clear indicator for the development of a country, it is interesting to analyze whether the deregulation of the electricity system influences this indicator or not. The electrification rate can serve for a good proxy for other indicators such as education, life expectancy, wealth and opportunity. The map below (Figure 4.4) shows the disparity in electrification rates worldwide. What immediately catches the eye, is that less developed countries (i.e. mainly in sub-Saharan Africa) score low while all developed countries boast almost 100% electrification. It is expected and therefore the stated hypothesis that control variables such as the GDP/capita or the electricity consumption/capita which are indicators of a country's development, correlate strongly with this indicator.

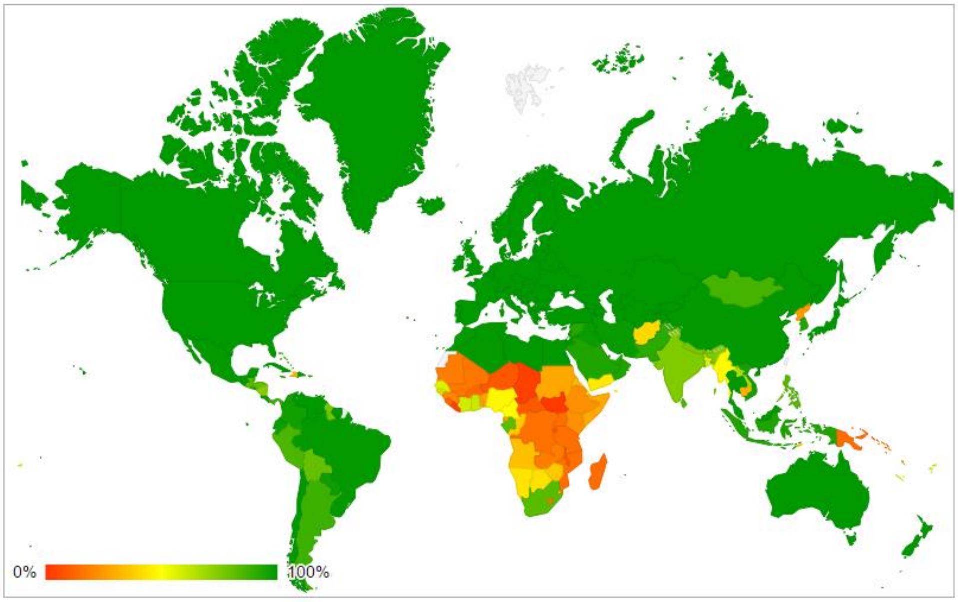

Figure 4.4 Electricity Access World Map, data from 2010 source: [48]

It must be indicated that the number of observations was only 24 since the timeline under inspection was constricted to 1990-2013. This was done due to the fact that historical data for the time 1975-1990 was missing for the impact indicator of access to electricity (% of the population).

4.2.7 Corruption Perception Index

"Corruption is the abuse of entrusted power for private gain." [49] Corruption is one of the major problems constraining development, destroying people's trust in political leaders and economic institutions and at times costing people their freedom, health, money and even lives. Politically, corruption is devastating in established democracies but even more so in emerging ones, since it is usually more rampant there and can lead to a complete distrust in any form of national order and law. On the economic side, corruption steals money from a country and places it in the pockets of individuals, an overwhelming blow to any kind of intended development. Most importantly for the cases studied, corruption hinders the development of fair market structures, distorts competition and deters thereby any form of foreign investment. [49]

Corruption is influenced by several factors such as low salaries/wages, bad job opportunities, lack of strict and fast law enforcement, lack of transparency, etc. Obviously, the deregulation of the electricity sector is not the main factor contributing to an improvement in the fight against corruption. However, it is suggested that any form of deregulation increases transparency and decreases corruption. This is done by taking the power from a monopoly and distributing it among several actors, which also increases competition. It is not entirely clear if corruption inhibits deregulation or if deregulation decreases corruption. As in many cases, it is not so evident what the cause is and what the effect. Which came first: the chicken or the egg? For purpose of simplicity, the Corruption Perception Index (CPI) will be treated just as any other of the afore-mentioned indicators.

Furthermore, as with the case of energy intensity and access to electricity, the number of observations is not 39 and the analyzed timeline for the CPI is not from 1975-2013. In contrast however, the analyzed timeline is not homogeneous among all analyzed case-studies for lack of available data for some of the countries. For Turkey, Chile and India the available data is from 1980-2013, while Ghana's data is only available from 1998-2013 and Iran from 2001-2013.

The data for the Corruption Perception Index (CPI) was provided by Transparency International [50]. Although the index only exists since 1996, the oldest report contains historical information for Turkey, Chile and India since 1980. Up until 2011, the CPI scale ranged from 0-10 with 0 being the most and 10 the least corrupt. This scale was changed in 2012 to range from 0-100. For the purpose of data homogeneity throughout the analyzed timeline, the last two years, i.e. 2012 and 2013, were converted from the 0-100 scale to fit the 0-10 scale. If Turkey is taken as an example to elucidate this procedure, 49 and 50 were changed to 4.9 and 5.0, respectively.

4.3 Control Variables

The impacts of the deregulation of electricity systems can be computed without the help of control variables and will be done in the first phase of the methodology. However, to render the results more realistic, comparable and practical, the choice to include control variables was approved and the computation of which will be called the second methodology phase. Furthermore, it is clear that some of the analyzed effects do not depend solely on electricity system deregulation but are further affected by numerous other variables. Including the so-called control variables is an attempt to obtain an equation that explains each impact indicator with increased precision than if they had been excluded. The author is aware that the obtained equations cannot be perfect due to missing and unaccounted for effects and that there will still be room for uncertainty and error. In addition, the question of causation and correlation has the right to be posed.

During the analysis, the variables used to describe the dependent variable in question can either be control variables or impact indicators that are themselves dependent on electricity sector deregulation. This does not pose a problem since cross-correlation and cross-causation are old-known phenomena that simply highlight the complexity of the analyzed system. To ensure the definitions are clear, a distinction is made between control variables, which will be described in the following and impact indicators which have been elucidated in the previous chapter. In the following analysis, a mixture of control variables and other impact indicators are used to describe the different dependent variables.

Therefore, for a first estimate of the impact of the deregulation indicators, the MLR procedure will be undergone without any control variables. It is interesting hereby to observe the R^2-value, which in the case of an accurate model measures how much of the phenomenon can be described with the analyzed data. Furthermore, it is of interest to see if these indicators are statistically significant or not. This process is then repeated with control variables for the reasons explained previously. The difference in coefficients, p-values and R^2-values between the two procedures (with and without control variables) is also significant. It is possible that SIRRE sub-indicators are statistically significant in the first procedure, but are later rendered insignificant through the addition of control variables or vice-versa. This simply signifies that some of the control variables influence the analyzed impact in a greater manner than the SIRRE sub-indicators, but not that the sub-indicators are in themselves statistically insignificant.

Not every control variable is used in the analysis of every impact indicator. The author has chosen for every impact indicator the control variables and other indicators that were thought to fit best or correlate with the dependent variable. The control variables chosen from are among the 9 depicted in Table 4-3 below. These control variables are of economic, political and societal nature and were selected for their relevance and data availability throughout the analyzed timeline for all countries.

Number	Control Variable
1	Electric power consumption
2	Total CO2 emissions from electricity and heat production
3	Electricity production from renewable sources, excluding hydroelectric
4	GDP/capita
5	GHGs/capita
6	Net inflows of foreign direct investment
7	Inflation of Consumer Prices
8	Unemployment Rate
9	Brent Spot Oil Price

Table 4-3 Control Variables

The electric power consumption is thought to significantly impact most of the impact indicators analyzed. This is the reason it has been selected as a control variable for all impact indicators except energy intensity and the CPI. The electric power consumption is a measure of how much electricity is consumed per capita and is measured in (kWh/capita).

The total CO2 emissions from electricity and heat production, measured in (% of total fuel combustion), is used as a control variable for the Shannon's diversity index, T&D losses and electrification rate. This control variable indicates how much percent of the country's GHG emissions are being emitted by the energy sector. An improvement could be including the average heating degree days of the country, but this was neglected in this thesis as it was not the main objective and outside of the scope.

The electricity production from renewable sources excluding hydroelectric, measured in (kWh), was only used as a control variable in the analysis of the T&D losses. A correlation was expected to exist, since the introduction of renewable energy technologies in a system usually requires new T&D lines to be installed. Small-scale micro grid projects could further affect the T&D losses. These have not been taken into consideration in this thesis for lack of data availability.

The GDP/capita is a macroeconomic indicator measuring a country's economic wealth and is sometimes also used to measure human development. This control variable has been utilized in every analysis, as its correlation with the analyzed impact indicator and electricity reforms has significant implications for the country's policy makers. The increase of GDP/capita is a primary objective for any country leader.

The GHGs/capita is an environmental indicator that measures how polluting a population of a certain country is. For developing countries, this indicator usually increases with increasing development and growing economy. It has been utilized in every impact indicator except the T&D losses and the electrification rate where it was replaced with the total CO2 emissions from electricity and heat production control variable.

The net inflows of foreign direct investment, measured in (% of GDP), is an economic indicator which measures how willing foreign private companies are to invest in the country. It has been utilized as a control variable in the analysis of the Shannon's diversity index, net energy imports, electrification rate and the CPI. The deregulation of the electricity sector or any other sector is thought to significantly influence this variable.

The inflation rate is also an economic indicator which measures how much money is devalued over time. As the inflation rate increases, the purchasing power parity (PPP) of a country decreases and the population can buy less with the same unit of money. This control variable is employed in the analysis of the energy intensity and the CPI.

The unemployment rate is an indicator that describes the percentage of the total work force of a country that is without a job. The data for this control variable has mostly been provided by the World Bank [14], but for India, Ghana and Iran the data was insufficient and the gaps have been filled with the help of the sources [51], [52], [53]. This control variable has been included in the analysis of the energy intensity and the CPI, as well as the inflation rate.

The Brent Spot oil price is the last of the discussed control variables and the data has been extracted from [54] in contrast to the rest of the control variables, where the data was given by the World Bank [14]. It has been used for the analysis of the energy intensity and access to electricity impact indicators. Shock waves were sent around the world with the abrupt change in oil price during the different oil crises. Obviously, this control variable has a significant impact on energy systems, which is the reason for its inclusion in this thesis.

4.4 Multiple Linear Regression and Econometrics

Econometrics applies statistics and mathematics with the objective of identifying and quantifying a relationship between a scalar variable and one or more explanatory (i.e. independent) variables. The ultimate stated goal of econometrics is to test a hypothesized causal relationship between the variables, enabling to extract useful information on important economic policy issues. Before conducting the econometric analysis, the fundamental question to ask is: "What is the causal relationship of interest?" In this thesis, the causal relationship of interest is how the electricity system deregulation impacts the indicators of choice under what conditions.

The by far most common method utilized in econometrics today is Regression. The author is aware that more advanced and complex methods are to be found in literature, but in the given circumstances of assumed linear relationship between the sets of values, multiple linear regression will be used. Linear Regression suggests by definition that the relationship between the values is linear and that there is only one line that would best describe this relationship. That is described with the standard linear regression model of ordinary least squares (OLS). Using the OLS, values for the coefficients are estimated at which the distance between the actual values and the line is at its minimum.

$$Y_{it} = \alpha \cdot X_{it} + \gamma_i + \delta_t + \varepsilon_{it}$$

Equation 4-3 Multiple Linear Regression, Methodology Phase I

Equation 4-3 will be used in the first phase of the methodology and describes the effect of electricity sector deregulation on the respective impact indicators. The inclusion of the control variables in the MLR equation is depicted in Equation 4-4, where the effect of the SIRRE sub-indicators as well as the control variables on the different dependent variables is measured. The equations calculate the relationship between the outcome variables Y_{it}, or indicators of interest, in year *i* and country *t*, and the deregulation indicator X_{it}. The objective is to deduce the coefficients of the equations (i.e. α, β, γ_i and δ_t) and to thereby be able to predict future trends of that indicator.

$$Y_{it} = \alpha \cdot X_{it} + \beta \cdot Z_{it} + \gamma_i + \delta_t + \varepsilon_{it}$$

Equation 4-4 Multiple Linear Regression, Methodology Phase II

Z_{it} captures all the control variables and can of course hold more than one coefficient, corresponding to the number of control variables incorporated within. X_{it} denotes all the indicators included in the Sectoral Indicator of Regulatory Reform: Electricity[7]. That means, that X_{it} boasts 4 coefficients corresponding to the 4 sub-indicators of the electricity deregulation indicator. γ_i represents the country-specific, time-variant effects whereas δ_t denotes the year-fixed effect that describes trends and dynamics that are common in

[7] The SIRRE sub-indicators are entry regulation, public ownership, vertical integration and market structure.

different countries. ε_{it} is a "random error" and incorporates all randomness effects during the decision-making process as well as all unknown variables. [13], [55]

Using this multiple linear regression methodology, it is important to make known the assumptions and the limitations of this model, which are weak exogeneity, linearity, constant variance (homoscedasticity), independence of errors and lack of multicollinearity in the predictors. There is plenty of literature to be found regarding this methodology such as [56], [57] to name but a few, and will not be further elaborated on in this thesis.

For each variable and SIRRE sub-indicator, a set of R-squared (R^2) values, observations, coefficients, standard errors, t-stat values and p-values will be obtained and displayed in tables in the results section. It is of utmost importance to clearly understand what is meant by each of these to understand the discussion and conclusions section.

MLR describes real data with a linear model, whereby the R^2-value represents how well the model fits, i.e. how well the estimated linear relationship fits the data. An R^2-value of 1 would mean that the model describes the data perfectly and 0 would mean no statistical significance what-so-ever. As a rule-of-thumb, an R^2-value of above 0.75 is accepted and the model describes the analyzed data "good enough". Deviations from the model occur since other factors play a role that have been neglected and not taken into account.

However, the R^2-value alone is insufficient to fully describe the model since it has its limitations, which is the reason t-state values, p-values, coefficients and standard errors must also be taken into consideration. The key limitations of the R^2-value are that it *cannot* indicate whether the coefficients are biased nor if the regression model is adequate. It is possible e.g. to obtain a "perfect" set of variables with a very high R^2-value that have nothing to do with the observed phenomenon, i.e. have statistically insignificant p-values. [58]

The term *observations* simply shows how many years have been considered for the analysis. An analysis of the timeline from 1975 to 2013 e.g. would equal 39 observations.

The standard errors represent the average distances that the analyzed values fall from the regression line obtained by the MLR. Conveniently, it shows how wrong the MLR results are. If the standard error corresponding to a coefficient is relatively large, it renders its result statistically insignificant. The t-stat value is simply defined as the coefficient divided by the standard error and depicted below in Equation 4-5 where b_i is the coefficient and σ_{b_i} is the corresponding standard error.

$$t_{stat} = \frac{b_i}{\sigma_{b_i}}$$

Equation 4-5 Test Statistic

The statistical significance can be seen more clearly when the p-value is looked at. The p-value describes the probability of more "extreme" t-stat values. At this point it is important to introduce the concept of the null hypothesis (H_0). The null hypothesis says that a parameter has no effect while the H_1 hypothesis says that the parameter has an effect. The p-value is defined as the probability of drawing a t-stat value that is at least as adverse to H_0 as the actual computed value with your data, assuming that H_0 is true. The rejection of the null hypothesis means that the parameter can be described as being statistically significant. This happens when the p-value adopts a value below a certain threshold. Common thresholds are 0.1, 0.05 and 0.01 and are often differentiated in literature (see [13]). [55]

A major drawback of the MLR methodology is that it is not absolute. MLR shows if the assumption of a linear relationship between two sets of variables is valid or not. Unfortunately, the actual magnitude of the values of these variables do not play a role at all; it is only the relative change that is analyzed by MLR. This means that if one country scores very highly on a certain variable which varies only a little over time, it would be the same as a country scoring very poorly with the same variation. The author is aware of this disadvantage, but the methodology was adopted nonetheless due to other strengths that it boasts compared to other econometric analysis tools.

4.5 Country Choice Defense

Certain parameters were taken into consideration for an appropriate choice regarding the countries to choose from for the case studies and most of which are displayed in Table 4-4 below. The first and foremost condition is that they should differ in their degree of deregulation for each case-study analysis to bring forth innovative and important knowledge on the topic. However, the overall SIRRE score in 2013 for all analyzed countries, with the exception of Chile, lies at around 3. On the other hand, the time of deregulation is also significant for the obtained results and very heterogenous for the analyzed countries, ranging from 1982 in Chile to 2002 in Iran, covering a span of two entire decades.

Country	Overall SIRRE score [2013]	Geographic Location	Economic Freedom Index	Democracy Index	Population (million)	Net energy trade	OECD Membership	SIRRE Data availability
Turkey	3.08	South-East Europe	65.2	5.04	80	import	Yes	Yes
Chile	1.39	South America	76.1	7.78	17	import	Yes	Yes
India	3.47	South Asia	52.6	7.81	1300	import	No	2008, 2013
Ghana	3.77	West Africa	56.2	6.75	25	export	No	No
Iran	3.75	West Asia	50.5	2.34	80	export	No	No

Table 4-4 Country Selection Parameters

Furthermore, the 5 analyzed case-studies must be developing countries, whereby the definition of a developing country is taken from the International Monetary Fund (IMF) and applied to the time of electricity sector reform start. The IMF defines a developing country as "a nation or sovereign state with a less developed industrial base and a low Human Development Index (HDI) relative to other countries". [59] Although this thesis focuses on developing countries, the analyzed case-studies chosen as analyzed countries are not typical developing countries anymore. Today, Chile is recognized as an industrialized country, while Turkey and Ghana are regional powers to be reckoned with. Additionally, India is a growing world superpower on the heels of its neighboring China while Iran is a strategic geopolitical energy superpower due to the vast amounts of energy resources it harbors. A lot has happened in terms of human development and economic growth since these countries began their electricity sector reforms. Nonetheless, at the time of commencing of reform enforcement, all the analyzed case-studies fulfilled the definition of a developing country.

A geographically diverse group of countries with a representative country from several continents and different parts of the world was aimed at in order to provide the outcomes with increased robustness and render them universally applicable. This was successfully achieved by choosing different countries from South America, West and South Asia, as well as West Africa and South-East Europe. Regarding the economic freedom index, the countries analyzed are also heterogeneous. While Chile is considered a "mostly free economy", boasting a score even higher the United Kingdom or the Netherlands, Iran is considered a "mostly unfree economy". This definition and classification of countries by their economic freedom is based on the similarly named index provided by the heritage foundation. [60] Additionally, countries with different forms of political rule[8] are analyzed, with Iran (mostly authoritarian) and India (flawed democracy) being on opposite ends of the spectrum, with the rest of the analyzed countries lying somewhere in between.

[8] Political rule is quantified using the Democracy Index ranging from 0-10, with 0 being the most authoritarian and 10 the most democratic system.

The difference in populations of the analyzed countries is similarly astonishing, with Chile having a population of only 17 million inhabitants, while India, the 2nd most populous country in the world, has an incredible 1.3 billion inhabitants. A difference in electricity systems depending on the populations is thereby imperative. That is to say, that it is easier for small countries to organize the electricity system under one state-owned company, whereas this responsibility is delegated to multiple regionally restricted companies in larger countries that could still be state-owned.

A heterogeneous group of net energy exporting and importing countries was desired for this thesis. The net energy importing countries have an increasing trend of net energy imports, while Iran as an energy exporter is forced to decrease its energy exports due its growing national energy demand. Ghana is currently in a transition process from a net energy importer to a net energy exporter.

The fact that Turkey and Chile are in the OECD means that data is available for all SIRRE sub-indicators from 1975-2013. This was also the major reason why these countries were chosen in order to have an example to follow while deducing the SIRRE sub-indicators for the countries where the data is unavailable. This is the case for Ghana and Iran, which are not members of the OECD. Although India is not an official member of the OECD, SIRRE sub-indicator data is available for 2008 and 2013. This is the first step of obtaining all the data for 1975-2013 and subsequent inclusion of India into the OECD which is predicted to happen in the near future.

To conclude the country selection procedure, it must be said that each analyzed case-study is unique and was chosen for different reasons. Moreover, one can assume that the author was successful in finding a heterogeneous group of countries that differ in multiple aspects. This increases the robustness of the results, since more factors play a role and more phenomena are observed that need to be explained. If the methodology presented previously is carried out correctly, the outcomes become universally applicable due to the diversity of the analyzed countries.

5 Case Studies

5.1 Turkey

5.1.1 Brief Country Description and Electricity System History

The Republic of Turkey, located in south-eastern Europe and western Asia was founded in 1923 and boasts a population of around 80 million inhabitants. As a member of the OECD, NATO, G-20 and due to its recent impressive economic growth and diplomatic endeavors it can be recognized as a regional power. Energy security is a top priority for Turkey since it imports more than 75% of its energy sources. Additionally, it is characterized by a strong increase in energy demand due to further industrialization and population growth.

Up until the 1980's, the Turkish Electricity Authority[9] dominated the electricity sector for generation, transmission and distribution. In 1984, this monopoly power was removed, paving the way for private participation and offering the potential to solve the problems inherent in full state ownership. The new investment models included Build Operate Transfer (BOT), Transfer of Operating Rights (TOOR) and Build-Own-Operate (BOO) which differed mainly in ownership conditions. This resulted in higher efficiency, increased supply and most-importantly lower prices for consumers. [61], [62] Although the reform process progressed slowly after 1984 due to internal resistance against privatization, the momentum increased in 2001. [63]

The Electricity Market Law (No. 4628), which came into effect in 2001, unbundled state-owned electricity assets, opened the market, allowed third-party access to the grid and practically sold all generation capacity to wholesalers, retailers, or consumers, either directly or through a spot market. The Turkish Electricity Authority was unbundled into Elektrik Üretim A.Ş. (EUAS) for generation, Türkiye Elektrik İletim A.Ş. (TEIAS) for transmission and lastly Türkiye Elektrik Ticaret ve Taahhüt A.Ş. (TETAS) for wholesale. Later, the wholesale component evolved into a competitive market rather than following the single-buyer model. [61], [64], [65], [66] An illustration of the Turkish electricity system is depicted in Figure 5.1 below.

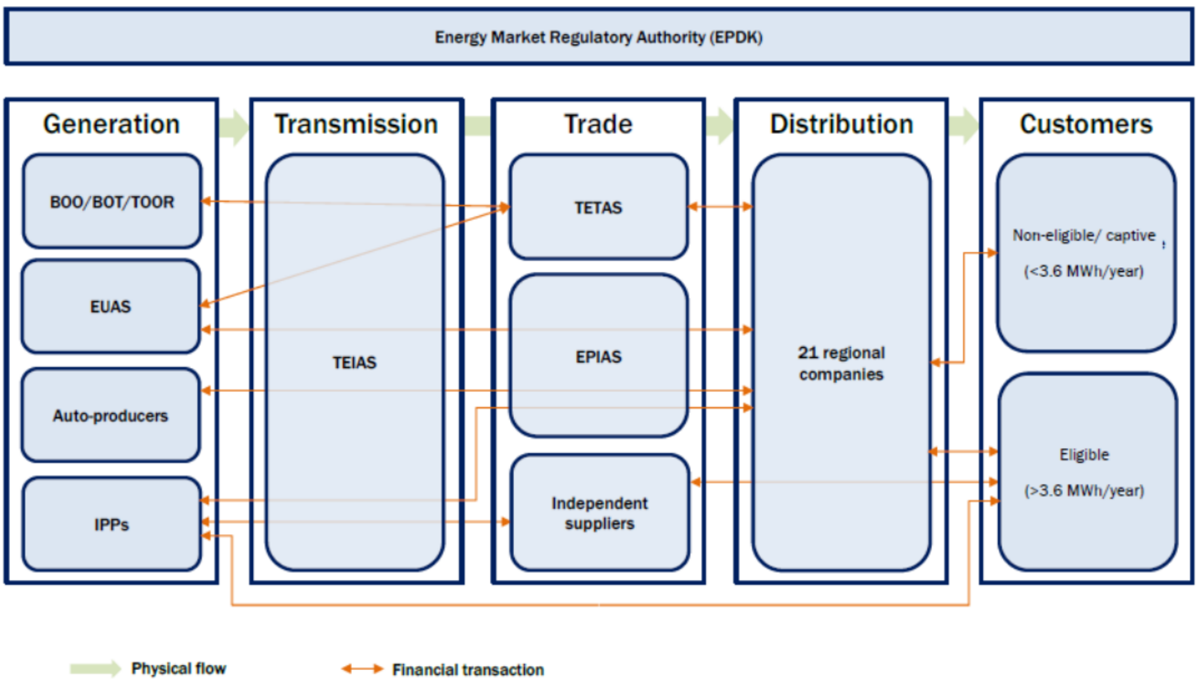

Figure 5.1 Turkish Electricity System Illustration, source: [61]

[9] The Turkish Electricity Authority is a state-owned, vertically integrated, natural monopoly.

Electricity sector reforms played a key role in the development of the Turkish electricity system since the start of deregulation in 2001. The yearly new installed generation capacity of EUAS is losing ground to privately-operated power generation as can be seen by the fact that three-quarters of the capacity installations between 2002 and 2012 were achieved by the private sector. In 2009, 98% of new capacity was installed by private companies. The steadily decreasing assets of the state-owned EUAS (40% by 2011) at the advantage of privately-owned companies (60% by 2011) is a sign of successful deregulation reforms. [62]

The Electricity Market Law of 2013 further unbundled the power sector in the distribution (now shared by 21 regional companies) and retail activities. The Turkish Energy Stock Market was established in 2015 with 30% of the electricity being traded through it the same year and the rest through bilateral contracts. The impacts of this development are unfortunately not captured in this thesis, since the analyzed time-line ends in 2013, where Turkey showed an overall SIRRE score of 3.08. [61]

The timeline of electricity sector deregulation is depicted quantitatively in Figure 5.2 below. Although the specific SIRRE sub-indicators were not analyzed as for the cases of India, Ghana and Iran due to available data provided by the OECD, it is possible to get a comprehensive idea of the reforms in the electricity sector for Turkey by taking a look at the figure below.

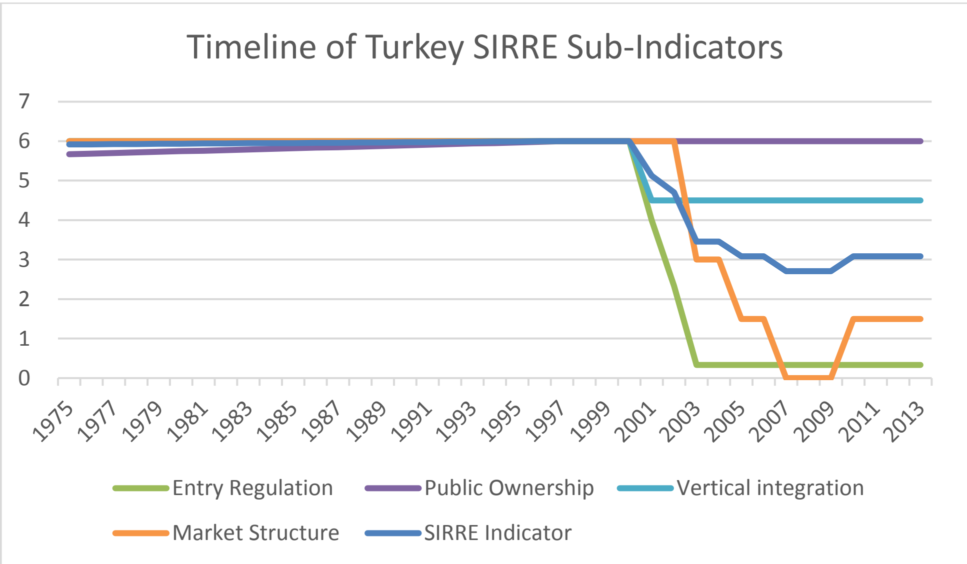

Figure 5.2 SIRRE Sub-Indicators vs. Time: Turkey

5.1.2 Indicator Analysis and Results

5.1.2.1 Shannon's Diversity Index

The diversification of the energy mix for power generation was analyzed using the Shannon's Diversity Index. The obtained results are illustrated in Table 5-1 and Table 5-2. It is noteworthy that not all sub-indicators of the SIRRE indicator are statistically significant. In fact, without the inclusion of the control variables, the Public Ownership sub-indicator is <<0.01 meaning extreme statistical relevance with the Market Structure indicator being <0.1. The fact that the other two SIRRE sub-indicators are negligible due to their high p-values and the R^2-value being 0.6715 does not allow the formulation of clear causation statements.

Country: Turkey R-squared: 0.6715 Observations: 39 Dependent Variable: Shannon's Diversity Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.00546	0.02211	-0.24706	0.80635
Public Ownership	0.64078	0.08616	7.43736	1.26E-08
Vertical Integration	-0.00339	0.05483	-0.06179	0.95109
Market Structure	0.02343	0.01243	1.88539	0.06795

Table 5-1 Shannon's Diversity Index Impact Results: Turkey

As for the case of the control variables, the only statistically significant indicators are the Electric power consumption (kWh per capita), GHGs/capita (kt of CO2 equivalent per capita) and CO2 emissions from electricity and heat production, total (% of total fuel combustion) – all boasting p-values <0.05. Furthermore, The Market Structure SIRRE sub-indicator becomes even more statistically significant boasting a new p-value of <0.01. The Entry Regulation sub-indicator has a p-value of <0.1 while the one for Public Ownership is rendered insignificant. However, the Vertical Integration indicator is statistically irrelevant throughout both procedures and can be disregarded for the case of Turkey. With an R-squared value >0.75, the results of this MLR are accepted and future values of the Shannon's Diversity Index for the electricity generation sector in Turkey can be predicted with adequate preciseness.

Country: Turkey R-squared: 0.8180 Observations: 39 Dependent Variable: Shannon's Diversity Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.04703	0.02536	-1.85425	0.07427
Public Ownership	-0.02894	0.24594	-0.11767	0.90717
Vertical Integration	0.07989	0.06445	1.23959	0.22541
Market Structure	0.05980	0.01836	3.25771	0.00294
Electric power consumption (kWh per capita)	-0.00033	0.00014	-2.31521	0.02815
GDP/capita (current US$ per capita)	1.57E-05	2.03E-05	0.77243	0.44633
GHGs/capita (kt of CO2 equivalent per capita)	169.57286	78.43197	2.16204	0.03931
Energy imports, net (% of energy use)	0.0059	0.0039	1.52727	0.13791
Foreign direct investment, net inflows (% of GDP)	0.00367	0.01515	0.24216	0.81042
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.01265	0.00392	3.23065	0.00315

Table 5-2 Shannon's Diversity Index Impact Results (with control variables): Turkey

5.1.2.2 Energy Intensity

The results obtained for the first methodology procedure, i.e. taking only the SIRRE sub-indicators into account and not the control variables, mediocre results were obtained that are depicted in Table 5-3. None of the sub-indicators are statistically relevant and the R-squared value is far below 0.75 – very bad results indeed.

Country: Turkey R-squared: 0.5263 Observations: 24 Dependent Variable: Energy Intensity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	0.04076	0.04155	0.98107	0.33889
Public Ownership	0.77850	0.71298	1.09189	0.28854
Vertical Integration	-0.05259	0.10429	-0.50428	0.61986
Market Structure	0.00844	0.02335	0.36146	0.72174

Table 5-3 Energy Intensity Impact Results: Turkey

The high R-squared value (>0.75), influenced by the SIRRE sub-indicators as well as the control variables, should not be interpreted wrongly while calculating the Energy Intensity. Although a high R-squared value is always desirable, each independent variable should be analyzed according to its p-value. In this case, none of the analyzed parameters have a p-value < 0.05, with only Energy Use having a value <0.1, which is still not optimal. This renders the results for the most part statistically insignificant and thereby quasi useless.

To try to predict future energy intensities for Turkey with the following coefficient would be a grave error and could potentially lead to failed policy implications. This highlights the importance of studying the results with a careful eye and not jumping to conclusions too fast. It is possible that statistically significant variables were unaccounted for and have therefore been clustered into the error term. In conclusion, it should be said that for the case of Turkey, it is not possible to clearly define or predict the energy intensity with the given SIRRE sub-indicators and control variables.

Country: Turkey ***R-squared: 0.8104*** ***Observations: 24*** ***Dependent Variable: Energy Intensity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.05182	0.04183	1.23884	0.24119
Public Ownership	-6.08944	3.43631	-1.77209	0.10404
Vertical Integration	0.00861	0.10953	0.07865	0.93873
Market Structure	-0.01503	0.03046	-0.49352	0.63135
Europe Brent Spot Price (US$ per Barrel)	-0.00253	0.00301	-0.84112	0.41819
Access to electricity (% of population)	0.08661	0.06466	1.33944	0.20744
GDP/capita (current US$ per capita)	-9.65E-05	5.44E-05	-1.77452	0.10362
GHGs/capita (kt of CO2 equivalent per capita)	-2.2948	1.6370	-1.40182	0.18855
Energy imports, net (% of energy use)	0.00549	0.01976	0.27805	0.78613
Energy use (kg of oil equivalent per capita)	0.00123	0.00065	1.87211	0.08800
Unemployment, total (% of total labor force)	0.00352	0.03929	0.08964	0.93019
Inflation, consumer prices (annual %)	0.00189	0.00272	0.69434	0.50187

Table 5-4 Energy Intensity Impact Results (with control variables): Turkey

5.1.2.3 Energy Use

What immediately catches the eye is the extremely low p-value of Public Ownership once again as in the case of Shannon's Diversity Index. This will be elaborated on later, since it is a reoccurring phenomenon and not unique to the impact of Energy Use. Furthermore, the Market Structure is statistically significant with its low p-value while Entry Regulation and Vertical Integration can be disregarded entirely for the first methodology phase. Moreover, the high R-squared value shows that a certain correlation can be made and the results not deemed worthless.

Country: Turkey ***R-squared: 0.9213*** ***Observations: 39*** ***Dependent Variable: Energy Use***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-8.69840	37.49058	-0.23202	0.81792
Public Ownership	1445.90624	146.06684	9.89894	1.51E-11
Vertical Integration	16.38145	92.94918	0.17624	0.86115
Market Structure	-55.45713	21.06694	-2.63242	0.01266

Table 5-5 Energy Use Impact Results: Turkey

As explained previously, energy use is impacted by a myriad of factors that are impossible to include completely in this analysis. However for the second phase of the methodology, an R-squared value very close to 1, with only four control variables included, signifies a very high correlation and predictability of the dependent variable. The electric power consumption has by far the lowest p-value (<<0.01) and is therefore the most statistically significant variable, which was to be expected beforehand as it is basically integrated within the dependent variable.

However, when one looks at the SIRRE sub-indicators, the lack of statistical significance is quite obvious for three of them that boast a p-value very close to 1. Vertical Integration is the only sub-indicator that has any statistical significance. This is an important deduction, as it shows that apart from the electric power consumption, the degree of regulation in form of vertical integration of the different electricity sector segments (generation, transmission, distribution, supply) has substantial impacts on the energy use of a country. Nevertheless, this mathematical relationship existing between these two sets of variables has to be taken with caution, since correlation does not automatically result in causation.

Country: Turkey ***R-squared: 0.9896*** ***Observations: 39*** ***Dependent Variable: Energy Use***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-4.47711	14.90746	-0.30033	0.76600
Public Ownership	-1.14138	182.71485	-0.00625	0.99506
Vertical Integration	82.90992	38.29658	2.16494	0.03847
Market Structure	1.58159	11.56963	0.13670	0.89218
Electric power consumption (kWh per capita)	0.41160	0.09292	4.42961	0.00012
GDP/capita (current US$ per capita)	-0.00205	0.01556	-0.13154	0.89623
GHGs/capita (kt of CO2 equivalent per capita)	-522.97144	665.92947	-0.78533	0.43842
Energy imports, net (% of energy use)	0.6904	2.5819	0.26738	0.79100

Table 5-6 Energy Use Impact Results (with control variables): Turkey

5.1.2.4 Net Energy Imports

The net energy import indicator is an important factor that plays into energy security, a definite priority in the minds of Turkish policy makers. [67] The results of the electricity deregulation impact are hence also interesting. The results of the first phase of the methodology are depicted in Table 5-7. The only statistically relevant sub-indicator the results have is Public Ownership. However, this is to be taken with care as the sub-indicator has a positive slope throughout the analyzed timeline, which is unrealistic and could be erroneous. This is further elaborated on in the following. The high R-squared value is useless due to the failing significance of the sub-indicators.

Country: Turkey ***R-squared: 0.9509*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-1.41285	1.26210	-1.11944	0.27080
Public Ownership	57.88217	4.91727	11.77120	1.53E-13
Vertical Integration	-2.78485	3.12909	-0.88999	0.37973
Market Structure	-0.18702	0.70921	-0.26370	0.79361

Table 5-7 Net Energy Import Impact Results: Turkey

Although none of the SIRRE sub-indicators are statistically significant in the second methodology phase, the Electric power consumption (kWh per capita) and GDP/capita (current US$ per capita) are. Since only 2 out of the 9 analyzed variables can be taken into consideration, the high R-squared value should not be given too much importance. Therefore, the net energy import indicator cannot be predicted with enough accuracy.

Country: Turkey ***R-squared: 0.9740*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-1.76771	1.13483	-1.55770	0.13015
Public Ownership	0.48288	13.06385	0.03696	0.97077
Vertical Integration	1.87646	3.01154	0.62309	0.53810
Market Structure	0.20831	0.94528	0.22037	0.82713
Electric power consumption (kWh per capita)	0.01930	0.00543	3.55330	0.00132
Energy mix diversification (Shannon's H)	10.45348	8.02373	1.30282	0.20289
GDP/capita (current US$ per capita)	-0.00222	0.00100	-2.21900	0.03447
GHGs/capita (kt of CO2 equivalent per capita)	-31.62164	45.65975	-0.69255	0.49410
Foreign direct investment, net inflows (% of GDP)	0.81205	0.79865	1.01677	0.31767

Table 5-8 Net Energy Import Impact Results (with control variables): Turkey

5.1.2.5 Electric Power Transmission and Distribution Losses

Turkey is characterized by extraordinarily high losses in the electric power transmission and distribution grids. Normally, as countries develop and increase their HDI, the existing electric grid increases in efficiency. This is not the case with Turkey. The losses of the T&D grids increase from 11.6% of the output in 1990 up to 19% within a decade. Thereafter there has been a decrease in these losses, however, the path followed is certainly not linear but marked with notable ups and downs, as can be clearly seen in Figure 5.3 which shows the evolution of the grid losses from 1975-2013. It is noteworthy that since the start year of electricity reforms (2001) the trend has been decreasing after a peak in 2000.

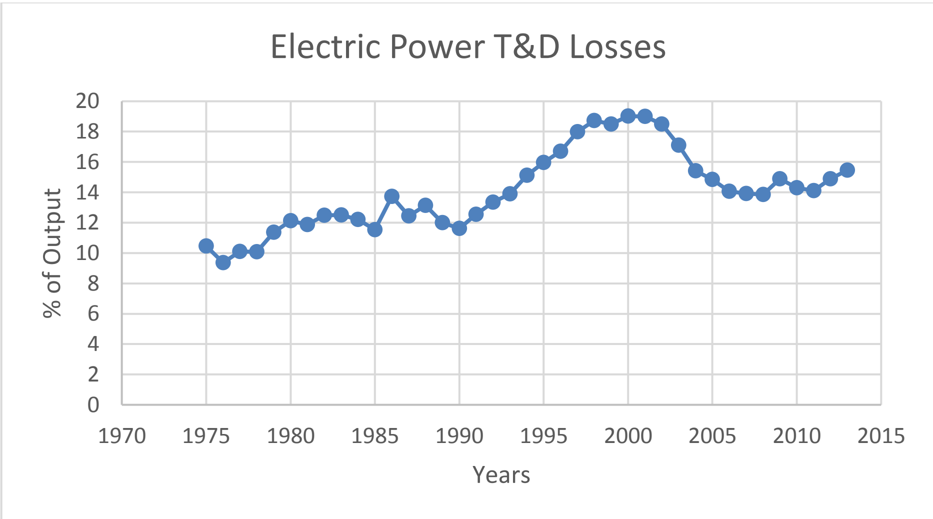

Figure 5.3 Turkish Electricity Power T&D Losses Between 1975 – 2013

For the electric power T&D losses impact indicator, the losses from 1990-2013 do not boast a real linear nature, as can be seen in Figure 5.3. However, for the sake of coherence, the methodology used is nonetheless MLR. This could be responsible for a slight error in the results, which the author is aware of and hereby states.

The results of the first analysis including the specific coefficients of the SIRRE sub-indicators can be seen in Table 5-9. The Public Ownership sub-indicator is statistically significant (<< 0.01), although to be handled with care as explained previously. Furthermore, the Market Structure sub-indicator is relevant with a p-value that is just below 0.05.

Country: Turkey **R-squared: 0.8197** **Observations: 39** **Dependent Variable: Electric T&D Losses**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.33681	0.55680	0.60490	0.54926
Public Ownership	22.56859	2.16936	10.40332	4.20E-12
Vertical Integration	-1.99103	1.38047	-1.44229	0.15837
Market Structure	0.64352	0.31288	2.05676	0.04745

Table 5-9 Electric Power T&D Losses Impact Results: Turkey

The results of the second analysis containing the specific coefficients of the SIRRE sub-indicators as well as the control variables can be seen in Table 5-10. As with the previous impact indicator, the results are far from optimal. None of the sub-indicators are statistically relevant and of the five control variables, only electric power consumption (kWh per capita) and GDP/capita (current US$ per capita) are relevant (< 0.01). In comparison, electricity production from renewable sources excluding hydroelectric (kWh) boasts a p-value of <0.1.

Country: Turkey **R-squared: 0.8899** **Observations: 39** **Dependent Variable: Electric T&D Losses**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.00874	0.58010	0.01507	0.98808
Public Ownership	-5.39964	7.29359	-0.74033	0.46505
Vertical Integration	0.72666	1.45094	0.50082	0.62028
Market Structure	0.78263	0.47996	1.63061	0.11379
Electric power consumption (kWh per capita)	0.01124	0.00288	3.90383	0.00052
Energy mix diversification (Shannon's H)	-5.08501	4.15955	-1.22249	0.23137
GDP/capita (current US$ per capita)	-0.0014	4.76E-04	-3.01540	0.00529
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.07924	0.09869	0.80291	0.42856
Electricity production from renewable sources, excluding hydroelectric (kWh)	-3.38E-10	1.72E-10	-1.96616	0.05892

Table 5-10 Electric Power T&D Losses Impact Results (with control variables): Turkey

Although the graph of the efficiency of the Turkish electricity grid has a peculiar shape, as can be seen in Figure 5.3, the statistical relevance of the sub-indicator of public ownership (see Table 5-9) is obvious when the low p-value is taken into consideration. Seeing as the public ownership sub-indicator coefficient is positive, one can deduce that the higher the government shares are in the companies owning and managing the grid, the higher the electric T&D losses will be and the less efficient the system is. This directly refutes the argument for regulation, which states that the bigger a company is and the less competition there is, the more it can harvest the economies of scale within the system and boost its efficiency.

5.1.2.6 Access to Electricity

The electrification rate in Turkey was at 88% back in 1990 and has steadily increased up to 100% in 2010. Apparently, when Table 5-11 is taken into consideration, entry regulation and vertical integration have no statistically significant impact on the electrification rate, whereas public ownership certainly does and even market structure of the electricity sector indicates a p-value of below 0.01962.

Country: Turkey R-squared: 0.9456 Observations: 24 Dependent Variable: Access to Electricity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.09570	0.46800	-0.20448	0.84015
Public Ownership	51.29007	8.03054	6.38687	3.99E-06
Vertical Integration	-1.05117	1.17467	-0.89487	0.38206
Market Structure	-0.67020	0.26298	-2.54848	0.01962

Table 5-11 Access to Electricity Impact Results: Turkey

In the second phase of the methodology, all SIRRE sub-indicators except Public Ownership become statistically insignificant. Of the control variables, the electric power consumption (< 0.01) correlates with the electrification rate and the CO2 emissions for the electricity and heat production as well as the Europe Brent spot price, which boasts p-values below 0.1. The correlation of public ownership indicates that the more shares the government owns in the electricity sector, the higher the electrification rate will be. This means that electricity sector deregulation in the case of Turkey does not enhance electrification. Further studies and analyses of other countries with a lower starting rate of electrification will be interesting for this study.

Counter-intuitively, the GDP/capita (usually an indicator of development) does not show any statistical significance.

Country: Turkey R-squared: 0.9977 Observations: 24 Dependent Variable: Access to Electricity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.23762	0.24180	-0.98270	0.34515
Public Ownership	16.09225	6.90169	2.33164	0.03796
Vertical Integration	-0.41992	0.56870	-0.73838	0.47447
Market Structure	0.09325	0.16527	0.56426	0.58297
Electric power consumption (kWh per capita)	0.00508	0.00143	3.54654	0.00402
Energy mix diversification (Shannon's H)	-6.15742	3.78179	-1.62818	0.12944
GDP/capita (current US$ per capita)	4.49E-05	1.87E-04	0.24057	0.81395
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.08958	0.04863	1.84195	0.09032
Europe Brent Spot Price (US$ per Barrel)	-0.02064	0.01053	-1.95972	0.07367
Energy intensity (MJ/$2011 PPP GDP)	0.65890	0.78502	0.83934	0.41768
Foreign direct investment, net inflows (% of GDP)	-0.17199	0.12542	-1.37125	0.19539

Table 5-12 Access to Electricity Impact Results (with control variables): Turkey

5.1.2.7 Corruption Perception Index

Despite the lacking data for corruption in Turkey before 1980, it can still be utilized without any problem since the deregulation of the electricity sector started much later and therefore the results are not influenced by the fact that the years 1975-1980 were not included in the analysis. The results shown in Table 5-13 are remarkable. Public Ownership and Market Structure are statistically significant (< 0.01), with Entry Regulation boasting a p-value below 0.1. The low R-squared value simply means that the CPI cannot be fully described solely with the SIRRE sub-indicators but requires further control variables for proper prediction.

Country: Turkey R-squared: 0.5234 Observations: 34 Dependent Variable: Corruption Perception Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	0.31486	0.15742	2.00007	0.05494
Public Ownership	-2.60472	0.86497	-3.01135	0.00535
Vertical Integration	-0.47100	0.39140	-1.20336	0.23857
Market Structure	-0.35003	0.08846	-3.95695	0.00045

Table 5-13 Corruption Perception Index Impact Results: Turkey

For the second phase of the analysis, i.e. the inclusion of the control variables, interesting results meet the eye. None of the control variables have a statistically significant influence on the CPI. This may be the effect of a wrong choice of control variables and the negligence of variables that play an important role for the calculation of the CPI. Whatever the case, none of the analyzed control variables can be used to predict the CPI for Turkey.

Of the 4 SIRRE sub-indicators, all of them are relevant to the calculation and future prediction of the CPI by boasting a p-value of under 0.05, with the exception of Market Structure, although it scored so well in the first phase. The difference in positive and negative signs of the SIRRE sub-indicator coefficients is difficult to explain, but will be done in the following chapter.

Country: Turkey R-squared: 0.9038 Observations: 24 Dependent Variable: Corruption Perception Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	0.38936	0.14243	2.73365	0.01706
Public Ownership	-11.59562	3.69769	-3.13591	0.00788
Vertical Integration	-0.93625	0.40533	-2.30987	0.03796
Market Structure	-0.14789	0.12396	-1.19306	0.25416
GDP/capita (current US$ per capita)	1.73E-04	1.18E-04	1.46812	0.16585
GHGs/capita (kt of CO2 equivalent per capita)	425.25722	631.60635	0.67329	0.51255
Unemployment, total (% of total labor force)	-0.04339	0.07785	-0.55738	0.58674
Inflation, consumer prices (annual %)	0.00049	0.00510	0.09632	0.92474
Energy intensity (MJ/$2011 PPP GDP)	0.17461	0.77591	0.22503	0.82545
Foreign direct investment, net inflows (% of GDP)	-0.15923	0.12766	-1.24724	0.23431

Table 5-14 Corruption Perception Index Impact Results (with control variables): Turkey

5.1.3 Derived New Knowledge and Discussion of Results

As explained previously, the Turkish electricity sector reforms were planned to take off in the 1980's but only practically commenced in 2001. The fact that data is being taken from 1975-2013 or from 1990-2013 is a key advantage, since the change in the respective impact indicator can be clearly traced back to electricity sector deregulation or simply the country development. With a timeline of 2000-2013, this would not have been the case.

Since the start of the electricity sector reforms in 2001, the Public Ownership SIRRE sub-indicator was expected to remain the same or decrease, but not to increase before that. The fact that this sub-indicator has a positive slope throughout the analyzed timeline could lead to wrong conclusions. This data was used as was provided by the OECD and was entirely trusted. However, the author recommends a reevaluation of the OECD data, since it is assumed to be erroneous. This is also the reason for the very low and very high p-values obtained at times during the first and second phases of the methodology (with and without control variables), respectively.

Drastic changes of the p-value for the Public Ownership SIRRE sub-indicator are not to be neglected. For example, during the energy use analysis in the first methodology phase, it has a value of 1.51E-11 (see Table 5-5) and in the second phase it has a value of 0.995 (see Table 5-6). These values are on complete opposite sides of the spectrum. The first one shows total statistical dominance over the other variables while the second one shows total statistical insignificance. This example is one of many, where public ownership is showing strange behavior.

The coefficients of the statistically significant SIRRE sub-indicators and control variables are key to understanding the relationship to the dependent variable. For the obtained results depicted in the previous chapter, several relationships can be distinguished and conclusions made.

For the Shannon's Diversity Index, the results imply that the higher the GHG emissions per capita and the percentage of CO2 emissions from electricity and heat production are, the more diverse the energy mix becomes. On the other hand, the higher the electric power consumption per capita, the less diverse it becomes. As for the SIRRE sub-indicators, the positive coefficient of Market Structure indicates that the larger the market share of the biggest company in the electricity sector is, the more diverse the energy mix becomes.

The results of the energy use analysis indicate that if the market share of the largest company in the electricity sector increases, the energy use per capita decreases. On the other hand, if the vertical separation between the different electricity sector segments (generation, transmission, distribution and supply) decreases, the energy use increases. Furthermore, as the electric power consumption per capita increases, so does the energy use. This is obvious and is only mentioned for the sake of a complete result description.

The electric power consumption is found to be correlated with net energy imports. The positive coefficient sign is logical since it means that the more electricity Turkey consumes, the more energy it needs to import to supply the increasing demand. Furthermore, the negative sign of the correlating GDP/capita control variable signifies that the more Turkey develops and the richer the population becomes, the more energy it has to import to satisfy the growing demand for luxury goods and services that require electricity to operate.

The electric power T&D losses increase with increasing electric power consumption and decrease with increasing GDP/capita. A similar explanation as for the net energy imports can be given. More importantly, the positive coefficient sign of Market Structure indicates that the more market shares the biggest company in the sector holds (this is usually state-owned), the higher the T&D losses will be. In conclusion, this means that electricity sector deregulation increases the efficiency of the electricity grid by decreasing T&D losses. A policy recommendation for Turkish policy-makers could therefore be to further deregulate the sector by privatizing the state-owned companies and thereby decrease the public ownership score.

Again, the Market Structure sub-indicator correlates with the analyzed impact indicator, this time access to electricity. The negative sign means that the access to electricity of Turkey increases with increasing electricity sector deregulation. Although this an important conclusion for policy recommendation that could benefit other countries, it is of little use to Turkey, since the country is already 100% electrified. Furthermore, the electrification rate increases with increasing electric power consumption of the population. This is logical and does not require further explanation.

A correlation exists between the deregulation of the electricity sector and corruption, with all of the SIRRE sub-indicators proving statistical significance during one of the analysis phases. However, it is quite surprising to find out that not all coefficients have the same sign. While the sub-indicators of public ownership, vertical integration and market structure have the expected negative sign, which means that the more regulated the sector is, the more corrupt the country is, the entry regulation sub-indicator appears to have the "wrong" or counter-intuitive sign. A possible explanation could be that corrupt Turkish officials and policy makers do not or cannot hinder other firms from entering the market, but focus more on keeping most of the market shares under their control in a vertically-integrated government-owned company.

5.2 Chile

5.2.1 Brief Country Description and Electricity System History

The Republic of Chile is a long and narrow country located in South America, bordered on the east by the Andes and on the west by the Pacific Ocean, and has a population of about 18 million inhabitants. As part of the Union of South American Nations (UNASUR) and the Community of Latin American and Caribbean States (CELAC), it leads in terms of stability and prosperity. Immense development, especially since the 1980's, allows it to boast the highest rankings in development, income per capita, economic freedom and low corruption in South America. [68] This development allowed it to join the OECD in 2010 and be ranked by the World Bank in 2013 as a "high-income economy". [69] Today, Chile does not fulfill the requirements of being called a developing country. It was chosen nonetheless as a case study because at the time of the electricity deregulation reforms that started in the 1980's, it was one.

The Chilean electricity system is sub-divided into 4 independent grids. The Sistema Interconectado Central (SIC) serves the center of the country and thereby the major population centers and owns about 75% of market shares, forming the largest electricity grid in Chile. The Sistema Interconectado del Norte Grande (SING) supplies the north of the country and owns about 24.5% market-share, with the Aysen and Magallanes medium-sized grids serving the sparsely-populated south of the country and making up <1% market-share together. [70], [71]

In the 1970's, the electricity sector in Chile was plagued by inflation, high fuel prices, and price controls which led to increased inefficiency and lack of public-owned investment. A drastic change was needed. The legal framework was designed and finally established in the Electricity Act of 1982, which was the first of its kind and is still the most important law defining the sector today, although amendments have been made. What followed were a vertical disintegration of the sector and a formation of a wholesale power trading mechanism – concepts central to modern electricity sector reform. [72]

The economists formulating the 1982 Electricity Act envisaged a system where generators would pay for transmission in order to bring the generated electricity to the customers. This was done using negotiated tariffs and compulsory access right if capacity was available. The connections and lines would have to be paid for by the generators, who could build their own or negotiate a price with transmission companies. This was revolutionary at the time and is now widely implemented under the name of "merchant transmission". The customers on the other hand were envisaged to be of two kinds, i.e. regulated and free. Generators could supply customers with a maximum demand above 2MW (free) directly, while regulated customers would have to contact distribution companies. [72]

With this new framework, multiple new institutions were established. The Comisión Nacional de Energía (CNE) is a decentralized and independent public service, technically and economically regulating the energy sector. Its purpose is to study and propose regulations, calculate regulated prices, provide the government with technical advice and oversee the sector. The Superintendencia de Electricidad y Combustibles (SEC) is responsible for collecting data for the purpose of enforcement and regulation and also provides data on company costs, which is used by the CNE for regulation. The SEC's main function is to supervise and control the enforcing of the laws governing the generation, production, transportation, distribution and storage of oil, gas and electricity according to the technical quality framework to ensure that the operations are performed risk-free and secure for all involved customers and installed units. Furthermore, the minister of energy can impose regulated tariffs and is able to issue rationing decrees during periods of drought since hydro power is a major source of power generation in the Chilean electricity grid. [72], [73]

In 2004 and 2005, the so-called Ley Corta I&II (Short Law I&II) were passed to battle the biggest short-comings of the system, such as an unwillingness to invest in new generation units and transmission lines. This brought about multiple changes with the most important ones being the change of free-to-regulated customer threshold level from 2MW to 0.5MW and an increase in regulation of access charges by distributors for competitive suppliers of customers. In general, the short law's main objectives are expansion of electric transmission and generation, regulation of decision-making, and provision of incentives for non-conventional and small generating units. [72], [74]

Chile was the first country to implement an electricity sector reform, which commenced in 1982. Encountering only a few set-backs, the reform in Chile is considered very successful and the lessons learned such as the advantages of private ownership and operation of the electricity industry are used for electricity reforms in other developing countries. [72]

Although at the time a developing country, Chile was the first country to reform its electricity sector and that successfully, bringing forth confirmed improvements in labor productivity, energy efficiency, wait time for repair service, installed capacity and length of transmission network. [75] The timeline of the deregulation process is depicted below in Figure 5.4. Notable jumps can be seen in the overall SIRRE indicator, which is due to changes in the respective sub-indicators. It is important to note that in contrast to the public ownership sub-indicator of Turkey, which is increasing, all Chile's SIRRE sub-indicators are decreasing throughout the analyzed timeline. The results of the first and second analysis for Chile will be announced and explained in the following chapters.

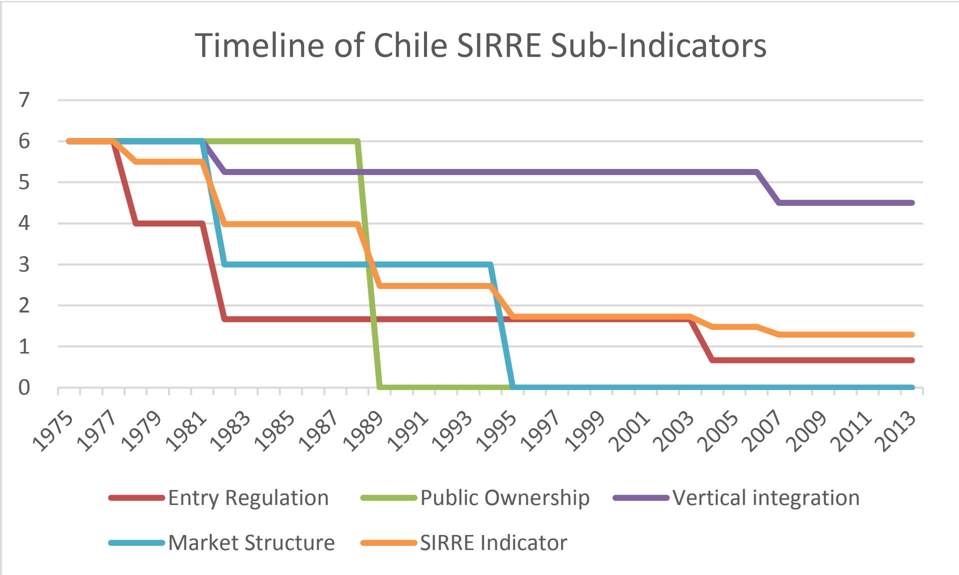

Figure 5.4 SIRRE Sub-Indicators vs. Time: Chile

5.2.2 Indicator Analysis and Results

5.2.2.1 Market Structure SIRRE sub-indicator

If it was not directly given, the market-share for electricity generation was calculated using Equation 5-1 below. 1995 was the first year where Endesa Chile had a market-share <50%. The critical year was 1994, when Endesa Chile boasted an installed capacity of 2513MW [76] and the total installed capacity of Chile was 4920MW [77]. Inserting these values into the equation below, a market-share of 51.1% was obtained.

$$Marketshare = \frac{ENDESA\ installed\ capacity}{Total\ installed\ capacity} = \frac{cap_{END}}{cap_{total}}$$

Equation 5-1 Market-Share in [%]

The Market Structure SIRRE sub-indicator was not fully accounted for in the data provided by the OECD [37] and was not available prior to 2008. The indicator was given a 0 as of 2008 which shows that the largest electricity generating company (, i.e. Endesa Chile) owns less than 50% of the available market shares. Instead of simply ignoring the market structure for the lack of data, other sources were found to compensate and complete the timeline. Endesa had a market-share of 37% in 2007 [78], 45.7% in 1995 and 51.1% in 1994 – corresponding to the market structure indicator value of 3 in 1994 and 0 as of 1995. The jump from

6 to 3 (having less than 90% market shares) is not known exactly for lack of data, however is defined to happen in 1982, the year major market entry reforms took place and Endesa Chile started its process of vertical disintegration, four years after the first reforms came into effect opening the market to new actors.

5.2.2.2 Shannon's Diversity Index

In the first methodology phase, all SIRRE sub-indicators are statistically significant for the dependent variable describing the diversity of the power generation mix. While vertical integration and market structure have p-values < 0.05, entry regulation and public ownership boast p-values that are even below 0.01. This shows that the deregulation of the electricity sector in Chile greatly influenced the power generation diversity. The p-values changed drastically during the second methodology phase when control variables were added to the equation.

Country: Chile ***R-squared: 0.7257*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.09588	0.03207	2.98991	0.00516
Public Ownership	-0.03605	0.01231	-2.92794	0.00605
Vertical Integration	-0.25783	0.09486	-2.71792	0.01026
Market Structure	-0.05348	0.02200	-2.43089	0.02049

Table 5-15 Shannon's Diversity Index Impact Results: Chile

All SIRRE sub-indicators became statistically insignificant with the inclusion of control variables. Similarly, most control variables are insignificant, excluding the net energy imports and the total CO2 emissions from electricity and heat production. The fact that the p-value of the latter is so low means that it dominates the equation and renders the SIRRE sub-indicators insignificant. This certainly does not mean that they can be neglected, but simply that the effect of the CO2 emission in the electricity and heat production on the Shannon's diversity index is far greater than that of electricity sector deregulation.

Country: Chile ***R-squared: 0.9784*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.00488	0.01403	-0.34803	0.73042
Public Ownership	-0.00472	0.00593	-0.79577	0.43286
Vertical Integration	-0.07445	0.05383	-1.38320	0.17753
Market Structure	0.01900	0.01120	1.69599	0.10098
Electric power consumption (kWh per capita)	-0.01130	0.00749	-1.50909	0.14248
GDP/capita (current US$ per capita)	-6.06E-06	5.35E-06	-1.13188	0.26729
GHGs/capita (kt of CO2 equivalent per capita)	27.29803	44.96034	0.60716	0.54864
Energy imports, net (% of energy use)	0.0067	0.0031	2.16507	0.03906
Foreign direct investment, net inflows (% of GDP)	-0.00522	0.00523	-0.99860	0.32654
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.01789	0.00319	5.60454	5.33E-06

Table 5-16 Shannon's Diversity Index Impact Results (with control variables): Chile

5.2.2.3 Energy Intensity

The Energy Intensity data provided is only available for the time period 1990-2013. This is insufficient data for this specific analysis since the major reforms in the Chilean electricity system came into effect in the 1980's. This is best explained with the public ownership sub-indicator displaying a number error in Table 5-17 for its p-value. This is due to the fact that the public ownership score jumped from 6 to 0 in 1989, one year before data was given and remained at that level between 1990-2013. No change in the variable results in a number error for the sub-indicator, which is why it was excluded and the analysis repeated.

Country: Chile ***R-squared: 0.5473*** ***Observations: 24*** ***Dependent Variable: Energy Intensity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.16910	0.11971	1.41255	0.17396
Public Ownership	0.00000	0.00000	65535	#NUM!
Vertical Integration	0.28926	0.16522	1.75078	#NUM!
Market Structure	-0.00506	0.03339	-0.15168	0.88104

Table 5-17 Energy Intensity Impact Results: Chile

The table below illustrates the results obtained, but it is clear that they are not descriptive of the entire deregulation process, which is also characterized by the low R-squared value. Furthermore, no significant p-values were obtained for any SIRRE sub-indicators. It certainly is a shame, but this means that the impact of the Chilean electricity reforms on the energy intensity cannot be entirely measured since the change in 1990-2013 was only from 2.48 to 1.29, whereas the major alteration from 6 to 2.48 happened prior to 1990.

Country: Chile ***R-squared: 0.5027*** ***Observations: 24*** ***Dependent Variable: Energy Intensity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.16910	0.12230	1.38269	0.18201
Vertical Integration	0.28926	0.16879	1.71376	0.10203
Market Structure	-0.00506	0.03411	-0.14847	0.88346

Table 5-18 Energy Intensity Impact Results: Chile (without Public Ownership)

Despite only being able to analyze part of the Chilean electricity sector deregulation process, multiple control variables have showed statistical significance. Inflation and energy use are particularly significant with p-values <0.01 whereas unemployment and the oil price have p-values below 0.05. Furthermore, the control variable of access to electricity and SIRRE vertical integration sub-indicator have p-values <0.1. All of the above results in a relatively high R-squared value of well above 0.75, meaning that although only part of the deregulation process is taken into consideration, a fairly accurate future prediction can be made.

Country: Chile ***R-squared: 0.9553*** ***Observations: 24*** ***Dependent Variable: Energy Intensity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.08958	0.07766	1.15343	0.27119
Vertical Integration	0.31545	0.17426	1.81020	0.09536
Market Structure	0.04303	0.03296	1.30537	0.21624
Europe Brent Spot Price (US$ per Barrel)	-0.00934	0.00409	-2.28539	0.04127
Access to electricity (% of population)	-0.07226	0.03362	-2.14948	0.05269
GDP/capita (current US$ per capita)	3.46E-05	3.07E-05	1.12689	0.28182
GHGs/capita (kt of CO2 equivalent per capita)	-148.6163	211.1370	-0.70389	0.49494
Energy imports, net (% of energy use)	0.00738	0.01108	0.66665	0.51761
Energy use (kg of oil equivalent per capita)	0.00192	0.00060	3.22006	0.00735
Unemployment, total (% of total labor force)	0.09114	0.03125	2.91644	0.01293
Inflation, consumer prices (annual %)	0.04672	0.01273	3.66956	0.00321

Table 5-19 Energy Intensity Impact Results (with control variables): Chile

5.2.2.4 Energy Use

The best results obtained so far can be seen in Table 5-20, where all SIRRE sub-indicators boast a very strong statistical significance with p-values below 0.01. The strong impact of electricity sector deregulation in Chile on the energy use can be further seen by the high R-squared value (>0.75).

Country: Chile ***R-squared: 0.8448*** ***Observations: 39*** ***Dependent Variable: Energy Use***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	132.59380	46.43597	2.85541	0.00728
Public Ownership	-52.99430	17.82611	-2.97285	0.00539
Vertical Integration	-393.05100	137.36240	-2.86142	0.00717
Market Structure	-130.79800	31.85818	-4.10563	0.00024

Table 5-20 Energy Use Impact Results: Chile

Table 5-21 depicts the results of the second methodology phase, including the control variables. Incredibly, all analyzed variables have a strong impact (i.e. p-values < 0.01) on the dependent variable, i.e. energy use, except entry regulation and net energy imports. In other words, three of the four control variables are significant as well as three of the four SIRRE sub-indicators. The R-squared value of >0.99 along with the low p-values shows how accurately future trends in the Chilean energy use per capita can be predicted if the following variables are considered.

Country: Chile ***R-squared: 0.9932*** ***Observations: 39*** ***Dependent Variable: Energy Use***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-18.77338	14.45472	-1.29877	0.20392
Public Ownership	-24.49240	5.39307	-4.54146	8.47E-05
Vertical Integration	165.40990	49.05563	3.37188	0.00207
Market Structure	-32.55808	10.41803	-3.12517	0.00392
Electric power consumption (kWh per capita)	0.15163	0.04276	3.54592	0.00131
GDP/capita (current US$ per capita)	0.02381	0.00616	3.86471	0.00055
GHGs/capita (kt of CO2 equivalent per capita)	145417.4	40946.2	3.55143	0.00129
Energy imports, net (% of energy use)	-4.6049	2.7547	-1.67166	0.10499

Table 5-21 Energy Use Impact Results (with control variables): Chile

5.2.2.5 Net Energy Imports

The first phase of the methodology brings forth the results represented in Table 5-22. Vertical integration is the only SIRRE sub-indicator that is statistically irrelevant, with all the others boasting p-values far below 0.01. The R-squared value of 0.832 is above 0.75 and therefore the net energy imports of Chile can be predicted with satisfactory accuracy utilizing only the SIRRE indicator. However, in order to make the results more realistic and accurate, phase two of the methodology was implemented as well.

Country: Chile ***R-squared: 0.8320*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	4.91188	1.58576	3.09748	0.00390
Public Ownership	-2.55646	0.60875	-4.19950	0.00018
Vertical Integration	-2.48482	4.69086	-0.52972	0.59975
Market Structure	-5.10708	1.08794	-4.69427	0.00004

Table 5-22 Net Energy Import Impact Results: Chile

Interestingly, the second phase of the methodology renders entry regulation and market structure statistically insignificant while the vertical integration sub-indicator becomes very relevant with a p-value < 0.01. Of the five added control variables in this phase, only the GHGs/capita is significant with a p-value of 0.00226. In the case of net energy imports for Chile, the SIRRE sub-indicators play a greater role than the control variables and enable future prediction.

Country: Chile ***R-squared: 0.9734*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-1.27571	1.00677	-1.26713	0.21519
Public Ownership	-1.09655	0.30616	-3.58162	0.00123
Vertical Integration	8.29780	2.94528	2.81733	0.00863
Market Structure	-0.32309	0.74682	-0.43263	0.66849
Electric power consumption (kWh per capita)	-0.00023	0.00315	-0.07462	0.94103
Energy mix diversification (Shannon's H)	-4.52953	8.93947	-0.50669	0.61620
GDP/capita (current US$ per capita)	-0.00025	0.00041	-0.61120	0.54583
GHGs/capita (kt of CO2 equivalent per capita)	10515.61	3139.21	3.34977	0.00226
Foreign direct investment, net inflows (% of GDP)	0.35431	0.35063	1.01047	0.32063

Table 5-23 Net Energy Import Impact Results (with control variables): Chile

5.2.2.6 Electric Power T&D Losses

For the dependent variable of electric T&D losses, similar results are obtained to the net energy import results discussed in the previous chapter. For the first methodology phase, solely vertical integration is statistically insignificant, while all other SIRRE sub-indicators have p-values below 0.01. Although the results obtained are similar to the net energy import results, the lower R-squared value of just below 0.75 does not permit future prediction with enough accuracy when solely using the SIRRE sub-indicators.

Country: Chile ***R-squared: 0.7343*** ***Observations: 39*** ***Dependent Variable: Electric T&D Losses***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-1.40973	0.34416	-4.09615	0.00025
Public Ownership	0.46819	0.13212	3.54372	0.00117
Vertical Integration	0.51510	1.01806	0.50596	0.61615
Market Structure	0.97206	0.23612	4.11686	0.00023

Table 5-24 Electric Power T&D Losses Impact Results: Chile

As for the second methodology phase, where the control variables are included in the MLR equation, the results obtained are far from perfect. None of the control variables are statistically significant and the SIRRE sub-indicator p-values increase as well with the exception of vertical integration. In this phase, vertical integration and market structure are statistically significant with p-values < 0.05, with entry regulation have one below 0.1. Public ownership is deemed irrelevant in this second phase. In conclusion, it can be said that among the analyzed parameters, the deregulation of the electricity sector has the highest impact on the electric power T&D losses.

Country: Chile R-squared: 0.8867 Observations: 39 Dependent Variable: Electric T&D Losses	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.56503	0.29013	-1.94749	0.06122
Public Ownership	0.18358	0.13641	1.34578	0.18880
Vertical Integration	-2.53921	1.09764	-2.31334	0.02799
Market Structure	0.52302	0.22814	2.29254	0.02932
Electric power consumption (kWh per capita)	-5.79E-04	7.80E-04	-0.74181	0.46417
Energy mix diversification (Shannon's H)	-4.85018	3.55845	-1.36300	0.18337
GDP/capita (current US$ per capita)	5.88E-05	1.68E-04	0.35042	0.72856
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	-0.03158	0.09503	-0.33227	0.74208
Electricity production from renewable sources, excluding hydroelectric (kWh)	-3.77E-10	3.28E-10	-1.15254	0.25851

Table 5-25 Electric Power T&D Losses Impact Results (with control variables): Chile

5.2.2.7 Access to Electricity

The provided data for Access to Electricity is only available for the time period 1990-2013. This is insufficient data for this specific analysis, since the major reforms in the Chilean electricity system came into effect in the 1980's. This is best explained with the public ownership sub-indicator displaying a number error in Table 5-26 for its p-value. This is due to the fact that the public ownership score jumped from 6 to 0 in 1989, one year before data was given and remained at that level between 1990-2013. No change in the variable results in a number error for the sub-indicator, which is why it was excluded and the analysis repeated, with the results depicted in Table 5-27.

Country: Chile R-squared: 0.8615 Observations: 24 Dependent Variable: Access to Electricity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-1.61732	0.58451	-2.76698	0.01227
Public Ownership	0.00000	0.00000	65535.00	#NUM!
Vertical Integration	-1.20110	0.80670	-1.48891	#NUM!
Market Structure	-0.94213	0.16301	-5.77950	0.00001

Table 5-26 Access to Electricity Impact Results: Chile

Table 5-27 below illustrates the results obtained without including the public ownership SIRRE sub-indicator, despite it being clear that they are not descriptive of the entire deregulation process. It certainly is a shame, but this means that the impact of the Chilean electricity reforms on the energy intensity cannot be entirely measured since the change in 1990-2013 was only from 2.48 to 1.29, whereas the major alteration from 6 to 2.48 happened prior to 1990. Nevertheless, entry regulation and market structure are statistically significant with p-values so low that the corresponding R-squared value boasts a value of 0.8464 – enabling future prediction with merely three variables. The public ownership sub-indicator retains a score of 0 throughout the entire analyzed timeline. Therefore it is ignored. Similarly, this sub-indicator remains constant with the highest possible score of 6, i.e. complete state ownership, throughout 1975-2013 for Ghana and Iran, which is why it is excluded for the entire analysis.

Country: Chile *R-squared: 0.8464* *Observations: 24* *Dependent Variable: Access to Electricity*	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-1.61732	0.60004	-2.69537	0.01392
Vertical Integration	-1.20110	0.82813	-1.45038	0.16245
Market Structure	-0.94213	0.16734	-5.62993	1.65E-05

Table 5-27 Access to Electricity Impact Results: Chile (without Public Ownership)

The results obtained for the second phase of the utilized methodology are depicted in Table 5-28 below. The high R-squared value of 0.9672 should not fool the reader into believing the table contains great results. A mere look at the p-values suffices to show that among the 7 analyzed control variables, only one is statistically significant. Electricity power consumption is the only relevant variable influencing the electrification rate among the control variables and the SIRRE sub-indicators in this second methodology phase.

Country: Chile *R-squared: 0.9672* *Observations: 24* *Dependent Variable: Access to Electricity*	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.39098	0.63492	0.61580	0.54866
Vertical Integration	0.33616	1.04347	0.32216	0.75246
Market Structure	0.03419	0.21047	0.16243	0.87346
Electric power consumption (kWh per capita)	0.00285	5.27E-04	5.41553	1.18E-04
Energy mix diversification (Shannon's H)	1.61940	2.53912	0.63778	0.53469
GDP/capita (current US$ per capita)	6.88E-05	1.28E-04	0.53851	0.59932
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	-0.05273	0.07516	-0.70163	0.49528
Europe Brent Spot Price (US$ per Barrel)	-0.01644	0.01659	-0.99109	0.33973
Energy intensity (MJ/$2011 PPP GDP)	-1.49423	1.21706	-1.22774	0.24131
Foreign direct investment, net inflows (% of GDP)	0.04257	0.07533	0.56514	0.58160

Table 5-28 Access to Electricity Impact Results (with control variables): Chile

5.2.2.8 Corruption Perception Index

Historical data for the Chilean CPI is available as of 1980. Although the first changes in the previously regulated electricity sector first started in 1978, the time range covered still allows adequate conclusions to be inferred from the results of the analysis. For the first methodology phase, only the electricity sector market structure has a statistically significant impact on the corruption in Chile, while the other SIRRE sub-indicators remain irrelevant. This results in the very low R-squared value of 0.457, which is far below 0.75 and disallows CPI future trend prediction using the SIRRE sub-indicators.

Country: Chile *R-squared: 0.4570* *Observations: 34* *Dependent Variable: Corruption Perception Index*	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.30109	0.24477	1.23012	0.22854
Public Ownership	0.04563	0.04603	0.99131	0.32973
Vertical Integration	-0.03189	0.43117	-0.07397	0.94154
Market Structure	-0.35245	0.08722	-4.04114	0.00036

Table 5-29 Corruption Perception Index Impact Results: Chile

As is custom for the second methodology phase, control variables were added to the MLR equation. The author wanted to include the energy intensity variable, data for which was only available from 1990 onwards.

This means that although some analyzed case-studies have more data available, the only actually used information was for the timeline 1990-2013. For Chile, the energy intensity did not have tremendous results, but still had a p-value < 0.1, just as the unemployment control variable, while all others appear to be irrelevant. As for the SIRRE sub-indicators, only three were analyzed and public ownership was disregarded since for the timeline of 1990-2013, it boasts a score of 0 all the way throughout and would only result in a number error to be displayed as a p-value. Of the three analyzed sub-indicators, only vertical integration is statistically significant (< 0.05). The "bad" results are accompanied with the corresponding "bad" R-squared value that is above 0.75, but still very low if taken into consideration that six control variables were included into the equation.

Country: Chile ***R-squared: 0.8079*** ***Observations: 24*** ***Dependent Variable: Corruption Perception Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.52363	0.38124	1.37349	0.19120
Vertical Integration	1.95692	0.80895	2.41908	0.02976
Market Structure	0.08137	0.14981	0.54317	0.59555
GDP/capita (current US$ per capita)	1.67E-04	9.49E-05	1.76020	0.10019
GHGs/capita (kt of CO2 equivalent per capita)	213.75963	448.32878	0.47679	0.64087
Unemployment, total (% of total labor force)	0.27647	0.14364	1.92474	0.07483
Inflation, consumer prices (annual %)	-0.0155	0.0379	-0.41004	0.68798
Energy intensity (MJ/$2011 PPP GDP)	-1.41957	0.78867	-1.79995	0.09345
Foreign direct investment, net inflows (% of GDP)	-0.03326	0.05108	-0.65120	0.52546

Table 5-30 Corruption Perception Index Impact Results (with control variables): Chile

5.2.3 Derived New Knowledge and Discussion of Results

The fact that the first deregulation measures were introduced in the Chilean electricity sector as early as 1978 poses a unique problem for this case-study. Furthermore, the almost linear path of further deregulation, demonstrated by the overall SIRRE behavior seen in Figure 5.4, additionally exacerbated the problem. The difficulty is namely that it cannot be clearly differentiated what the impacts of electricity system deregulation are and which are simply the effect of the country's increasing human development and growing economy. This is due to the fact that data is almost only available for the time-period after electricity sector reforms already commenced and none for the time when it was still strictly regulated. This problem is not found in the other case-studies, since they deregulated their systems much later and data is available for the time when the system was still regulated as well as after reforms began.

Although all SIRRE sub-indicators correlate with the Shannon's diversity index, not all their coefficient signs are the same. The negative coefficient sign of the public ownership, vertical integration and market structure sub-indicators show that the more the electricity sector is deregulated, the more diverse its power generation mix becomes. The opposite is true for the entry regulation sub-indicator. A possible explanation is that allowing third-party access to the transmission grid and the introduction of a wholesale market with free electricity supplier choice for customers does not diversify the fuels for power generation, but rather causes the opposite.

Chile relied predominantly on hydro power generation as its primary electricity fuel source at the beginning of the analyzed timeline. The installed hydro power capacity was not sufficient to supply the increasing electricity demand, which is why thermal power plants had to be installed. This is the reason why the Shannon's diversity index increases when CO2 emissions from the electricity and heat production increase as well. Likewise, as the net energy imports increase (obviously non-hydro fuels), so does the Shannon's diversity index.

The deregulation of the electricity sector in Chile has little influence on the energy intensity of the country. This might be because the timeline considered is 1990-2013, whereas the major reforms occurred before

1990. Nevertheless, several relationships between control variables and the Chilean energy intensity could be distinguished. As unemployment, inflation and energy use per capita increase, so does the energy intensity. The explanation is simple. If a higher percentage of the population does not work, it takes more energy to produce the same GDP since the unemployed population is still using energy but not contributing to the country's GDP. As inflation increases, the purchasing power decreases, which is the reason for the increase in energy intensity (MJ/$2011 PPP GDP) due to the unit it is measured with. As for the per capita energy use, the cause is evident. Additionally, Chile's energy intensity decreases with an increase in the oil price since the same amount of energy costs more to purchase.

In contrast to the energy intensity, the Chilean electricity reforms had a huge impact on the per capita energy use. This is clearly shown through the extremely low p-values of all the sub-indicators. With the majority of the sub-indicator coefficient signs being negative, this means that the more deregulated the electricity sector in Chile becomes, the higher the energy use per capita is. As explained previously, it is not completely certain if this is due to electricity sector deregulation or simply increased development and a growing economy. Regarding the control variables, it can be said that as the electric power consumption, GDP/capita and GHGs/capita increase, so does the per capita energy use. The obtained results are nothing new, but simply a confirmation of the logical assumption and prediction.

The energy that Chile imports is of the nature that emits GHGs, i.e. coal, oil or gas. Therefore, with the increase of net energy imports, the GHGs/capita increase accordingly. The opposite is also true and can be a variable used for predicting the trend of future energy imports. As for the impact of the electricity sector deregulation, it is visible that as the SIRRE indicator decreases, the net energy import increases. However, can it be said that deregulation causes energy imports to rise? The author believes this is not the case for Chile. Rising net energy imports are assumed to be simply a symptom of increasing energy demand and exhausted local fuel resources.

None of the control variables prove statistical significance when the relationship with electric power T&D losses was analyzed. The coefficient signs are irrelevant, since they can simply be disregarded and do not play a role in predicting future trends of the dependent variable. The variating signs of the SIRRE sub-indicators further exacerbates phenomenon explanation. However, it can still be said that with increasing wholesale market establishment and third-party access to the transmission grid, the T&D losses increase. This is the opposite with public ownership and market structure, where increasing deregulation signifies a decrease in T&D losses. In conclusion, it is not evident what exactly the effect of electricity sector deregulation on the T&D losses is, with different sub-indicators leading to different explanations. The fact that generators pay for the transmission of their produced power to customers, also known as "merchant transmission", could be the cause behind this ambiguity.

The analysis of the access to electricity indicator as a dependent variable results in the conclusion that the more Chile deregulates its electricity sector, the higher the electrification rate will be. A current electrification rate of almost 100% means that further deregulation cannot increase the percentage of the population with access to electricity as it is already maxed out. Although this is true for Chile, the lesson learned in this country can have significant policy recommendation implications for leaders of other developing countries with extremely low electrification rates as is the case for the most part of sub-Saharan Africa. What can be further derived from this analysis is that the higher the per capita electric power consumption, the higher the electrification rate will be. This fact is obvious and has no further policy implications.

From the CPI results obtained, it can be deduced that the lower the market share of the largest company in the different segments of the electricity sector (generation, import and supply) is, the higher the CPI index is and the less corrupt Chile becomes. This result is logical, due to the fact that when corruption is prevailing, market power is usually concentrated within one big actor, whereas the distribution of power (in this case through market shares) thwarts the increase of corruption. However, the Chile CPI analysis results do not allow strong conclusions to be inferred due to the lack of proven statistical significance which is made manifest through the low R-squared values.

5.3 India

5.3.1 Brief Country Description and Electricity System History

Mahatma Gandhi's non-violent efforts freed India from British rule and helped it gain its independence in 1947. India is the seventh-largest country by landmass located in south Asia and the second most populated country on earth with a population of 1.3 billion inhabitants, en-route to surpassing China. The electricity sector reform that started in 1991 was only a small part of nation-wide market-based economic reforms catapulting into unprecedented development and GDP growth when it became one of the fastest growing major world economies. Due to this tremendous growth, it is now considered a newly industrialized country and has the potential to follow China as a growing world superpower, but at the time of the electricity sector reforms it was definitely considered a developing country, hence the analysis.

India is the fourth-largest consumer of energy in the world and yet it ironically has the largest population of un-electrified households, i.e. about 300 million individuals. India's power sector was dominated by state-owned vertically integrated entities called State Electricity Boards (SEBs) that were responsible for power generation, transmission and distribution. [79] The obvious signs of electricity theft, uncollected bills, mammoth T&D losses and most importantly the inability to provide a consistent and reliable power supply to customers meant that this system was failing and drastic changes were required. [80]

Although electricity reforms started in 1991, the failure to enforce them provided mediocre results. The impressive growth in installed capacity was not enough to meet the demands of the growing electricity consumption. Despite the cheap tariffs, the poor quality of the government-provided electricity forced many private companies to install their own electricity generation units, so-called captive power generation, to ensure that they could continue to be able to compete economically. The poor financial state and increasingly insolvent SEBs did not have sufficient resources to finance expansion programs or raise investments from other alternative sources. The solution was privatization and competition. [81]

This process was accelerated through the Electricity Act of 2003 [82], which called for mandatory unbundling of the SEBs into separate and independent companies for generation, transmission and distribution. In the distribution sector, most SEBs have unbundled, but private participation is limited to 15 distributor licenses while most distribution is still state-owned. [79] The most important changes due to the 2003 Electricity Act are allowed transmission and distribution licenses, stricter punishment in case of electricity theft, consumer compensation in case of inadequate delivery, allowed bidding and free entry to generation market. [83]

Due to the electricity sector reforms, numerous institutions were either created or given new tasks and responsibilities. The Central Electricity Authority (CEA) is e.g. responsible for collecting and analyzing data for the electricity sector, monitoring electricity sector performance, providing policy recommendations and advising the Ministry of Power on technical issues. The Ministry of Power, created in 1992, is the central government body that regulates the electricity sector in India and is responsible for the administration of the Electricity Act of 2003. [84] Furthermore, the technical standards for grid connectivity, electric transmission lines and the construction of power plants are set likewise by the CEA. This means that companies willing to construct power plants or transmission lines need to comply with the standards set by the CEA even though they might be conservative and therefore not optimal, a glitch in the 2003 Act. [85]

Each Indian state has its own State Electricity Regulatory Commission (SERC), which is tasked with the monitoring of retail pricing, irrespective of whether the state-run companies implement these decisions or not. This way, the state utilities are held accountable to their pricing regulations. The SERCs are also responsible for the implementation of the renewable power obligation (RPO) targets by ensuring that all distribution companies draw a percentage of renewable energy, including solar. As of 2013, all distribution companies are under legal obligation to purchase 3.4% renewable energy under the surveillance of the responsible SERCs. [86] Even if privatization of the different electricity sectors proceed and the SERCs increase tariffs, high levels of corruption and theft continue to plague the sector. [80]

5.3.2 Indicator Analysis and Results

The data for the SIRRE sub-indicators of India is only provided for the years 2008 and 2013. This leaves a lot of work to be done if a quantitative analysis is to be made regarding the impacts of electricity reforms. This has been done in 5.3.2.1 to 5.3.2.4 and the result can be seen in the following figure showing each SIRRE sub-indicator and the overall SIRRE score. The reader is hereby reminded that 6 stands for total regulation while 0 means complete deregulation of the electricity sector.

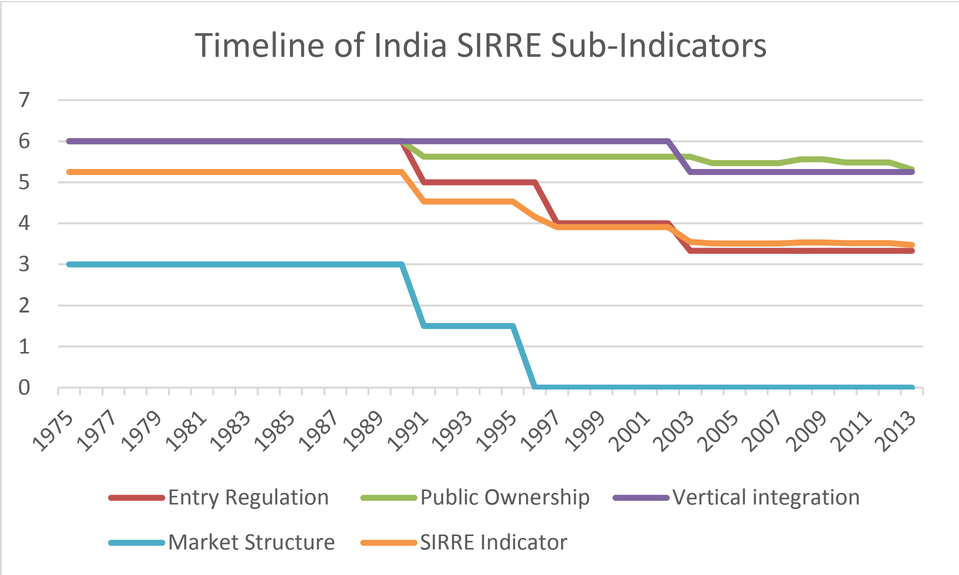

Figure 5.5 SIRRE Sub-Indicators vs. Time: India

5.3.2.1 Entry Regulation

The Entry Regulation SIRRE sub-indicator is obtained by answering questions ER.Q1-Q4 in Table 4-1 and calculating the average of the individual scores of each question. This has to be done for the entire timeline under consideration, whereby changes only tend to occur in the years where the reforms were implemented or acts enforced. The obtained timeline of India's Entry Regulation SIRRE sub-indicator is shown in Figure 5.6 below.

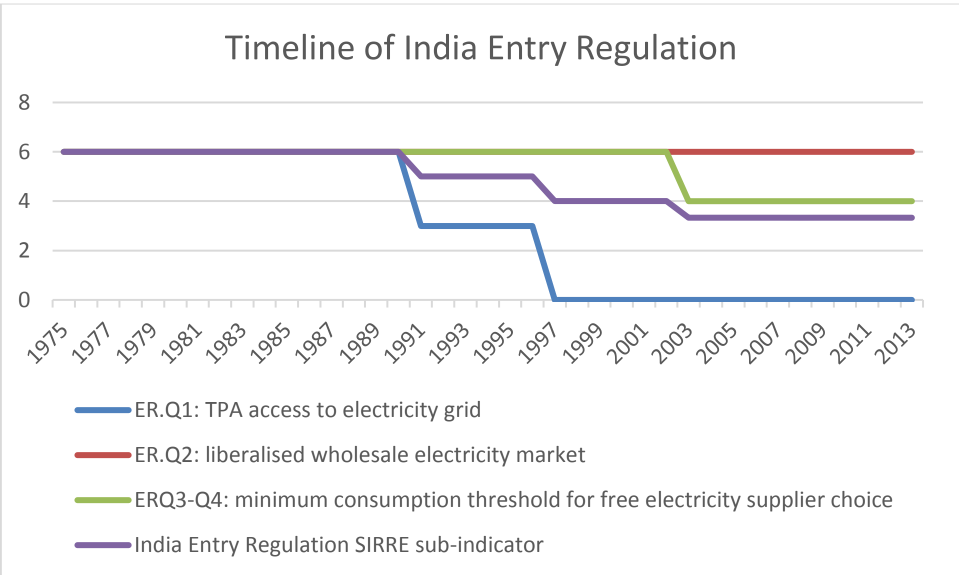

Figure 5.6 Entry Regulation vs. Time: India

India's electricity reforms commenced in 1991. Therefore, it can be assumed that all questions concerning entry regulation prior to 1991 can be answered with a 6, implying total state control and regulation. However, the reforms of 1991 lacked success and the only thing that changed was that third-party generators were now allowed to sell their power to the grid under negotiated terms with the government that had to approve the proposal. In 1996, the government allowed direct approval under certain conditions, meaning that third-party access to the electricity transmission grid was totally regulated now, earning a 0 on ER.Q1. [81]

The 2003 Electricity Act allowed surplus energy generated by captive power plants to be sold to the grid, which created a situation, in which several generators and distributors compete for customers in a bulk market. However, a wholesale market (which is **not** a bulk market) is necessary for a competitive retail market where customers can choose their own electricity providers. This is not yet the case in India, but a competitive bulk market is an important predecessor of a wholesale market, and given the appropriate amendments to the electricity act, can evolve into one. Nevertheless, India scores a 6 on ER.Q2 through the whole timeline. [80]

Without a wholesale market, the only way to achieve an overall Entry Regulation score of 3.33 in 2008, which is given by the OECD [37], is to score either 0 and 4, or 3 and 1 on ER.Q1 and ER.Q3-4, respectively. At first, it was thought that ER.Q3-4 scored a 6 since customers cannot choose their electricity providers. This is however not the case in India, since the 2003 Electricity Act allows customers with a consumption of over 1000 MWh to choose their electricity supplier. This is logical since free entry into the generation sector is granted due to delicensing and elimination of techno-economic clearances for all generation projects (except hydro); ER.Q1 thereby scores 0, which means that ER.Q3-4 must score a 4. [83]

5.3.2.2 Public Ownership

NTPC Ltd. is India's largest electricity generating company with an installed capacity of 51,527MW and a diversified fuel mix. Although it only owns 17.73% of national installed capacity, it provides 24% of total power due to higher efficiency than other companies. It was completely owned by the government of India until 2004, the year when it first divested 10.5% of the company and became a listed company. The shareholding of the government was further reduced with a public offer in 2010 from 89.5% to 84.5%. Another 9.5% were divested in 2013, the last analyzed year, pushing the shareholding of the government down to 75%. More divestments have occurred since then, but will not be discussed in this analysis. [87]

The largest power transmission company in India is Power Grid Corporation of India Limited (POWERGRID). It has been wholly owned by the Indian government since its incorporation as a public limited company on October 23, 1989. [88]

The power distribution sector in India is divided into many small companies, each distributing the transmitted electricity within their province. Therefore, there is not one single company dominating the rest or having the by far highest market share. Since POWERGRID also has power distribution on its product portfolio, it is assumed to be the largest distributor of electricity. As explained before, it is completely state-owned.

Since the overall Public Ownership score is known to be 5.56 and 5.31 in 2008 and 2013, respectively, and all other sub-indicators are known, it is possible to calculate the electricity supply public ownership score. The government owns 81% and 79% of the largest electricity suppliers in 2008 and 2013, respectively. Furthermore, it is known that SEBs provided 75% of supply and most of the distribution facilities to customers in 1994. For the years in between, step functions until the year with the next change are simply implemented. [80], [81]

This timeline obtained using the data for the Public Ownership sub-indicator is depicted in Figure 5.7 below.

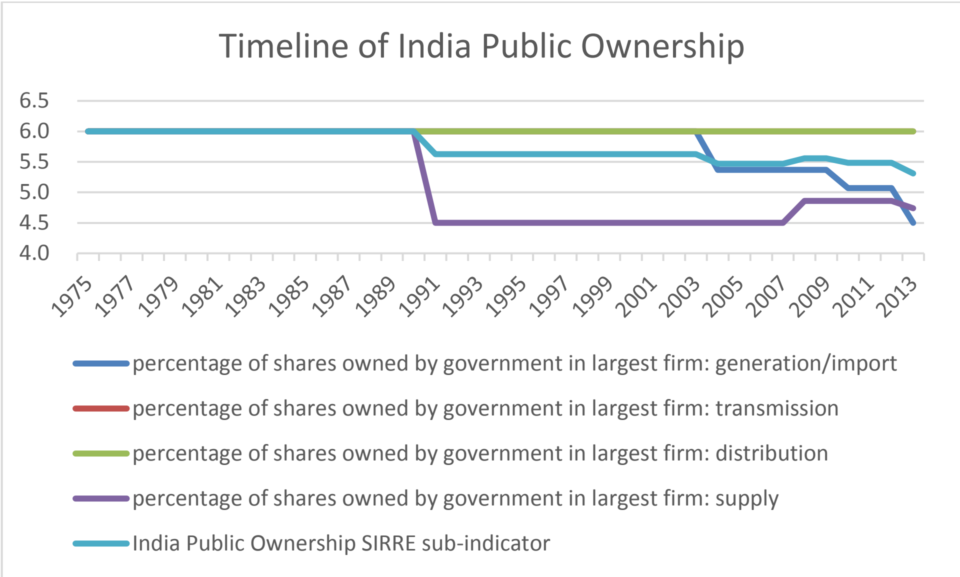

Figure 5.7 Public Ownership vs. Time: India

5.3.2.3 Vertical Integration

Before the Electricity Act of 2003, there was no legal or accounting separation of any kind between the different segments of the electricity sector. This only changed with the enforcement of this act, although the change is not particularly significant. The only segments that experienced any alteration were the distribution and supply segments that received accounting separation. The overall Vertical Integration score therefore dropped from 6 to 5.25 in 2003 and has remained constant since then.

5.3.2.4 Market Structure

It is true that the afore-mentioned NTPC Ltd. is India's largest electricity generating company today with an installed capacity of over 50GW. Although this remains true, it does not own more than 16% of the installed capacity market-share. This figure varies between 13% and 17% over the years (1990-2013). The data for the overall Indian installed power capacity is provided by the United Nations (UN) database [89], whereby the installed NTPC capacity is taken from their website [90].

Before the electricity reform took place, the government of India had total control of the electricity sector. However, in contrast to other countries where this is done in the form of one company, in India this was achieved through multiple companies due to the sheer immensity of its population and thereby energy demand. Telangana Power Generation Corporation, Gujarat Urja Vikas Nigam Limited and Tamil Nadu Electricity Board are but a few of the available examples of such companies. For the score of the corresponding question (MS.Q1-2), this means a score of 0 along the entire timeline.

The given score of 0 for the Market Structure indicator in 2013 means that both the market share of the largest company in generation as well as supply score 0. The historical market share for supply is not given directly, but in this case it is assumed to have descended to below 90% in 1991 and to below 50% in 1996, corresponding with the changes in the Entry Regulation sub-indicator. The overall SIRRE score for 2008 is 4.72, however the Market Structure sub-indicator was not taken into consideration and solely the other three sub-indicators were averaged in order to obtain this value. Since the Market Structure sub-indicator was specifically calculated, the new average of all four sub-indicators and overall score becomes 3.54 in 2008, notably less than if this sub-indicator would have been ignored.

5.3.2.5 Shannon's Diversity Index

The low R-squared value obtained during the first methodology phase summarizes the validity of the results well in terms of statistical significance. The public ownership SIRRE sub-indicator is relevant with its p-value < 0.01 while the p-value for entry regulation is merely below 0.1. The Indian results for the Shannon's diversity index show that the deregulation of the Indian electricity sector does not have profound effects on the diversity of the power generation fuel mix. The results of the first phase of the methodology are depicted in Table 5-31.

Country: India ***R-squared: 0.6491*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.06573	0.03530	-1.86212	0.07125
Public Ownership	0.29951	0.07355	4.07214	0.00026
Vertical Integration	-0.03829	0.04219	-0.90772	0.37042
Market Structure	-0.00899	0.02346	-0.38324	0.70393

Table 5-31 Shannon's Diversity Index Impact Results: India

Although a few conclusions can be derived from the results obtained by adding control variables into the MLR equation in methodology phase II, Table 5-32 is not the highlight of this thesis. While public ownership gives up its statistical significance, the p-value of entry regulation decreases to a level that is below 0.05. The constant coefficient sign found in the two tables for public ownership and entry regulation facilitates the conclusion and policy recommendation formulation found in the next chapter. Of the analyzed control variables, electric power consumption has a p-value of < 0.05 and GDP/capita boasts a p-value of < 0.01. This implies statistical significance for both variables and their ability to contribute to trend forecasting for the diversity index.

Country: India ***R-squared: 0.8510*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.07583	0.02777	-2.73029	0.01082
Public Ownership	0.07963	0.07067	1.12679	0.26939
Vertical Integration	0.01061	0.03875	0.27378	0.78626
Market Structure	-0.01723	0.01791	-0.96209	0.34424
Electric power consumption (kWh per capita)	-0.00095	0.00038	-2.52022	0.01771
GDP/capita (current US$ per capita)	2.59E-04	8.69E-05	2.98263	0.00586
GHGs/capita (kt of CO2 equivalent per capita)	-1.81390	133.21506	-0.01362	0.98923
Energy imports, net (% of energy use)	0.0025	0.0027	0.93005	0.36029
Foreign direct investment, net inflows (% of GDP)	0.00299	0.00894	0.33388	0.74096
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.00013	0.00160	0.08280	0.93460

Table 5-32 Shannon's Diversity Index Impact Results (with control variables): India

5.3.2.6 Energy Intensity

For the first phase of the energy intensity analysis as a dependent variable, all the SIRRE sub-indicators are statistically irrelevant except the vertical integration sub-indicator (< 0.01), which expresses how independent each electricity sector segment (i.e. generation, transmission, distribution and supply) is from the others. The already remarkably high R-squared value is a good sign for the weight that the Indian deregulation of the electricity sector has on the country's energy intensity. Energy intensity is a measure for how efficiently a country transforms a unit of energy into GDP and therefore of particular importance for a country like India, that is on its way to becoming tomorrow's superpower.

Country: India R-squared: 0.8992 Observations: 24 Dependent Variable: Energy Intensity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	0.41325	0.43774	0.94406	0.35699
Public Ownership	-0.06238	1.11133	-0.05613	0.95582
Vertical Integration	1.67574	0.54518	3.07374	0.00625
Market Structure	0.30291	0.29201	1.03733	0.31260

Table 5-33 Energy Intensity Impact Results: India

Since the data for unemployment in India was not provided by the World Bank [14], it was taken from [52] for 1991-2013 with the assumption that the unemployment in 1990 is equal to that in 1991. As for the SIRRE sub-indicator results of the second methodology phase (see Table 5-34), they are identical to those without the control variables depicted in Table 5-33, with the exception of the p-value of vertical integration not being < 0.05. Of the analyzed 8 control variables, 5 are statistically irrelevant, the p-value of net energy imports is below 0.01, GDP/capita is below 0.05 and the per capita energy use is below 0.1. The resulting high R-squared value is due to the inclusion of numerous control variables and their statistical significance.

Country: India R-squared: 0.9925 Observations: 24 Dependent Variable: Energy Intensity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.24425	0.20279	-1.20448	0.25368
Public Ownership	-0.17204	0.49730	-0.34594	0.73591
Vertical Integration	0.91658	0.33386	2.74539	0.01905
Market Structure	0.17778	0.10825	1.64225	0.12879
Europe Brent Spot Price (US$ per Barrel)	0.00243	0.00462	0.52557	0.60962
Access to electricity (% of population)	-0.00034	0.01942	-0.01760	0.98627
GDP/capita (current US$ per capita)	-0.00196	0.00088	-2.23487	0.04712
GHGs/capita (kt of CO2 equivalent per capita)	1098.1701	958.2174	1.14606	0.27609
Energy imports, net (% of energy use)	-0.18680	0.04623	-4.04049	0.00195
Energy use (kg of oil equivalent per capita)	0.01017	0.00556	1.82846	0.09470
Unemployment, total (% of total labor force)	-0.18193	0.20821	-0.87381	0.40090
Inflation, consumer prices (annual %)	0.00439	0.01669	0.26283	0.79754

Table 5-34 Energy Intensity Impact Results (with control variables): India

5.3.2.7 Energy Use

Table 5-35 displays the attained results for the first phase of the methodology. Market structure and entry regulation are statistically irrelevant while the p-value of vertical integration is < 0.05 and that of public ownership is < 0.1. It is noticeable that all coefficient signs for the first round of results are negative (i.e. <0), although not all are statistically significant. For the energy use analysis, it is key to include certain control variables that aid in future trend prediction, of which the results are shown in Table 5-36.

Country: India R-squared: 0.8590 Observations: 39 Dependent Variable: Energy Use	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-15.64532	40.78278	-0.38363	0.70364
Public Ownership	-159.03044	84.97517	-1.87149	0.06990
Vertical Integration	-102.88240	48.73878	-2.11089	0.04221
Market Structure	-4.04530	27.09862	-0.14928	0.88221

Table 5-35 Energy Use Impact Results: India

The second set of results is presented in Table 5-36. The extremely high R-squared value of 0.9979 (very close to 1, meaning complete explanation of the observed data) allows the reader to hope for similar "good" results in terms of low p-values and high statistical relevance. This is true and can be seen by the significance of the electric power consumption, GDP/capita and GHGs/capita, the first one having a p-value of <<0.01 and the latter two having p-values < 0.05. Furthermore, the public ownership SIRRE sub-indicator becomes relevant with the decrease of its p-value to below 0.05.

Country: India ***R-squared: 0.9979*** ***Observations: 39*** ***Dependent Variable: Energy Use***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-4.65791	5.78642	-0.80497	0.42717
Public Ownership	31.18146	13.38104	2.33027	0.02671
Vertical Integration	6.40747	8.04758	0.79620	0.43217
Market Structure	-0.84910	3.61488	-0.23489	0.81589
Electric power consumption (kWh per capita)	0.31943	0.05963	5.35691	8.50E-06
GDP/capita (current US$ per capita)	0.03807	0.01433	2.65642	0.01253
GHGs/capita (kt of CO2 equivalent per capita)	62956.54	27018.24	2.33015	0.02671
Energy imports, net (% of energy use)	0.7968	0.4819	1.65348	0.10866

Table 5-36 Energy Use Impact Results (with control variables): India

5.3.2.8 Net Energy Imports

The results of the first phase of the methodology analysis of the net energy imports can be seen below as the dependent variable in Table 5-37. Only vertical integration shows signs of weak statistical significance with a p-value < 0.1, while the other SIRRE sub-indicators are not relevant to the analysis at all. The high R-squared value should not confuse the reader since it is only of any importance with corresponding high p-values, which is unfortunately not the case for India, and no relationships between the variable sets can be distinguished. As with the case of energy use, all coefficient signs are negative, which would mean in case of statistical relevance that the more deregulated the system is, the lower the net energy imports are. However, this conclusion cannot be reached due to low p-values.

Country: India ***R-squared: 0.9043*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-3.92295	2.98633	-1.31364	0.19776
Public Ownership	-2.98164	6.22232	-0.47918	0.63488
Vertical Integration	-6.47720	3.56891	-1.81490	0.07837
Market Structure	-0.77099	1.98430	-0.38854	0.70004

Table 5-37 Net Energy Import Impact Results: India

Table 5-38 shows the results of the second methodology phase, where the control variables are included for expected improved results. For the Indian net energy import case, this is not particularly true. All SIRRE sub-indicators are deemed statistically irrelevant and only one control variable, namely GDP/capita, shows a p-value of slightly below 0.1, which expresses weak significance. Although a high R-squared is obtained, if all variables with a p-value above 0.1 were omitted, the value would become unbelievably low and rendered useless. It is not possible to predict the future trend of net energy imports in India with the variables considered in this investigation.

Country: India R-squared: 0.9631 Observations: 39 Dependent Variable: Net Energy Imports	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-2.78214	2.40653	-1.15608	0.25709
Public Ownership	-1.32979	5.33780	-0.24913	0.80502
Vertical Integration	3.08080	2.99838	1.02749	0.31269
Market Structure	-0.74297	1.39412	-0.53293	0.59814
Electric power consumption (kWh per capita)	0.00362	0.02688	0.13483	0.89368
Energy mix diversification (Shannon's H)	15.51447	14.70069	1.05536	0.29998
GDP/capita (current US$ per capita)	0.01085	0.00632	1.71564	0.09690
GHGs/capita (kt of CO2 equivalent per capita)	-803.31	10493.45	-0.07655	0.93950
Foreign direct investment, net inflows (% of GDP)	0.25222	0.70855	0.35596	0.72444

Table 5-38 Net Energy Import Impact Results (with control variables): India

5.3.2.9 Electric Power T&D Losses

The results obtained for the analysis of electric power T&D losses in the first round of the methodology are depicted in Table 5-39. Surprisingly, although three of the four SIRRE sub-indicators are statistically significant, the R-squared value remains below 0.75 – a frustrating phenomenon. Market structure is irrelevant in this analysis, while entry regulation and vertical integration boast a p-value of < 0.05 and public ownership a value of even < 0.01.

Country: India R-squared: 0.7002 Observations: 39 Dependent Variable: Electric T&D Losses	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-4.52700	2.05087	-2.20736	0.03414
Public Ownership	16.77545	4.27320	3.92573	0.00040
Vertical Integration	4.98142	2.45096	2.03244	0.04998
Market Structure	-1.42525	1.36273	-1.04589	0.30299

Table 5-39 Electric Power T&D Losses Impact Results: India

Table 5-40 depicts the results of methodology phase II with the included control variables. A number of them do prove statistical significance such as CO2 emissions from electricity and heat production (% of total fuel combustion) and electricity production from renewable sources, excluding hydroelectric (kWh), both with p-values < 0.01, energy mix diversification (Shannon's H) with a p-value < 0.05 and lastly electric power consumption (kWh per capita) with a p-value of < 0.1. In this second methodology phase, the only SIRRE sub-indicator that is statistically relevant is public ownership with a p-value of < 0.05.

Country: India R-squared: 0.8947 Observations: 39 Dependent Variable: Electric T&D Losses	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-2.50994	1.57900	-1.58957	0.12278
Public Ownership	9.89580	3.65597	2.70675	0.01127
Vertical Integration	1.01771	1.94690	0.52273	0.60513
Market Structure	-0.33182	0.91489	-0.36268	0.71947
Electric power consumption (kWh per capita)	-0.03319	0.01777	-1.86830	0.07185
Energy mix diversification (Shannon's H)	26.72727	10.27471	2.60127	0.01447
GDP/capita (current US$ per capita)	-0.0068	5.32E-03	-1.27757	0.21154
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.55620	0.11686	4.75971	4.95E-05
Electricity production from renewable sources, excluding hydroelectric (kWh)	2.88E-10	9.28E-11	3.10074	0.00427

Table 5-40 Electric Power T&D Losses Impact Results (with control variables): India

5.3.2.10 Access to Electricity

Before the presentation of the results in the following two tables, the author would like to point out the data set has been corrected. Two data points, notably years 2001 and 2011, are perceived to be measurement errors since it is not logical for the electrification rate to decrease except in exceptional cases such as in war, famine or natural catastrophes. This has not been the case in India for 2001 or 2011. In these years, a severe dip in the otherwise linear increase of the electrification can be seen clearly in Figure 5.8 below. The author has set out to correct these errors and the new values are simply the averages of the years before and after the years in question. The new values are 60.93% and 78.1% for 2001 and 2011, respectively. The author hereby asks the reader to check for himself the World Bank study [91] on the electrification rate in India.

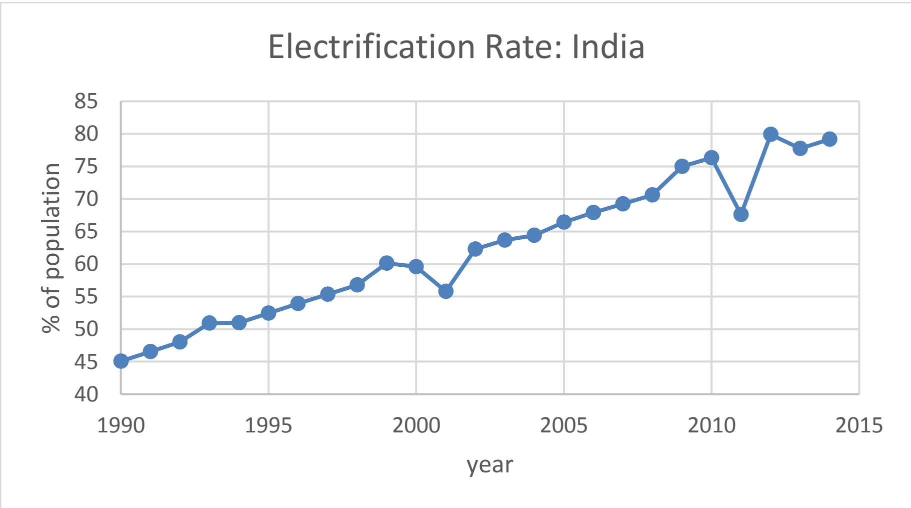

Figure 5.8 Access to Electricity [%] vs. Time: India

The results of the impacts of the deregulation of the Indian electricity sector on the access to electricity can be seen in Table 5-41 below. Of the four analyzed SIRRE sub-indicators, only vertical integration shows weak statistical significance (p-value < 0.1), with the others being completely irrelevant. This shows that for the case of India, the electricity sector reforms had little to do with the strongly increasing electrification rate. It must be noted that the results displayed in Table 5-41 below were obtained with the corrected data for 2001 and 2011 as explained previously.

Country: India ***R-squared: 0.8445*** ***Observations: 24*** ***Dependent Variable: Access to Electricity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-4.68758	4.94816	-0.94734	0.35536
Public Ownership	-6.31585	12.56222	-0.50277	0.62091
Vertical Integration	-12.19175	6.16262	-1.97834	0.06257
Market Structure	-1.78198	3.30083	-0.53986	0.59557

Table 5-41 Access to Electricity Impact Results: India (corrected)

Including the control variables in the MLR equation leads to the results in Table 5-42. The extremely high R-squared value should not misguide the reader to believe that the results are "good". This is certainly not the case, since none of the analyzed control variables nor SIRRE sub-indicators show any signs of statistical significance. This does not allow any conclusions to be inferred or policy recommendations to be derived. The results for the access to electricity impact indicator in India are hereby declared worthless.

Country: India ***R-squared: 0.9918*** ***Observations: 24*** ***Dependent Variable: Access to Electricity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-2.64126	1.97601	-1.33666	0.20612
Public Ownership	6.62380	4.96871	1.33310	0.20725
Vertical Integration	1.09823	2.53990	0.43239	0.67313
Market Structure	0.06899	1.11513	0.06186	0.95169
Electric power consumption (kWh per capita)	0.03016	0.02780	1.08471	0.29936
Energy mix diversification (Shannon's H)	-0.60924	18.91483	-0.03221	0.97483
GDP/capita (current US$ per capita)	0.01164	0.01035	1.12470	0.28271
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.40666	0.31667	1.28418	0.22332
Europe Brent Spot Price (US$ per Barrel)	-0.05014	0.04165	-1.20375	0.25190
Energy intensity (MJ/$2011 PPP GDP)	-1.38885	2.27499	-0.61049	0.55293
Foreign direct investment, net inflows (% of GDP)	0.44507	0.58584	0.75972	0.46209

Table 5-42 Access to Electricity Impact Results (with control variables): India

5.3.2.11 Corruption Perception Index

Table 5-43 depicts the results of methodology phase I, where the impacts of the deregulation of the electricity system on the CPI are analyzed. The results are very similar to those of the access to electricity impact indicator in the sense that only vertical integration shows signs of weak statistical significance (p-value < 0.1), with the other SIRRE sub-indicators being irrelevant. On the other hand, the R-squared value of 0.46 is far less than the one obtained in the previous analysis (access to electricity), although both have similar p-values.

Country: India ***R-squared: 0.4602*** ***Observations: 34*** ***Dependent Variable: Corruption Perception Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.09989	0.32374	-0.30855	0.75987
Public Ownership	0.80979	0.68083	1.18942	0.24392
Vertical Integration	-0.74892	0.38753	-1.93253	0.06311
Market Structure	0.17320	0.21514	0.80505	0.42734

Table 5-43 Corruption Perception Index Impact Results: India

The results of the second methodology phase are displayed in Table 5-44 below. Qualitatively, exactly the same results were obtained as in the previous analysis (access to electricity), namely worthless results. All p-values, i.e. those of the SIRRE sub-indicators as well as those of the control variables, were above 0.1. This translates into absolute statistical insignificance for every variable considered in the analysis and there is no way any conclusion or policy recommendation can be derived out of these results. It has to be said that the results for Chile were definitely "more successful" than those for India, but results are results and cannot be changed but must be presented the way they are.

Country: India ***R-squared: 0.8492*** ***Observations: 24*** ***Dependent Variable: Corruption Perception Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.09586	0.19650	-0.48782	0.63380
Public Ownership	0.18736	0.54657	0.34280	0.73723
Vertical Integration	-0.12958	0.30640	-0.42293	0.67926
Market Structure	0.17219	0.13361	1.28878	0.21994
GDP/capita (current US$ per capita)	-0.00044	0.00067	-0.66256	0.51918
GHGs/capita (kt of CO2 equivalent per capita)	1195.212	824.400	1.44980	0.17081
Unemployment, total (% of total labor force)	0.15753	0.19883	0.79227	0.44242
Inflation, consumer prices (annual %)	0.02779	0.01874	1.48308	0.16189
Energy intensity (MJ/$2011 PPP GDP)	-0.11113	0.20809	-0.53405	0.60232
Foreign direct investment, net inflows (% of GDP)	0.07807	0.07231	1.07957	0.29996

Table 5-44 Corruption Perception Index Impact Results (with control variables): India

5.3.3 Derived New Knowledge and Discussion of Results

Many conclusions are to be derived for the Indian electricity sector, as well as new recommendations for Indian policy makers. This has not been true for every analyzed impact indicator, seeing as statistical significance issues rendered many results worthless. Nonetheless, new knowledge was obtained and causalities were drawn out of the remaining analyzed indicators.

Before proceeding to the individual impact indicators, it is important to comment on the uniqueness of India's electricity system. Even before the start of electricity sector reforms, instead of organizing the sector through one vertically integrated state-owned company, numerous state-owned, geographically-bound regional electricity companies performed this task. The government of India organized the sector this way because of the enormous size of India's population, energy demand and therefore electricity system. This decentralized electricity sector responsibility and management is quantified in the market structure SIRRE sub-indicator. The fact that this market structure sub-indicator was statistically insignificant for every single analyzed dependent variable shows that it has no impact on market reforms. Therefore for the case-study of India, it can be deduced that it does not matter whether the sector is organized in small regional electricity companies or one big centralized company.

The deregulation of the Indian electricity sector has an ambivalent impact on the diversification of the power generation fuel source mix, which is quantified using the Shannon's diversity index. While increasing third-party access to the transmission grid and the establishment of a liberalized wholesale electricity market diversifies the Indian power generation fuel mix, the opposite is true with public ownership. If the state-owned shares of the largest company in every segment of the electricity sector increase, the energy mix becomes increasingly diversified. This seems counterintuitive and a possible explanation could be that when IPPs enter the competitive market, most of them focus on similar fuels for generating their power, thereby decreasing diversity.

As the electric power consumption per capita increases, the diversity of the power generation fuel mix decreases. This phenomenon can be explained by stating that at the beginning of the analyzed timeline India already had a notable share of coal-produced power (>50%). With increasing demand, India simply installed huge amounts of coal power plants that were locally available, resulting in this percentage increasing to > 75% in 2014. Furthermore, the diversification increases as the GDP/capita increases. This can be explained with the increasing share of renewable power technologies. 1986 was the first year India installed any renewable power and the share of electricity generated therewith increased to over 5% by 2014.

As the vertical integrity of the generation, transmission, distribution and supply segments of the Indian electricity sector increases, so does the energy intensity. This means that increasing, unbundling and separating the afore-mentioned segments leads to a higher efficiency in the sector and more GDP wrung out of every unit of energy. This is absolutely key for a country like India and should be on the mind of every Indian policy-maker dealing with energy issues.

Per definition, energy intensity is measured in unit of energy per unit of GDP (MJ/$2011 PPP GDP), which explains why it increases with increasing energy use and decreases with increasing GDP/capita. As net energy imports decrease, the energy intensity increases, which means that the economy is becoming less energy efficient. A possible explanation could be that if India uses local energy resources, it relies on coal that is available in abundance, whereas when energy resources are imported, it is mainly oil and gas. The reader is hereby reminded that oil and gas are more efficient energy resources than coal with greater extractable energy per unit.

Multiples factors influence the per capita energy use or are influenced by it. Whatever the case, when these variables are taken into consideration, a future trend can be accurately forecasted. As the electric power consumption per capita, GDP/capita and GHGs/capita increase, so does the energy use. This is nothing novel and has been witnessed in previous case-studies as well. The electricity consumption can be explained by its basically being integrated in the overall energy use. The GDP/capita can be explained by saying that as a country develops and its population becomes increasingly wealthy, they demand a higher quality of life, which corresponds with more electrical appliances in our world today. Last but not least, because India resides over a "dirty" power generation mix (a lot of coal), as the energy use increases, so do the GHG emissions. In the case of India, it is not clear how to interpret the results for the impacts of the electricity sector reforms due to the changing coefficient signs from negative to positive and the dominance of the control variables over the SIRRE sub-indicators.

The different SIRRE sub-indicators impact the electric power T&D losses of India differently. Increased third-party access to the transmission grid and the establishment of a liberalized wholesale electricity market is found to increase the T&D losses. On the other hand, a decrease in government-owned shares in the largest companies in the different electricity sector segments and vertical separation thereof decrease T&D losses. This is a perfect example of electricity sector deregulation impact ambiguity. In the case of India, vertical integration and public ownership have the most room for reform improvement and could thereby lead to a decrease in T&D losses. This may prove to be invaluable for a country like India that is continually plagued by extremely high T&D losses (as high as 28.24% in 2001).

It is found that an increase in diversity of the power generation mix, CO2 emissions from electricity and heat production and the electricity production from renewable non-hydro sources lead to a subsequent increase in T&D losses. An explanation cannot be provided at this point by the author and the reader is challenged to think of possible explanations for the witnessed phenomena.

The results obtained for the analysis of the Indian net energy imports, the electrification rate as well as the CPI do not allow any conclusions or policy recommendations to be deduced for lack of statistical significance.

5.4 Ghana

5.4.1 Brief Country Description and Electricity System History

Ghana is a country located along the Atlantic Ocean in West Africa and boasts a culturally, ethnically and religiously heterogeneous population of over 27 million inhabitants. The republic of Ghana gained its independence from the British on the 6th of March 1957 to become the first sub-Saharan African free nation. Due to Ghana's growing economy, increasing development and democratic political system, it has emerged as a regional power in the region. Although this remains true in West Africa, globally the country is still below average in terms of human development and GDP/capita. To a lesser extent today, but specifically at the time of the energy reform process, Ghana is considered a developing country.

Ghana's electricity sector is unique in the sense that it has mammoth hydro power potential. 1998 was the first year in Ghana's history that hydro power did not provide more than 99% of the generated electricity. For many years, the installed hydro power capacity sufficed to supply the country with electricity. However, due to recent (last 2 decades) economic development and rise in the electrification rate, more capacity is needed to fulfill the ever-increasing electricity demand. Among other reasons, this was a main cause for the implementation of the Power Sector Reform Programme (PSRP) by the Ghanaian government with the help of experts from Chile, where the electricity sector reforms were deemed successful. [92], [93]

Under pressure from the World Bank, Ghana began to deregulate and privatize several sectors of its economy. [94] This was done to a greater degree of success in some and to a lesser in others. In the Ghanaian electricity sector, the reforms came into effect in 1997, drastically altering the landscape of the sector. Prior to that, the Ministry of Energy and Mines was ultimately responsible for the electricity sector and helped by the Volta River Authority (VRA) and the Electricity Corporation of Ghana (ECG). While the VRA was responsible for power generation and transmission, the ECG's responsibilities contained mostly electricity distribution and supply to the customers. [92], [93]

With the Electricity Acts of 1997 (538 and 541), the VRA and the ECG were privatized and new institutions were put in place to regulate the electricity sector, namely the Energy Commission (EC) and the Public Utilities Regulatory Commission (PURC). Furthermore, the power generation market was opened for third-party access and IPPs to install own generation units and have access to the transmission grid, which was still owned by the VRA. After the transmitted electricity is transformed to a lower voltage, the ECG supplies the southern provinces, while the in-1987-established Northern Electricity Department (NED) supplies the northern part of the country. NED was legally transformed into the independent Northern Electricity Distribution Company (NEDCo), which was still wholly owned by the VRA. The structure of the Ghanaian market today is depicted in Figure 5.9 below. [95]

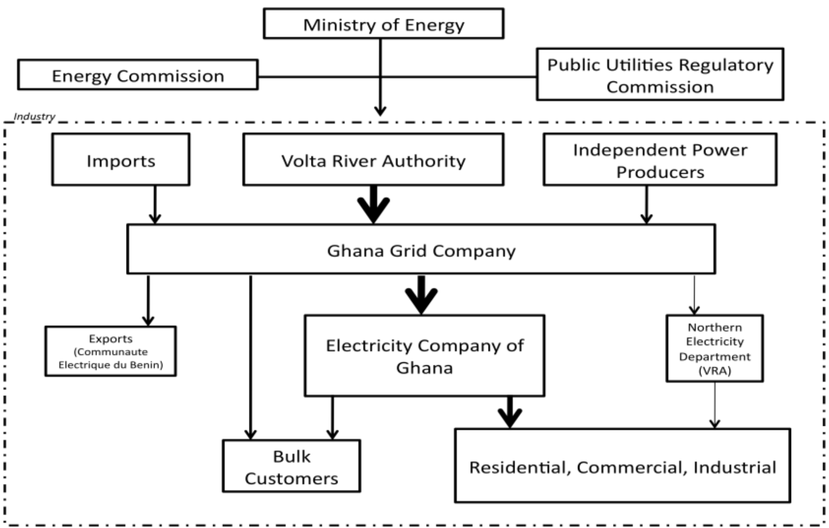

Figure 5.9 Structure of the Ghanaian Electricity Sector 2010, source [96]

With the Electricity Act 692 in 2005, the electricity transmission responsibilities were transferred from the VRA to the newly created Ghana Grid Company (GridCo). Although a legal separation was put in place, the ownership of both companies still fully belongs to the government of Ghana. Its main function is to undertake economic dispatch and transmission of electricity from wholesale suppliers to bulk customers. Further functions include metering and billing of customers, planning the transmission system and managing the wholesale power market. The idea behind the creation of GridCo was to promote competition by providing transparent, non-discriminatory and open access to all power market actors (generators and customers) in order to increase power delivery efficiency. [97]

The EC and PURC are regulatory institutions designed to complement each other and divide the responsibilities of managing the electricity between them. The PURC's main job is to provide guidelines on chargeable rate for electricity services, promote fair competition, examine and approve rates, protect the customer's interests and finally to monitor the standard utilities' performance. On the other hand, the responsibilities of the EC include granting licenses for the transmission, supplying and distributing wholesale electricity, enforcing the standards of performance for the relevant public utilities, ensuring uniform rules of practice and governing all segments of the electricity sector. [96], [98]

5.4.2 Indicator Analysis and Results

Figure 5.10 below depicts the scores of the SIRRE sub-indicators as well as the over SIRRE indicator for Ghana from 1975-2013. The graph shows the overall progress with notable years being 1987, 1997, 2000, 2005 and 2008. For a description of each SIRRE sub-indicator and how it was obtained for the analyzed timeline, the reader is hereby referred to sections 5.4.2.1 - 5.4.2.4.

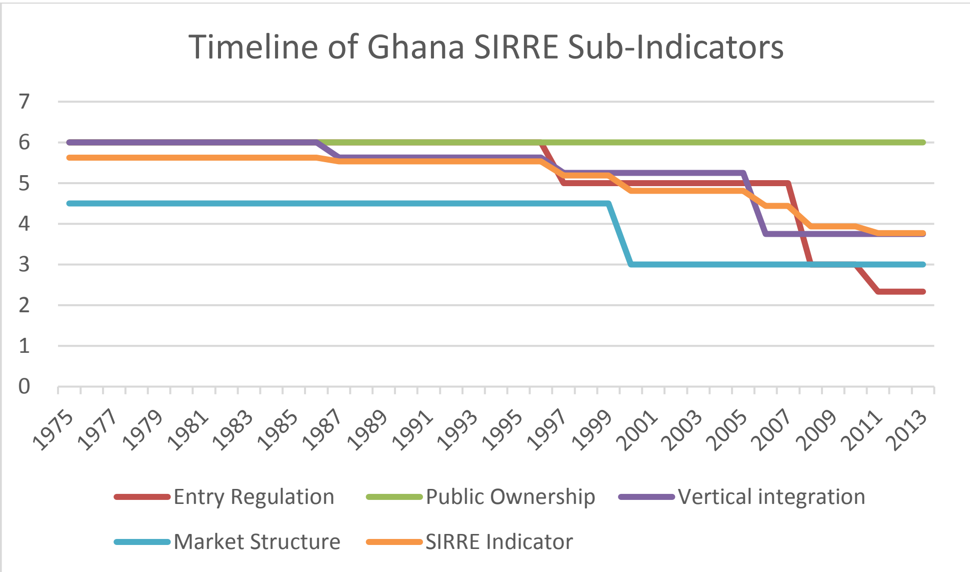

Figure 5.10 SIRRE Sub-Indicators vs. Time: Ghana

5.4.2.1 Entry Regulation

Prior to the energy reforms that commenced in 1997, the VRA was solely responsible for power generation with the exception of a few back-up units in the aluminum mines. Under pressure from the World Bank to implement deregulation measures in all sectors of the economy, the government of Ghana passed Electricity Acts 538 and 541 in 1997, which can be considered the start of the electricity sector reform. [94] They called for the unbundling of state-owned vertically-integrated companies and allowed the entrance of independent power producers, thereby granting third-party access to the transmission grid under negotiated terms. The jump to regulated third-party access is yet to be implemented and can be a future step of increased deregulation. [99], [100] As for the establishment of a liberalized wholesale market for electricity, this was finalized in 2008 when the parliament enacted the technical rules and operational regulations (legislative instrument 1934 and 1937, respectively) thereof. Prior to this date, no wholesale market was present except for the predecessor, a bulk market, where electricity is traded in bulk form through bilateral contracts. [101]

The freedom of customers to choose their electricity supplier is clearly regulated in Ghana. As of 2011, if a customer has satisfied the stipulated consumption requirement of (a) maximum demand of at least 1 MVA for a consecutive period of 3 months **or** (b) minimum annual energy consumption of 2000 MWh, then they are issued bulk customer permits allowing them to start trading as such on the deregulated wholesale electricity market. The customers not fulfilling those requirements cannot choose their electricity supplier, but are forced to accept their supplying company depending on their geographic location; i.e. in the south of the country ECG or NEDCo for the northern part. The only exception is the private distributing company, Enclave Power Company. [102], [103], [96]

The Entry Regulation SIRRE sub-indicator is plotted along with the sub-scores of ER.Q1-4 over time in Figure 5.11 below.

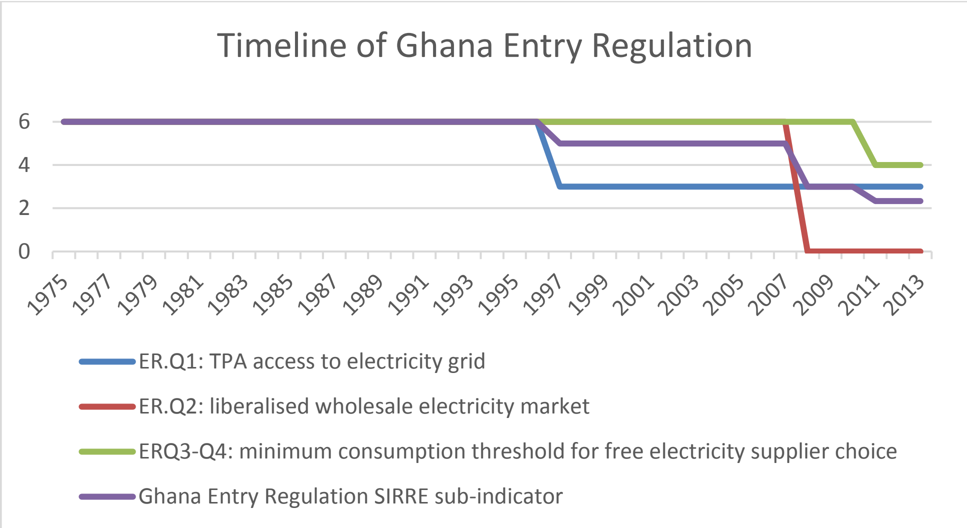

Figure 5.11 Entry Regulation vs. Time: Ghana

5.4.2.2 Public Ownership

Up until recent reforms, the only electrical power generating company in Ghana was the Volta River Authority (VRA), established in 1961 and owned to 100% by the Ghanaian Government. VRA owns a relatively diverse set of power plants today with mainly hydro, but also thermal and solar included in the mix in order to not only supply the Ghanaian but also foreign markets. [102] From the time of its establishment until today, the VRA has been wholly state-owned, entitling it to a Public Ownership sub-indicator score of 6 for generation.

Although GridCo was established for the exclusive operation of the national interconnected transmission system, with the aim of separating the transmission functions of the VRA from its power generating activities, 100% of the shares are still owned by the Government of Ghana, just as was the case under VRA leadership. This receives the public ownership transmission score of 6 for the entire analyzed timeline. [97], [104]

The distribution segment of the electricity has been successfully privatized through electricity reforms. Nevertheless, the wholly state-owned (therefore deserving a score of 6 along the whole analyzed timeline) distribution and supply Electricity Company of Ghana (ECG) holds more than 70% of the market shares. It distributes electricity mostly in the southern administrative regions while a like-wise state-owned electricity distributing company, i.e. the Northern Electricity Department (NEDCo) supplies the north of the country.

The only private distribution company is the Enclave Power Company but holds very few market-shares. [97]

The overall Public Ownership SIRRE sub-indicator scores a 6 for the entire analyzed timeline! This means that the state owns 100% of the largest company in every segment of the electricity sector. A depiction in the form of a graph is hence unnecessary.

5.4.2.3 Vertical Integration

As previously explained, the electrical transmission grid of Ghana was operated exclusively by the VRA until 2006. Up until that year, the VRA was responsible for power generation as well as its transmission, giving it a score of 6 on the SIRRE sub-indicator scale for generation and transmission. Due to the energy reforms of 2005, the transmission responsibilities were handed over to a newly established electricity utility, namely GridCo, which was incorporated in December 2006. Since the state owns 100% of both the VRA and GridCo, only separation of a legal kind took place, giving generation and transmission a vertical integration score of 3 as of 2006. [97], [104]

In 1987, the second Ghanaian state-owned distribution company, the Northern Electricity Department (NED), was established to take over the assets of the ECG in the north of the country for the purpose of enhancing the electrification of rural areas. The NED was wholly owned by the VRA, which had assets in generation and transmission as well, meaning that the separation was only of an accounting nature. [92] Later on in 1997, the NED was transformed into the Northern Electricity Distribution Company (NEDCo.) to implement the power sector reforms. While this company is still wholly-owned by the VRA, the separation is not only accounting but also legal. [95], [105]

As for the vertical integrity of the electricity supply, it has always been a part of the electricity distribution and therefore merits a score of 6 throughout the whole timeline. In the Ghanaian electricity sector this holds little importance. The sub-scores and the overall vertical integration score is depicted below in Figure 5.12.

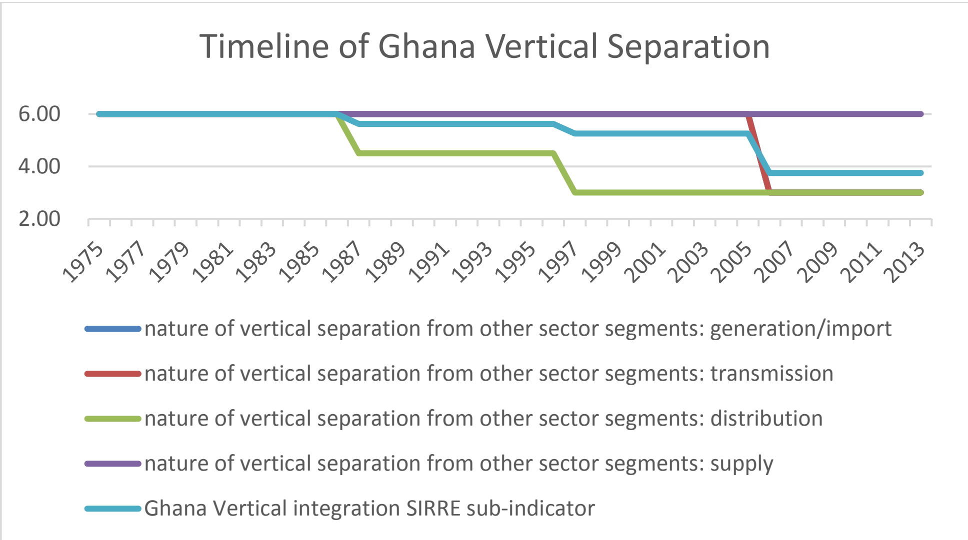

Figure 5.12 Vertical Separation vs. Time: Ghana

5.4.2.4 Market Structure

Up until 2000, all installed power capacity in Ghana was owned by the VRA. This includes the Akosombo and Kpong hydro power stations as well as 10% of the Takoradi and 100% of the Tema thermal power plants, the latter of which was added in 2008. Due to the reforms in the energy sector and opening up of the generation market, independent power producers (IPPs) entered the market. This first happened in 2000 with the installation of the Takoradi plant, reducing the market-share of the VRA to 60.5% of installed capacity. In 2010, 600MW of generation capacity was installed by private companies, further decreasing the market-share of the VRA to 57.62%, which has continued to fall after 2013. [102], [105]

The ECG currently owns over 70% of the electricity supply segment. This market-share has not notably fluctuated over the considered timeline and has never been below 50%. Furthermore, the market-share has never risen to above 90% due to shares being taken up by the NED/NEDCo, the mines and export. This deserves a 3 for the entirety of the analyzed timeline. [106], [107]

5.4.2.5 Shannon's Diversity Index

The attained results of the first methodology phase are displayed in Table 5-45. Since the Public Ownership SIRRE sub-indicator remains constant over the entirety of the analyzed timeline[10], an error is obtained during the calculation and no p-value is depicted. This is logical since the coefficient and the standard error values are 0, therefore no p-value can be calculated mathematically. The reason has been described and explained in detail previously, see chapter 4: Methodology. Unfortunately, it was not possible to include the Public Ownership sub-indicator in the analysis of the case-study Ghana and the rest of the analysis will be conducted without the Public Ownership sub-indicator so as not to distort the remaining results.

Country: Ghana ***R-squared: 0.8722*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.09209	0.03608	-2.55213	0.01537
Public Ownership	0.00000	0.00000	65535.00	#NUM!
Vertical Integration	-0.07573	0.05526	-1.37043	#NUM!
Market Structure	-0.17949	0.04350	-4.12631	0.00023

Table 5-45 Shannon's Diversity Index Impact Results: Ghana (with Public Ownership)

Therefore, the results of the first methodology phase have been recalculated without the public ownership SIRRE sub-indicator and displayed in Table 5-46 below. Although the electricity reforms impact analysis takes only three variables into consideration, the R-squared value of 0.87 is remarkable. This is due to the strong statistical significance of market structure (p-value <<0.01) and the low p-value for entry regulation of < 0.05. Noteworthy is furthermore the negative coefficient signs of all the SIRRE sub-indicators which will be explained in the following chapter.

Country: Ghana ***R-squared: 0.8721*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.09209	0.03557	-2.58876	0.01394
Vertical Integration	-0.07573	0.05448	-1.39010	0.17328
Market Structure	-0.17949	0.04288	-4.18553	0.00018

Table 5-46 Shannon's Diversity Index Impact Results: Ghana (without Public Ownership)

As is custom in this thesis, the research methodology has been repeated, only this time with control variables for phase II of the methodology. The results are displayed in Table 5-47 below. The statistical significance of the SIRRE sub-indicators does not change, with vertical integration remaining the only irrelevant variable. This time however, entry regulation is strong with a p-value of <<0.01, while market structure has a p-value of < 0.05. Additionally, the net energy imports correlate with the diversification of the power generation fuel mix, boasting a p-value of < 0.05. Extraordinary is the p-value of the CO2 emission from electricity

[10] All major companies in the generation, transmission, distribution and supply of electricity are wholly owned by the Ghanaian government.

and heat production of 1.22E-11, which is far below 0.01. This is also the reason for the very high R-squared value.

Country: Ghana ***R-squared: 0.9895*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.08413	0.01931	-4.35717	0.00015
Vertical Integration	0.01250	0.02977	0.42005	0.67755
Market Structure	-0.04152	0.01860	-2.23214	0.03349
Electric power consumption (kWh per capita)	-0.00012	8.28E-05	-1.48897	0.14729
GDP/capita (current US$ per capita)	1.25E-05	6.68E-05	0.18682	0.85310
GHGs/capita (kt of CO2 equivalent per capita)	9.32132	9.81229	0.94996	0.34998
Energy imports, net (% of energy use)	-0.0021	9.45E-04	-2.27364	0.03057
Foreign direct investment, net inflows (% of GDP)	-0.00422	0.00594	-0.71008	0.48332
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	0.01969	0.00183	10.76217	1.22E-11

Table 5-47 Shannon's Diversity Index Impact Results (with control variables): Ghana

5.4.2.6 Energy Intensity

Table 5-48 depicts the results of the first phase of the methodology. The extremely high R-squared value of 0.96 is obviously due to the very low p-value of market structure and to a lesser extent vertical integration. This implies strong statistical significance of those two SIRRE sub-indicators. Due to the high R-squared value it would be possible to predict future trends of the energy intensity utilizing only the SIRRE sub-indicators but for the sake of methodology homogeneity, the second phase of the methodology was undergone nonetheless, obtaining the results depicted in Table 5-49. It is of further importance that the analyzed timeline is only 1990-2013, however since the Ghanaian electricity reforms started only after 1990, this is no problem for this analysis, in contrast to the Chilean case-study.

Country: Ghana ***R-squared: 0.9606*** ***Observations: 24*** ***Dependent Variable: Energy Intensity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.16185	0.11807	1.37081	0.18562
Vertical Integration	0.63463	0.19314	3.28589	0.00369
Market Structure	1.45549	0.14117	10.31002	1.89E-09

Table 5-48 Energy Intensity Impact Results: Ghana (without Public Ownership)

The results for the second methodology phase can be seen in Table 5-49 below. Before proceeding to the description of the different p-values it must be mentioned that the data provided by the World Bank [14] for the unemployment rate in Ghana was incomplete. Therefore for the time period of 1991-2013, the data from [51] was added with the assumption that the unemployment rate in 1990 was equal to the rate in 1991. Of the SIRRE sub-indicators, market structure remains statistically significant (p-value < 0.05) along with a number of control variables resulting in an R-squared value very close to 1. The significant control variables include access to electricity (% of population) and energy use (kg of oil equivalent per capita) with p-values far below 0.01 and GDP/capita (current US$ per capita) as well as net energy imports (% of energy use) with p-values < 0.05.

Country: Ghana **R-squared: 0.9993** **Observations: 24** **Dependent Variable: Energy Intensity**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.04986	0.03192	1.56216	0.14422
Vertical Integration	-0.12560	0.08962	-1.40140	0.18642
Market Structure	0.27668	0.09524	2.90501	0.01320
Europe Brent Spot Price (US$ per Barrel)	0.00220	0.00244	0.90252	0.38454
Access to electricity (% of population)	-0.05489	0.00436	-12.5989	2.81E-08
GDP/capita (current US$ per capita)	-6.21E-04	2.17E-04	-2.85988	0.01436
GHGs/capita (kt of CO2 equivalent per capita)	-1.4418	14.4487	-0.09979	0.92216
Energy imports, net (% of energy use)	0.00895	0.00316	2.83305	0.01509
Energy use (kg of oil equivalent per capita)	0.01668	0.00144	11.60140	7.04E-08
Unemployment, total (% of total labor force)	0.01188	0.00939	1.26554	0.22970
Inflation, consumer prices (annual %)	0.00115	0.00134	0.85486	0.40937

Table 5-49 Energy Intensity Impact Results (with control variables): Ghana

5.4.2.7 Energy Use

Table 5-50 displays the results of the first phase of the methodology. It is remarkable that although two of the three analyzed SIRRE sub-indicators are statistically significant, the R-squared still has a value of only 0.68. Market structure is extremely statistically relevant with a p-value of far below 0.01, while entry regulation has a p-value of slightly below 0.05. Since the R-squared value is so low, it is advisable to add a few control variables into the equation to render the results more realistic and usable, e.g. to predict future trends of the dependent variable.

Country: Ghana **R-squared: 0.6848** **Observations: 39** **Dependent Variable: Energy Use**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-15.51660	7.34455	-2.11266	0.04184
Vertical Integration	9.12082	11.24835	0.81086	0.42293
Market Structure	54.79323	8.85413	6.18844	4.36E-07

Table 5-50 Energy Use Impact Results: Ghana

The second phase of the methodology brings forth interesting and "successful" results that are shown in Table 5-51. With *successful* is meant that many control variables and SIRRE sub-indicators are statistically relevant, which leads to a high R-squared value. As a matter of fact, all analyzed variables in the following table boast a p-value that is below 0.1, meaning that each of them has at least a weak statistical significance. The obtained results will be discussed in the next chapter to derive important conclusions and policy recommendations for Ghana and beyond.

Country: Ghana **R-squared: 0.9241** **Observations: 39** **Dependent Variable: Energy Use**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-11.89921	5.50422	-2.16184	0.03847
Vertical Integration	-16.69210	9.82505	-1.69893	0.09935
Market Structure	54.68617	5.86619	9.32226	1.67E-10
Electric power consumption (kWh per capita)	0.21757	0.02831	7.68618	1.14E-08
GDP/capita (current US$ per capita)	-0.05376	0.01973	-2.72503	0.01047
GHGs/capita (kt of CO2 equivalent per capita)	7633.88	2254.61	3.38589	0.00194
Energy imports, net (% of energy use)	-0.8717	0.2904	-3.00197	0.00526

Table 5-51 Energy Use Impact Results (with control variables): Ghana

5.4.2.8 Net Energy Imports

The deregulation of the Ghanaian electricity sector has considerable impacts on net energy imports, which are quantified using the SIRRE indicator. The results are depicted in Table 5-52 without control variables and in Table 5-53 with control variables. Although the R-squared value obtained is very low, the p-values of the SIRRE sub-indicators show strong correlation and dependency. Both entry regulation and market structure boast strong statistical significance with p-values < 0.01 while vertical integration has a p-value < 0.05.

Country: Ghana ***R-squared: 0.4692*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	11.01139	2.89139	3.80834	0.00054
Vertical Integration	-9.17422	4.42823	-2.07176	0.04572
Market Structure	-13.45250	3.48568	-3.85937	0.00047

Table 5-52 Net Energy Import Impact Results: Ghana

Table 5-53 shows the results of the second phase of the methodology, which analyzes the chosen control variables as well as the SIRRE sub-indicators. Market structure is rendered statistically insignificant while the p-value of vertical integration decreases to < 0.01 and that of entry regulation increases to < 0.1. Regarding the control variables of the five analyzed indicators, only the net inflows of foreign direct investment and GDP/capita have a p-value of < 0.1 and < 0.01, respectively.

Country: Ghana ***R-squared: 0.7181*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	6.68202	3.71692	1.79773	0.08229
Vertical Integration	-15.57353	5.35268	-2.90948	0.00676
Market Structure	-5.53288	3.83576	-1.44245	0.15954
Electric power consumption (kWh per capita)	-0.01196	0.01686	-0.70941	0.48355
Energy mix diversification (Shannon's H)	10.54703	16.80577	0.62758	0.53502
GDP/capita (current US$ per capita)	-0.03686	0.01153	-3.19656	0.00327
GHGs/capita (kt of CO2 equivalent per capita)	74.26	1998.88	0.03715	0.97061
Foreign direct investment, net inflows (% of GDP)	2.18245	1.15286	1.89308	0.06803

Table 5-53 Net Energy Import Impact Results (with control variables): Ghana

5.4.2.9 Electric Power T&D Losses

The results of the first phase of the methodology are portrayed in Table 5-54 below. Although only one of the SIRRE sub-indicators, namely market structure, is statistically significant and has a p-value of < 0.01, the R-squared value is extremely high and boasts a value of 0.943. This can be explained with the incredibly low p-value of the market structure, which lies at 6.54E-17 and is far below the threshold of 0.01.

Country: Ghana ***R-squared: 0.9430*** ***Observations: 39*** ***Dependent Variable: Electric T&D Losses***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.06523	0.73409	-0.08885	0.92971
Vertical Integration	1.05925	1.12428	0.94216	0.35257
Market Structure	-13.37560	0.88498	-15.1140	6.54E-17

Table 5-54 Electric Power T&D Losses Impact Results: Ghana

Including the control variables in the MLR equation in the second phase of the methodology brings forth the results shown below in Table 5-55. Most of the analyzed variables show some kind of correlation, with only entry regulation of the SIRRE sub-indicators and electric power consumption of the control variables being statistically insignificant. The energy mix diversification (Shannon's H), GDP/capita (current US$ per capita) and total CO_2 emissions from electricity and heat production (% of total fuel combustion) boast p-values below 0.01, while electricity production from non-hydro renewable sources (kWh) as well as the vertical integration and market structure SIRRE sub-indicators have p-values below 0.05. The plethora of statistically significant variables couples with a high R-squared value leads to the capability of future trend prediction for the electric power T&D losses in Ghana.

Country: Ghana ***R-squared: 0.7956*** ***Observations: 39*** ***Dependent Variable: Electric T&D Losses***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-4.54737	3.61146	-1.25915	0.21769
Vertical Integration	-11.04961	4.50050	-2.45519	0.02010
Market Structure	-6.82248	3.24595	-2.10185	0.04407
Electric power consumption (kWh per capita)	-0.01382	0.01476	-0.93635	0.35657
Energy mix diversification (Shannon's H)	-77.75554	28.19723	-2.75756	0.00982
GDP/capita (current US$ per capita)	-0.0250	0.00819	-3.04829	0.00477
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	1.95987	0.60490	3.24001	0.00292
Electricity production from renewable sources, excluding hydroelectric (kWh)	-5.66E-06	2.65E-06	-2.13353	0.04118

Table 5-55 Electric Power T&D Losses Impact Results (with control variables): Ghana

5.4.2.10 Access to Electricity

Table 5-56 depicts the "excellent" results obtained from methodology phase I, where it can be clearly seen that electricity sector reforms have a significant impact on the electrification rate, with all the SIRRE sub-indicators being statistically relevant. Entry regulation and market structure boast p-values below 0.01 while vertical integration has a moderate p-value of < 0.05. This results in the high observable R-squared value below of 0.9323, which is way above the threshold of acceptance of 0.75. All observed coefficient signs are negative and the corresponding variables statistically significant, which has important repercussions on the conclusions and policy recommendations discussed later.

Country: Ghana ***R-squared: 0.9323*** ***Observations: 24*** ***Dependent Variable: Access to Electricity***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-4.21972	1.28856	-3.27475	0.00379
Vertical Integration	-5.01512	2.10788	-2.37923	0.02742
Market Structure	-7.41088	1.54073	-4.80999	0.00011

Table 5-56 Access to Electricity Impact Results: Ghana

The results of the second methodology phase are depicted in Table 5-57 and include the control variables as well as the original SIRRE sub-indicators. Most of the analyzed variables are statistically significant and therefore correlate with the electrification rate dependent variable. Of the SIRRE sub-indicators, market structure has a p-value of < 0.05, while vertical integration's is below 0.1. When it comes to the control variables, energy intensity (MJ/$2011 PPP GDP) and energy mix diversification (Shannon's H) boast p-values < 0.01, while electric power consumption (kWh per capita), GDP/capita (current US$ per capita) and total CO_2 emissions from electricity and heat production (% of total fuel combustion) have p-values < 0.05. An R-squared value of 0.98, which is very close to 1, rounds off the "nearly perfect" results.

Country: Ghana R-squared: 0.9800 Observations: 24 Dependent Variable: Access to Electricity	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	1.60379	2.03422	0.78840	0.44460
Vertical Integration	-6.52271	3.21321	-2.02997	0.06334
Market Structure	13.97767	5.07467	2.75440	0.01640
Electric power consumption (kWh per capita)	0.07311	0.02444	2.99189	0.01040
Energy mix diversification (Shannon's H)	56.30635	15.59278	3.61105	0.00316
GDP/capita (current US$ per capita)	-0.02299	0.00927	-2.47885	0.02767
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	-0.80168	0.32598	-2.45927	0.02871
Europe Brent Spot Price (US$ per Barrel)	-0.01504	0.10303	-0.14599	0.88617
Energy intensity (MJ/$2011 PPP GDP)	-12.44125	3.27070	-3.80385	0.00219
Foreign direct investment, net inflows (% of GDP)	0.78751	0.53033	1.48494	0.16140

Table 5-57 Access to Electricity Impact Results (with control variables): Ghana

5.4.2.11 Corruption Perception Index

The results of the first methodology phase for the CPI as the dependent variable can be seen in Table 5-58 below. The reader is hereby notified that the analysis was only conducted for the timeline of 1998-2013, which can be seen by the number of observations: 16, and measures the CPI starting in 1998. This is merely one year after the start of the electricity sector reforms and the results can therefore simply be measuring the country's development or economic growth in general and not necessarily the change due to the reforms. Nevertheless, the results obtained show that only the entry regulation SIRRE sub-indicator is statistically relevant while the others can be discarded.

Country: Ghana R-squared: 0.7467 Observations: 16 Dependent Variable: Corruption Perception Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.29906	0.07843	-3.81292	0.00247
Vertical Integration	0.04612	0.12417	0.37145	0.71678
Market Structure	-0.15556	0.12689	-1.22593	0.24374

Table 5-58 Corruption Perception Index Impact Results: Ghana

Table 5-59 depicts the results obtained in the analysis of the second methodology phase including the control variables. Although the analyzed timeline was long enough to capture the influence of the electricity sector reforms, all the variables can be disregarded due to their lack of statistical significance, which can be seen by their p-values that all happen to be above 0.1. This does not allow any conclusions to be made regarding the CPI in Ghana or its future trend, neither can any policy recommendations that deal with combatting corruption in Ghana be made.

Country: Ghana R-squared: 0.9042 Observations: 16 Dependent Variable: Corruption Perception Index	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-0.38400	0.24690	-1.55526	0.17088
Vertical Integration	0.09803	0.34758	0.28203	0.78740
Market Structure	-0.33426	0.40517	-0.82498	0.44094
GDP/capita (current US$ per capita)	3.97E-04	6.22E-04	0.63771	0.54721
GHGs/capita (kt of CO2 equivalent per capita)	8.23253	98.95538	0.08319	0.93640
Unemployment, total (% of total labor force)	0.07969	0.04429	1.79928	0.12207
Inflation, consumer prices (annual %)	-0.01638	0.01445	-1.13320	0.30037
Energy intensity (MJ/$2011 PPP GDP)	0.01487	0.21672	0.06862	0.94752
Foreign direct investment, net inflows (% of GDP)	-0.08159	0.08754	-0.93203	0.38729

Table 5-59 Corruption Perception Index Impact Results (with control variables): Ghana

5.4.3 Derived New Knowledge and Discussion of Results

Electricity sector deregulation reforms have had multiple impacts on the economy, society and policy of the analyzed country. Some of these impacts are described below through discussing the results of performed analyses of the seven impact indicators. As with everything in life, some impacts of the reforms were negative while others proved positive.

From the first analysis, namely the impact of the Ghanaian electricity sector reforms on the diversification of the power generation fuel mix, a few conclusions can be derived. Firstly, the establishment of a liberalized wholesale electricity market and the opening of the generation electricity sector segment to competition increases the diversity of fuel mix used for power generation. Secondly, as the market share of the largest company in each sector segment[11] decreases, the diversification of the generation mix increases. This is totally plausible for Ghana since it relied to 100% on hydropower until 1997, supplied by the government-owned VRA, and therefore any new IPP non-hydro installed capacity will increase the diversity of the power generation mix.

As net energy imports increase, the diversification of the Ghanaian power generation mix decreases. If one looks at the complete dominance of hydro power in the early years of the analyzed timeline, this would seem counterintuitive. However, when one looks at the final years of the analyzed timeline, Ghana's energy imports shifted from predominantly oil nature to gas. This means that instead of the taking over hydro power market shares, gas replaced oil-powered generation units, thereby decreasing the diversity of the power mix. Furthermore, it can be seen that as CO2 emissions from electricity and heat production increase, so does the Shannon's diversity index. On the other hand, this phenomenon can be explained by the strong dominance of hydro power in the early years, seeing as any added non-hydro technology would both increase CO2 emissions and the diversity of the power mix.

If Ghana wants to become more economically competitive by increasing its energy efficiency, it should proceed with deregulating its electricity sector. This becomes clear by looking at the results of the energy intensity analysis, which show that the higher the regulation of the electricity sector is, the higher the energy intensity of Ghana will be. This is an important conclusion for policy recommendation in Ghana and in other developing countries wishing to undergo electricity sector reforms.

As explained in previous case-study analysis discussions, when the GDP/capita increases, the energy intensity decreases. On the contrary, when energy use increases, the energy intensity increases. This is due to the nature of the analyzed impact indicator, which is defined as a unit of energy per unit of GDP (MJ/$2011 PPP GDP). Interestingly, as the electrification rate increases, the energy intensity decreases and Ghana becomes more energy efficient. This is logical, as access to electricity can be used as a measure of

[11] VRA is the largest company in the power generation sub-sector in Ghana.

the country's development. Another explanation could be that the usage of electricity as a fuel (generated by hydro or thermal power) is more energy efficient than the fuels the population was using prior to electrification. Using kerosene for lighting instead of electricity suffices as an example to clarify this point. Furthermore, as the net energy imports increase, so does the energy intensity. This can be explained by stating that it is more energy efficient to generate power from hydro resources than from oil or gas, the fuels that Ghana is importing.

The deregulation of the electricity sector as it is described by the entry regulation SIRRE sub-indicator has a negative impact on the per capita energy use. That is to say as competition enters the generation sub-sector and a liberalized wholesale market is established, energy use increases. This would provide an argument against continuing sector reforms if Ghana were most interested in decreasing its per capita energy use. On the other hand, the more deregulated Ghana is in terms of market structure, the less energy it uses per capita. That means that the more market shares are held by the largest company, the higher the energy use per capita will be.

The strong correlation between the control variables of electric power consumption and GHGs/capita with energy use should come as no surprise to the reader. The first is basically integrated therein, while the latter is a cause thereof and both can be used to predict the per capita energy use. The negative coefficient of GDP/capita is surprising as it indicates that the wealthier Ghana is, the less energy the population will use. This contradicts many experiences in other developing countries and is due to the strange behavior of the per capita energy use and the GDP/capita over the analyzed timeline that can be seen in Table 9-4 and Table 10-4 in Appendix A and Appendix B, respectively. The lack of correlation is expected to be caused by a certain lag or dead time between the two variables. On the contrary, the fact that as net energy imports increase, the energy use per capita decreases, seems logical and can be easily explained by the rise in electricity price that influences consumer behavior.

The impact of the electricity sector reforms on the net Ghanaian energy imports is strong yet ambivalent. While a deregulation in the entry regulations for IPPs and an electricity market establishment increases net energy imports, the increased separation of the different vertically integrated electricity sector segments and decreasing market share of the largest state-owned company decreases energy imports. If Ghana is seeking to deregulate its electricity sector and at the same time decrease its energy imports, it must proceed with decreasing the market share of VRA and further separate generation, transmission, distribution and supply, which can only be done through privatization and the sale of state-owned assets, since legal separation has already been attained. Regarding the control variables, it can be said that as the GDP/capita increases, the net energy imports decrease. This can be explained by looking at the most recent years of the analyzed timeline in Table 10-4, Appendix B where it becomes clear, that Ghana is transforming from a net energy importer to a net energy exporter because it becomes technically capable of harvesting its own energy resources and seeks to boost its economy with the sale thereof.

The electricity sector reforms have a negative effect on the T&D losses in Ghana. The results obtained show that with increasing sector deregulation, the T&D losses increase. If T&D losses would be on the agenda forefront of the Ghanaian policy makers, this could cause a problem. However, this is not the case although it might be one of the points for them to consider, but they are rather considered with energy intensity and how to squeeze every GDP dollar out of every unit of energy.

As the diversification of the power generation fuel sources increases, the T&D losses decrease. A similar yet slightly different observation is that when electricity production from non-hydro renewable sources increases, the T&D losses decrease. Both these phenomena can be explained by the fact that Ghana has been reliant on hydro for a long time and it has only been since the last two decades that other fuel sources have entered the market. It is assumed that the transmission lines to the hydro power plants are aging and therefore less efficient. With new installed capacity, new transmission lines are built to the generation units that are of the latest technology and therefore less plagued by losses. Non-hydro renewable power generation only started in Ghana in 2013, which is the last year of the analyzed timeline. T&D losses increase with increasing CO2 emissions from electricity and heat production, which is logical since both are practically a measurement of energy efficiency. Last but not least, the T&D losses decrease when the GDP/capita increases. This is obvious since GDP/capita is sometimes used synonymously with a country's development and the more developed a country is, one would presume, the lower the T&D losses are.

For an ambitious developing country like Ghana that is already becoming a regional power in West Africa, an electrified population is a must and key to human development and a growing economy. The results obtained show that the analyzed electricity sector reforms have significant impacts on the electrification rate. With increasing deregulation of the sector, Ghana's access to electricity increases. This is true not only for a certain sub-indicator, but for all available SIRRE sub-indicators apart from public ownership since it has an unchanging score of 6 throughout the whole timeline and is therefore disregarded. If access to electricity is a priority for Ghanaian policy makers, it is key for them to continue their electricity reforms and privatize the electricity sector by selling state-owned assets.

The electrification rate in Ghana increases with increasing electric power consumption per capita and power generation technology diversification. The first witnessed phenomenon is self-explanatory while the second is related to previously discussed conclusions and observations that Ghana was previously entirely run on hydro power and with new installed thermal generation units, diversification increases as well as net generated electricity which translated into increasing per capita power consumption and electrification rate rise. On the contrary, the Ghanaian electrification rate increases with decreasing GDP/capita, total CO2 emissions from electricity and heat production as well as energy intensity. The author would first like to remind the reader to take a look at the strange behavior of the GDP/capita displayed in Table 10-4, Appendix B, which could be an explanation for the results. Lastly, it is reasonable that with increasing energy efficiency of the country (and decreasing energy intensity) and more GDP wrung out of every unit of energy, the electrification rate increases as more government money would be available to installed new generation units and transmission lines.

The only conclusion that can be drawn from the CPI analysis is that with the establishment of a liberalized whole market for electricity and removing of thresholds to allow customers to choose their electricity supplier as well as allowing third-party access to the electricity transmission grid correlates with decreasing corruption in Ghana. The author is careful to mistake correlation for causation and does not wish to make this mistake. Causation is very difficult to prove and it will suffice at this point to say that these two variable sets correlate than to say that they cause each other.

Electricity sector reforms in Ghana have had double-sided impacts in Ghana. Although some of these deregulation effects are negative, the pros of deregulation certainly outweigh the cons. For a country like Ghana, top priorities of Ghanaian policy makers should be to make the electricity more energy efficient, i.e. decrease the energy intensity of the economy and to increase the access of electricity until 100% of the population is electrified. For these reasons, the author encourages Ghanaian policy makers to continue pursuing this path of deregulation in the electricity sector.

5.5 Iran

5.5.1 Brief Country Description and Electricity System History

The Islamic Republic of Iran is located in West Asia and boasts a population of about 80 million inhabitants. It was created in 1979, when the so-called Islamic Revolution ousted the Shah and Khomeini returned from exile to form a government, hold a referendum and found an Islamic Republic. Its gigantic energy reserves and its proximity to the strait of Hormuz, where 20% of the world's oil passes through daily, make it a geopolitical power to be reckoned with.

Instead of being directly operated by a ministry or department, prior to electricity sector reforms in 2002, Iran's vertically integrated electricity monopoly was entrusted to Iran Electric Holding Company for Generation, Transmission and Distribution (Tavanir), a state-owned public entity affiliated with the Ministry of Energy. The government of Iran legislated sector policies as well as planned, built and operated new infrastructure. Customer complaint management, tariff setting and other regulatory activities were all overseen by the ministry and delegated to Tavanir. Tavanir, established in 1968, was and remains fully government-owned. [35], [108]

As part of the Organization of the Petroleum Exporting Countries (OPEC) Iran resides over the largest natural gas supply and the 4th largest oil reserves in the world, which enables it to exert considerable pressure on the world economy and international energy security. The abundant and cheap energy resources were able to compensate for extremely low energy efficiencies and the mammoth energy consumption habits of the local population. Finally, the terrible financial situation of the electricity sector which was a result of high subsidies provided by the government, overcame resource abundancy and forced the sector to change. The residential electricity tariff lies between 1 and 2¢ per kWh in Iran, about 10 times lower than the price range in OECD member countries. Although the target model has not yet been reached, these pressures for reforms have introduced market principles in the sector's organization. [35], [109]

Article 9 of the third law of the economic, social and cultural development plan (2000-2004) introduced the government's new strategy in managing the sector. This law particularly intended to place power generation in private hands and to limit the government's responsibilities in the sector. Before true privatization was possible, an unbundling of the state-owned Tavanir was necessary. In 2002, Tavanir was split into 16 regional electricity companies (RECs), with each REC responsible for the entire electricity supply chain in its jurisdiction area. Additionally, 27 power generation companies and 38 electricity distribution companies that were affiliated with one REC each were created. A schema depicting the structure of the electricity sector in Iran is given in Figure 5.13 below. [35], [110]

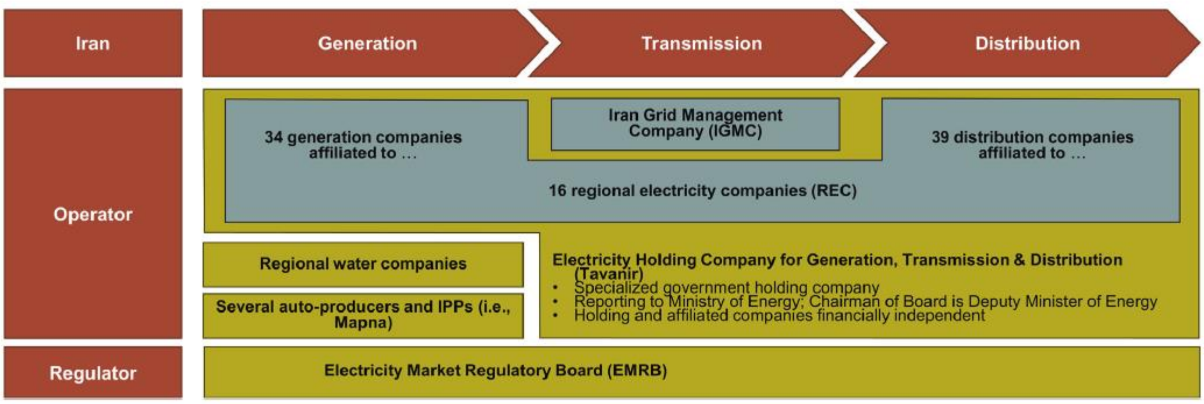

Figure 5.13 Structure of the Iranian Electricity Sector in 2013, source: [35]

Iran Grid Management Company (IGMC) was incorporated in 2003 as a subsidiary of Tavanir and although it does not own any power transmission assets, it is responsible for the planning of the electricity sector segment. Furthermore, IGMC is the electricity system's operator and market manager – key roles for the sector reforms. The Iranian electricity market was launched in 2003 and although customers can only inform the IGMC of their predicted energy demand but not choose their supplier, the power generators compete in this market, producing a merit order effect with the cheapest producer selling first. [35], [111]

A true barrier to privatization was article 44 of Iran's constitution that says that the Iranian economy is made up of three sectors, namely state, cooperative and private. Among others, the banking and power industry were declared monopoly state activities. By clearing this legal hurdle, the 2004 amendment brought along the privatization of the electricity industry, the progress of which is depicted in Figure 5.16. Although electricity sector reforms have been implemented and a wholesale electricity market introduced in Iran, subsidized electricity tariffs continue to plague the sector and are ultimately responsible for poor financial performance. [35]

5.5.2 Indicator Analysis and Results

It is true that the deregulation of the electricity sector in Iran started quite late (i.e. in 2002) compared to the other case-studies analyzed. Nevertheless, the process of deregulation has certainly not been monotonous (see Figure 5.14) and many lessons can be learned from it. The obtained SIRRE sub-indicators as well as the overall SIRRE indicator score are visible in Figure 5.14 below.

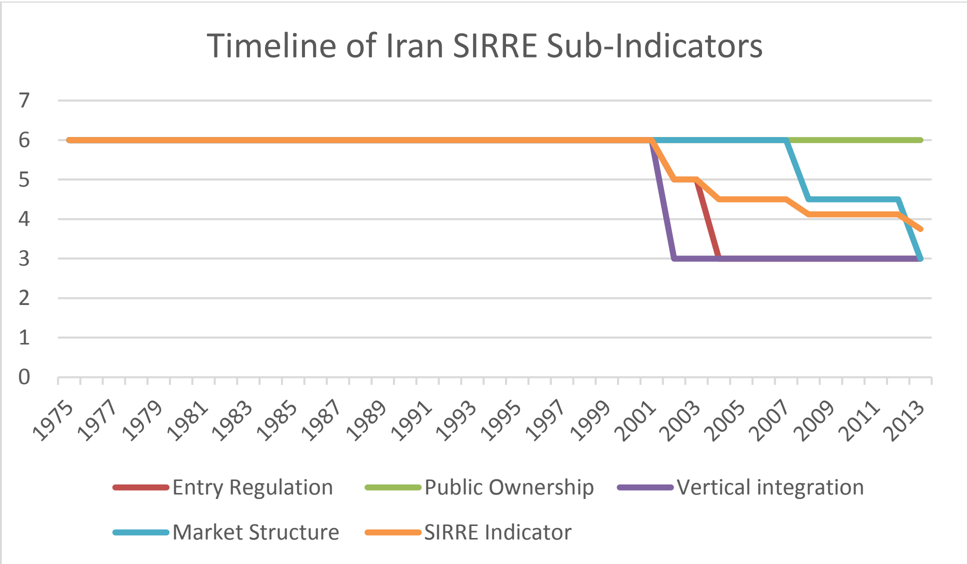

Figure 5.14 SIRRE Sub-Indicators vs. Time: Iran

5.5.2.1 Entry Regulation

Even though captive generation units existed before the start of the electricity reforms in 2002, it was not possible for third parties to access the transmission grid in order to sell their electricity surplus. The transmission grid access was granted in 2002 and the annual Tavanir report for that year mentions five BOT projects with a total of 5000MW capacity. However, real entry of IPP's started with the Rudeshur project contract with the private Mah-Taab Teheran-based company in 2003. [35] Nevertheless, the change from no third-party access at all to a negotiated access is attributed to year 2002.

The Iranian electricity market was launched in October 2003 but only established in 2004, putting an end to the regional single-buyer models and centralizing electricity trade in a mandatory power pool. By doing this, Iran instigated the first electricity market based on competitive supply bidding in the region. However, if the deals are notified to the system operator, bilateral physical forward trading is still allowed. Therefore, the incorporation of centralized and decentralized commitments makes the Iranian electricity market a hybrid model. [35], [112]

Although electricity generating companies can sell their electricity on the market, demand bids are not possible. The electricity buyers simply inform their demand forecasts to IGMC, which then predicts the country demand curve. By stacking the submitted bids and summing the price-insensitive demand forecast, it is possible for the IGMC to determine the marginal price of electricity by connecting the supply and demand curves. The buyers then purchase the electricity from IGMC at the marginal price plus a fixed charge for administration services and capacity payments. [35], [111] In conclusion, the consumers are not free to choose their supplier, but must purchase from their local electricity supplier at a price fixed by the IGMC. Despite electricity reforms, ERQ3-Q4 receive a score of 6 throughout the entire timeline of 1975-2013.

The timeline of the Entry Regulation SIRRE sub-indicator is depicted below in Figure 5.15.

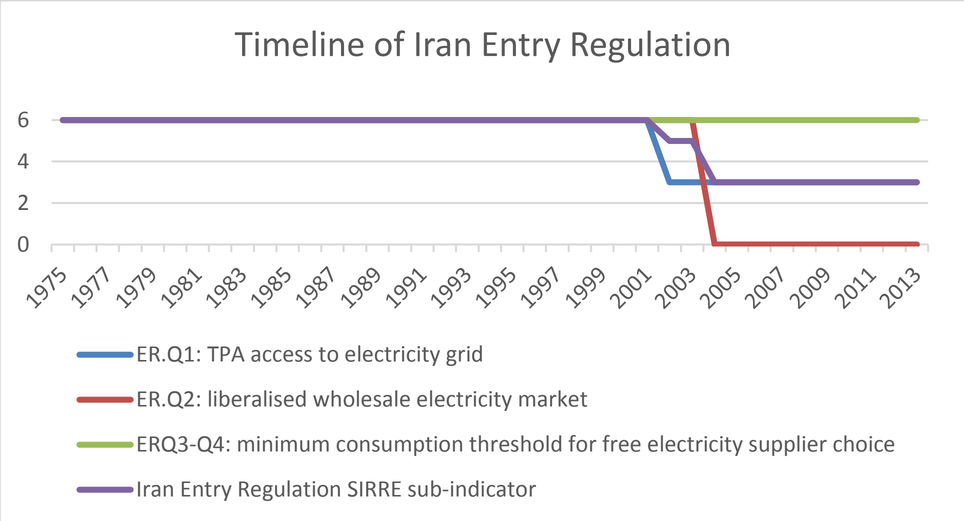

Figure 5.15 Entry Regulation vs. Time: Iran

5.5.2.2 Public Ownership

Tavanir was established in 1968 as a vertically integrated state power company holding a monopoly right over the generation, transmission, distribution and supply of electricity and working under the Power Ministry, which had previously managed the water and electricity sector of Iran for many years. Although the electricity sector reforms of 2002 took away this monopoly right and reorganized the sector in several ways, Tavanir still produced more than 85% of the country's electricity in 2010. Tavanir was and still is wholly owned by the Government of Iran. [108], [35]

In 2002, Tavanir was split into 34 generation companies, 16 regional electricity transmission companies and 39 electricity distribution companies. Although all these subsidiary companies are legally and financially independent, they are still affiliated to and supervised by the Tavanir Holding Company. Furthermore, Iran's electric interconnections with the neighboring countries such as Afghanistan, Armenia, Iraq, Pakistan and Turkey, are exclusively managed by Tavanir. This means that although the major vertically integrated state-owned company has unbundled due to the reforms, the largest firm in the electricity segments of generation, import, transmission, distribution and supply is still state-owned. [35], [110]

This gives the public ownership overall SIRRE sub-indicator a score of 6 for the entire timeline as in the case study of Ghana and makes the depiction of the timeline in the form of a figure unnecessary. If this sub-indicator has been included in the analysis, a similar error as in the case of Ghana would appear in the results, hence the motivation for the subsequent exclusion.

5.5.2.3 Vertical Integration

Tavanir, the state-owned vertically-integrated company was restructured into multiple regional companies in 2002 to prepare for the intended privatization and selling of sector assets,. 16 regional electricity companies (RECs) were created and remained under the supervision of the new Tavanir. In their respective provinces, they were responsible for the generation, transmission and distribution of electricity.

Additionally, 27 power generation companies were created that supplied only one REC each with electricity. On the distribution side, 38 companies were established that were equally associated with the RECs to operate the networks and manage customer relationships. Although still under the control of the incumbent Tavanir, several contracting businesses, engineering firms and specialist consulting companies have gained a certain level of independence. As to the degree of autonomy, all the newly created companies were established as individual and separate legal entities, having their own management and accounting. Of course, they are all still state-owned. [35]

5.5.2.4 Market Structure

The government's new strategy was highlighted with 3rd development plan (2000-2004) that brought reforms to the Iranian electricity sector. Although the reforms allowing third-party access to the transmission grid started in 2002 and the electricity market was established two years later, Tavanir statistics [113] suggest that the first IPPs started producing power in 2000. The development of the private sector in power really took off in 2004 with the amendment of article 44 in the Iranian constitution. Private power generation has been steady and strong since and is depicted in Figure 5.16 below. The notable jump in 2013 marks the sale of almost 20GW of installed capacity from state-owned companies into private hands. [35]

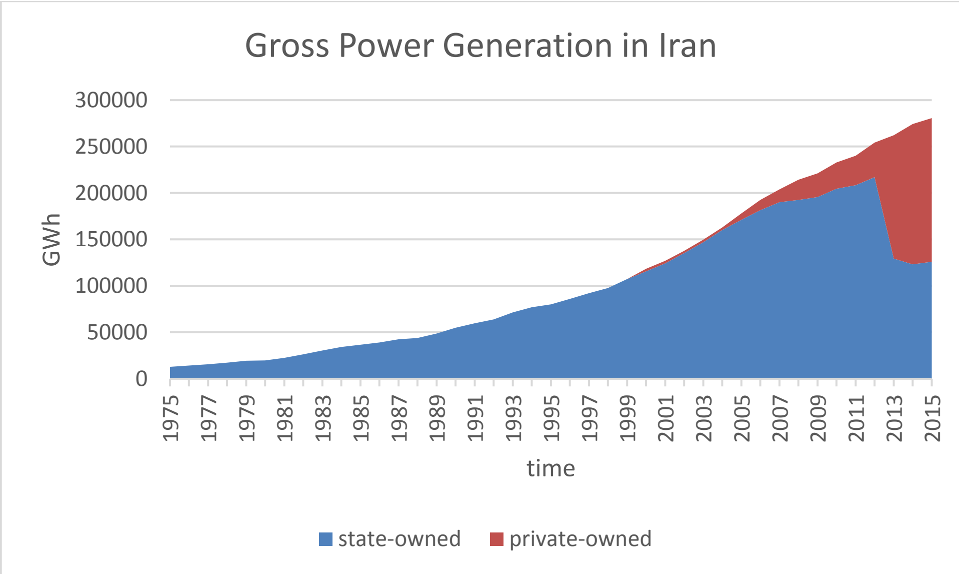

Figure 5.16 Timeline of Gross Power Generation in Iran

2008 indicates the first year that private-generated power rose above 10% in the Iran. Although Tavanir was reorganized into numerous regional electricity companies, they all operate under its supervision and are affiliated with the "mother" company. Therefore, it is assumed that all government-owned companies belong to Tavanir, which is in essence the largest company in the sector. The notable 2013 jump in Figure 5.16 pushes the market shares owned by the government of Iran to just below 50% for the first time, namely 49.59%. [113]

Electricity supply is completely regulated by the 39 electricity distribution companies that are all state-owned and under the supervision of the Tavanir mother company. The government therefore holds 100% of the shares in this electricity segment and the score awarded to this sub-indicator is obviously a 6 for the entire timeline. [35], [110]

5.5.2.5 Shannon's Diversity Index

Similar to the case-study of Ghana, the Public Ownership SIRRE sub-indicator remains constant over the entirety of the analyzed timeline[12]. Therefore, an error is obtained during the calculation and no p-value can be depicted. This is logical since the coefficient and the standard error values are 0, therefore no p-value can be mathematically calculated. Unfortunately, it is not possible to include the Public Ownership sub-indicator in the analysis for the case-study of Iran and the rest of the analysis will be conducted without the Public Ownership sub-indicator in order not to distort the remaining results. The results of the first round of the methodology are depicted in Table 5-60. Although the low R-squared value summarizes the results quite well, the vertical integration SIRRE sub-indicator is still considered statistically significant by boasting a p-value of < 0.05.

Country: Iran ***R-squared: 0.4155*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.01718	0.04885	-0.35174	0.72714
Vertical Integration	0.08731	0.04236	2.06130	0.04676
Market Structure	-0.02278	0.03793	-0.60073	0.55189

Table 5-60 Shannon's Diversity Index Impact Results: Iran

Table 5-61 reveals the results obtained in the second phase of the methodology when the control variables were included in the MLR equation. Although five control variables were added, the failure of any of them to prove statistical significance resulted in the relatively low R-squared value of 0.79. Regarding the SIRRE sub-indicators, vertical integration, which was relevant during the first phase, was deemed irrelevant in the second phase of the methodology. In its place, market structure entered into significance with its p-value similarly being < 0.05.

Country: Iran ***R-squared: 0.7901*** ***Observations: 39*** ***Dependent Variable: Shannon's Diversity Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.04667	0.04506	-1.03553	0.30898
Vertical Integration	0.00423	0.05451	0.07765	0.93864
Market Structure	-0.08341	0.03750	-2.22435	0.03407
Electric power consumption (kWh per capita)	-1.78E-06	1.83E-04	-0.00970	0.99233
GDP/capita (current US$ per capita)	-2.42E-06	1.65E-05	-0.14655	0.88450
GHGs/capita (kt of CO2 equivalent per capita)	-43.59797	44.09112	-0.98882	0.33093
Energy imports, net (% of energy use)	-2.36E-04	1.95E-04	-1.21414	0.23449
Foreign direct investment, net inflows (% of GDP)	-0.01451	0.04927	-0.29455	0.77043
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	-0.02083	0.01339	-1.55566	0.13064

Table 5-61 Shannon's Diversity Index Impact Results (with control variables): Iran

5.5.2.6 Energy Intensity

Table 5-62 depicts the results of the first round of methodology that only considers the SIRRE sub-indicators and no control variables. None of the sub-indicators correlate with the energy intensity dependent variable. The fact that all of them are statistically irrelevant and boast p-values greater than 0.1 leads to a miserable R-squared score of 0.3869. With such values, no prediction of any future trend is reasonable and the results are deemed utterly useless.

[12] The biggest companies in generation, transmission, distribution and supply of electricity are wholly owned by the government of Iran.

Country: Iran **R-squared: 0.3869** **Observations: 24** **Dependent Variable: Energy Intensity**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.14256	0.24754	-0.57593	0.57109
Vertical Integration	-0.09779	0.21866	-0.44722	0.65953
Market Structure	-0.14046	0.19216	-0.73095	0.47328

Table 5-62 Energy Intensity Impact Results: Iran

The second phase of the methodology is always conducted for the purpose of making the results more realistic and enabling better future trend predictions by adding more variables into the equation, thereby increasing the R-squared value. The results of this phase have been bestowed with considerable success and are depicted in Table 5-63. With such a "bad" starting position such as the results in Table 5-62 show, the results in the table below do seem quite good. Vertical integration proves statistical significance by boasting a p-value of < 0.05. The same is true for a number of control variables, such as net energy imports (% of energy use), energy use (kg of oil equivalent per capita) and consumer price inflation (annual %), all boasting p-values of < 0.01. Furthermore, GDP/capita (current US$ per capita) has a p-value of < 0.05, while the GHGs/capita (kt of CO2 equivalent per capita) control variable has a p-value of < 0.1. These results will be discussed in the following chapter.

The author would like to point out that the data for the unemployment control variable was incomplete as provided by the World Bank [14]. This data set was completed with information from [53] for 1991-2013 with the valid assumption that the unemployment in 1990 was equal to the one in 1991. This procedure is known to the author from the previous case-studies of India and Ghana.

Country: Iran **R-squared: 0.9804** **Observations: 24** **Dependent Variable: Energy Intensity**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.07273	0.10299	-0.70618	0.49356
Vertical Integration	0.15362	0.06158	2.49482	0.02818
Market Structure	0.02824	0.07813	0.36146	0.72404
Europe Brent Spot Price (US$ per Barrel)	0.00238	0.00480	0.49545	0.62923
Access to electricity (% of population)	0.15970	0.31486	0.50721	0.62120
GDP/capita (current US$ per capita)	-0.00016	7.50E-05	-2.19756	0.04835
GHGs/capita (kt of CO2 equivalent per capita)	-587.5899	318.4453	-1.84518	0.08982
Energy imports, net (% of energy use)	0.01787	0.00452	3.95471	0.00191
Energy use (kg of oil equivalent per capita)	0.00189	0.00059	3.21518	0.00742
Unemployment, total (% of total labor force)	-0.04654	0.04923	-0.94527	0.36317
Inflation, consumer prices (annual %)	0.01176	0.00367	3.20777	0.00752

Table 5-63 Energy Intensity Impact Results (with control variables): Iran

5.5.2.7 Energy Use

Table 5-64 depicts the results of the first methodology phase analysis of the per capita energy use as the dependent variable. Although all SIRRE sub-indicators have relatively low p-values, market structure and vertical integration don't qualify for statistical significance and entry regulation only barely slips under the 0.1 threshold for weak relevance, but will still not be discussed in the following chapter. Noteworthy is furthermore that all the coefficient signs are negative and the R-squared value is at 0.8086 which is above the 0.75 limit for acceptability.

Country: Iran R-squared: 0.8086 Observations: 39 Dependent Variable: Energy Use	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-223.88561	131.69934	-1.69998	0.09801
Vertical Integration	-177.99700	114.18351	-1.55887	0.12803
Market Structure	-158.62017	102.23776	-1.55148	0.12978

Table 5-64 Energy Use Impact Results: Iran

The results of the second phase of the methodology are portrayed in Table 5-65. The results obtained for the control variables are much "better" in terms of correlation than the results for the SIRRE sub-indicators where only entry regulation has a p-value of < 0.1, a sign of weak statistical significance. As for the control variables, electric power consumption (kWh per capita), GHGs/capita (kt of CO2 equivalent per capita) and the net energy imports (% of energy use) all have p-values of < 0.01, boasting strong statistical significance. Furthermore, GDP/capita (current US$ per capita) has a p-value of < 0.1, which disqualifies it from being discussed in the following chapter, as is the case of the entry regulation SIRRE sub-indicator. The very high R-squared value of 0.9927 is due to the strong influence of the control variables rather than the SIRRE sub-indicators.

Country: Iran R-squared: 0.9927 Observations: 39 Dependent Variable: Energy Use	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-60.38107	32.22368	-1.87381	0.07041
Vertical Integration	34.78896	25.38353	1.37053	0.18036
Market Structure	21.00251	31.85504	0.65931	0.51456
Electric power consumption (kWh per capita)	0.41314	0.10886	3.79522	0.00064
GDP/capita (current US$ per capita)	-0.02628	0.01302	-2.01912	0.05219
GHGs/capita (kt of CO2 equivalent per capita)	179233.63	36880.22	4.85988	3.21E-05
Energy imports, net (% of energy use)	0.6684	0.1386	4.82162	3.58E-05

Table 5-65 Energy Use Impact Results (with control variables): Iran

5.5.2.8 Net Energy Imports

The mediocre results of the first methodology phase are presented below in Table 5-66. A lack of statistical significance of any of the SIRRE sub-indicators and the corresponding extremely low R-squared value of 0.1284 is proof of the low quality of the results. It is clear that no conclusion and certainly no policy recommendation can be deduced from the results depicted in the table below. These results are only fit to be disregarded and ignored.

Country: Iran R-squared: 0.1284 Observations: 39 Dependent Variable: Net Energy Imports	Coefficients	Standard Error	t-Stat	P-value
Entry Regulation	-4.57027	97.40690	-0.04692	0.96284
Vertical Integration	-51.56513	84.45191	-0.61059	0.54542
Market Structure	-14.86023	75.61665	-0.19652	0.84534

Table 5-66 Net Energy Import Impact Results: Iran

Table 5-67 depicts the second phase of the methodology with the results including the control variables. Still, none of the SIRRE sub-indicators are statistically significant and only two of the five analyzed control variables are. However, the relevant control variables, namely the electric power consumption (kWh per capita) and the GHGs/capita (kt of CO2 equivalent per capita) boast extremely low p-values that are far below the threshold of 0.01. This is responsible for the drastic increase of the R-squared value from 0.1284 in the first phase of the methodology to 0.9051 when the control variables were included.

Country: Iran ***R-squared: 0.9051*** ***Observations: 39*** ***Dependent Variable: Net Energy Imports***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	24.28863	49.30877	0.49258	0.62589
Vertical Integration	-51.10167	57.49186	-0.88885	0.38116
Market Structure	36.03835	42.95223	0.83903	0.40809
Electric power consumption (kWh per capita)	0.66887	0.07585	8.81877	7.85E-10
Energy mix diversification (Shannon's H)	-94.01362	191.76519	-0.49025	0.62752
GDP/capita (current US$ per capita)	0.00207	0.01731	0.11962	0.90558
GHGs/capita (kt of CO2 equivalent per capita)	-231359.3	21287.6	-10.8683	6.36E-12
Foreign direct investment, net inflows (% of GDP)	-76.31005	50.43833	-1.51294	0.14076

Table 5-67 Net Energy Import Impact Results (with control variables): Iran

5.5.2.9 Electric Power T&D Losses

The results obtained from the first round of the methodology are depicted in Table 5-68 below. Of the three analyzed SIRRE sub-indicators, only vertical integration has a p-value below 0.1, with the rest being statistically insignificant. Even though vertical integration scores better than the other sub-indicators, it still doesn't qualify it for discussion in the next chapter, since only variables with p-values below 0.05 are discussed. The R-squared value is relatively better than the one obtained during the net energy imports analysis, however it is, objectively speaking, still far below 0.75 and therefore of little relevance for future trend prediction.

Country: Iran ***R-squared: 0.5138*** ***Observations: 39*** ***Dependent Variable: Electric T&D Losses***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.56952	1.22881	-0.46347	0.64590
Vertical Integration	-1.89952	1.06538	-1.78295	0.08327
Market Structure	1.50541	0.95392	1.5781	0.12353

Table 5-68 Electric Power T&D Losses Impact Results: Iran

Table 5-69 shows the results of the second phase of the methodology including control variables. What immediately catches the eye in Table 5-68 and Table 5-69, is that the analysis of the electric power T&D losses appears to be very similar to the previous one, namely that of the net energy imports. The SIRRE sub-indicators show no signs of statistical relevance and of the five analyzed control variables, only the electric power consumption (kWh per capita) and total CO2 emissions from electricity and heat production (% of total fuel combustion) are statistically significant with both variables boasting p-values of < 0.01.

Country: Iran ***R-squared: 0.7472*** ***Observations: 39*** ***Dependent Variable: Electric T&D Losses***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	117.01041	69.94298	1.67294	0.10474
Vertical Integration	-1.12675	53.16996	-0.02119	0.98323
Market Structure	61.82886	115.93355	0.53331	0.59775
Electric power consumption (kWh per capita)	0.91196	0.13760	6.62743	2.45E-07
Energy mix diversification (Shannon's H)	-222.15411	351.23633	-0.63249	0.53186
GDP/capita (current US$ per capita)	-0.0054	0.02876	-0.18826	0.85194

CO_2 emissions from electricity and heat production, total (% of total fuel combustion)	-95.30094	16.53844	-5.76239	2.71E-06
Electricity production from renewable sources, excluding hydroelectric (kWh)	4.88E-08	1.33E-06	0.03671	0.97096

Table 5-69 Electric Power T&D Losses Impact Results (with control variables): Iran

5.5.2.10 Access to Electricity

The impact of the deregulation of the electricity sector in Iran on the electrification rate was analyzed and the results are depicted in Table 5-70 below. It is noteworthy to mention that at the beginning of the analyzed timeline, i.e. 1990, Iran already had a high electrification rate, namely 96.15%. Nevertheless, the electricity sector reforms can still have an impact on the access to electricity in Iran, which is confirmed by the market structure p-value of < 0.05, thereby proving statistical significance – the only SIRRE sub-indicator doing so. Furthermore, all coefficient signs are negative and the R-squared value boasts a value right above the threshold of 0.75.

Country: Iran **R-squared: 0.7728** **Observations: 24** **Dependent Variable: Access to Electricity**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.14918	0.19434	-0.76766	0.45166
Vertical Integration	-0.25109	0.17166	-1.46266	0.15910
Market Structure	-0.33614	0.15086	-2.22812	0.03751

Table 5-70 Access to Electricity Impact Results: Iran

Table 5-71 below displays the results of the second phase of the methodology with the inclusion of the control variables. In this analysis, the R-squared value is extremely high, boasting a value of 0.992, despite none of the SIRRE sub-indicators having any statistical significance. Furthermore, of the control variables, only electric power consumption and energy intensity are statistically relevant with the former having a p-value of < 0.01, while the latter has a p-value of < 0.05. Both qualify for subsequent discussion in the following chapter. The fact that the analyzed timeline for the electrification rate is only from 1990-2013 does not affect the results in any way since the electricity sector reforms in Iran commenced during this time period.

Country: Iran **R-squared: 0.9920** **Observations: 24** **Dependent Variable: Access to Electricity**	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	0.10926	0.07700	1.41884	0.17947
Vertical Integration	0.16855	0.10720	1.57223	0.13991
Market Structure	0.09092	0.05936	1.53163	0.14958
Electric power consumption (kWh per capita)	0.00203	3.02E-04	6.71382	1.44E-05
Energy mix diversification (Shannon's H)	-0.17885	0.34904	-0.51242	0.61695
GDP/capita (current US$ per capita)	-4.78E-05	6.24E-05	-0.76609	0.45731
CO_2 emissions from electricity and heat production, total (% of total fuel combustion)	-0.00944	0.02877	-0.32795	0.74817
Europe Brent Spot Price (US$ per Barrel)	0.00059	0.00355	0.16671	0.87016
Energy intensity (MJ/$2011 PPP GDP)	0.19445	0.08394	2.31651	0.03749
Foreign direct investment, net inflows (% of GDP)	0.16274	0.11322	1.43738	0.17424

Table 5-71 Access to Electricity Impact Results (with control variables): Iran

5.5.2.11 Corruption Perception Index

The results of the first phase of the CPI analysis are displayed in Table 5-72 below. The reader is hereby notified that the analysis was only conducted for the timeline of 2001-2013, which can be seen by the number of observations: 13. This is merely one year before the start of the electricity sector reforms and therefore the results could simply be measuring the country's development or economic growth in general and not the change due to the reforms. Nevertheless, the results obtained show that only the market structure SIRRE sub-indicator is statistically relevant with a p-value of < 0.01, while the others can be discarded. Moreover, the low R-squared value leaves a lot to be hoped for.

Country: Iran ***R-squared: 0.6492*** ***Observations: 13*** ***Dependent Variable: Corruption Perception Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.56952	0.48255	-1.18022	0.26816
Vertical Integration	-0.13108	0.55995	-0.23408	0.82016
Market Structure	1.50541	0.37460	4.01867	0.00302

Table 5-72 Corruption Perception Index Impact Results: Iran

Table 5-73 displays the results of the second methodology phase. As in the first phase of the methodology, the market structure SIRRE sub-indicator is statistically significant with a slightly higher p-value that is still under the 0.05 threshold. Of the six analyzed control variables, only the consumer prices inflation variable is also significant, with a similar p-value to the market structure sub-indicator. The relatively high R-squared value should not deceive the reader, but should be ignored due to the lack of proven statistical significance in the analyzed variables.

Country: Iran ***R-squared: 0.9458*** ***Observations: 13*** ***Dependent Variable: Corruption Perception Index***	*Coefficients*	*Standard Error*	*t-Stat*	*P-value*
Entry Regulation	-0.43384	0.20114	-2.15695	0.11992
Vertical Integration	0.67973	0.38823	1.75081	0.17828
Market Structure	0.49436	0.13843	3.57126	0.03752
GDP/capita (current US$ per capita)	-1.58E-04	1.79E-04	-0.87885	0.44419
GHGs/capita (kt of CO2 equivalent per capita)	254.32991	679.74125	0.37416	0.73317
Unemployment, total (% of total labor force)	0.30316	0.13925	2.17704	0.11767
Inflation, consumer prices (annual %)	0.08409	0.02352	3.57561	0.03740
Energy intensity (MJ/$2011 PPP GDP)	-0.62556	0.34743	-1.80052	0.16959
Foreign direct investment, net inflows (% of GDP)	0.36719	0.42327	0.86750	0.44949

Table 5-73 Corruption Perception Index Impact Results (with control variables): Iran

5.5.3 Derived New Knowledge and Discussion of Results

Iran is an interesting country for several reasons and its energy system has an amazing potential despite multiple obstacles and weak points. From the obtained results in the previous chapter, a few conclusions could be derived and the implications discussed. Although the results were not as interesting as other previously analyzed case-studies, many new phenomena were still witnessed. Not every observation was able to be discussed or explained. For this reason, the author challenges the reader to try to come up with own explanations for the witnessed phenomena.

The market structure and vertical integration indicators of the electricity sector reforms have had an impact on the diversification of the power generation fuel mix in Iran. The results allow the author to conclude that the more vertically integrated the different electricity sector segments[13] are, the more diverse the energy mix will be. This stands in direct contradiction to the next observed phenomenon, which is that the less market shares the dominant market player owns, the more diversified the power generation fuel mix will be. The contradiction is that when the electricity sector deregulates, the generation fuel mix increases and at the same time decreases in diversity. This is a paradox and necessitates the differentiating of "electricity sector deregulation" into its sub-indicators. Once this has been understood, the Iranian policy makers can choose how to proceed with their process of deregulation should the diversification of their energy mix be a main priority. Energy security is not on Iran's main agenda since it is a net exporter of energy, but it has other worries that will be discussed in the following.

The Iranian electricity sector reforms have only had moderate impacts on the energy intensity. The only derivable conclusion from the obtained results is that with increasing vertical separation of the electricity sector segments, the energy intensity variable decreases and Iran becomes more energy efficient. As explained in previous case studies, the definition of energy intensity as unit of energy per GDP (MJ/$2011 PPP GDP) means that as the GDP/capita decreases, the energy intensity increases. On the other hand, as the per capita energy use increases, the energy intensity subsequently increases. As inflation increases, the energy intensity increases and it takes more units of energy to wring out the same amount of GDP. This can be explained as the denominator is measured in purchasing power parity and as inflation increases, this decreases, thereby increasing the energy intensity.

An interesting control variable to discuss is net energy imports (% of energy use). The results show that as net energy imports increase, Iranian energy intensity increases as well. Since Iran is a net energy exporter, the sign of the net energy imports control variable is always negative. Therefore, the afore-mentioned statement can be translated to: as net energy exports decrease, Iranian energy intensity increases. This should be a waving red flag for Iranian policy makers that are concerned with large revenues from exporting energy resources. With the increasing national energy demand in sight, it is safe to say that if Iran continues to be inefficient in its energy use, the revenue from its energy exports will decrease since the country will need them to supply its own energy demand. Energy efficiency and therefore a decrease in energy intensity is key for an energy-inefficient, energy exporting country like Iran. All measures should be taken to pursue this goal, including unbundling the vertically integrated electricity sector segments through privatization and sale of state-owned company assets.

Although statistical significance issues hindered the formulation of any conclusions for the impact of the Iranian electricity reforms on the country's energy use, other conclusions can be made. As seen in previous case-studies, Iran's energy use increases with increasing electric power consumption, GHGs/capita and net energy imports. The first explanation is simply that the electric power consumption is part of the total energy use per capita and is therefore strongly correlated, as seen previously in all analyzed case-studies. As Iran's energy sector is very dependent on GHG emitting fuels, it is no surprise to find that they are quantitatively correlated. This allows the variable of GHGs/capita to be used to forecast the trend of Iran's per capita energy use. The last phenomenon can be explained by stating that as the national per capita energy use increases, less energy resources will be available for export. In conclusion, the higher the national energy use, the lower the net energy exports will be.

From the obtained results during the net energy imports analysis, no conclusions could be made regarding the effect of the Iranian electricity reforms on the country's net energy imports. It is assumed that for an energy exporting country like Iran, where a big part of the GDP of the country depends on the income generated by these revenues, the government will not allow the market or other economic factors to dictate the country's export policies. Other variables such as political stability or the oil and gas price are expected to influence this impact indicator much more than the deregulation of the electricity sector.

[13] The electricity sector segments consist of generation, transmission, distribution and supply. Sometimes import is added as one of these segments.

As the electric power consumption per Iranian increases, so do the net energy imports, or in other words, the net energy exports decrease. This is logical and has been previously explained. It suffices here to mention that as the electric power demand of the national population increases, less energy remains for export purposes. Furthermore, as the GHGs/capita decrease, the net energy exports decrease as well. However, since the Iranian energy sector is heavily reliant on GHG emitting fuels, a decrease in GHGs/capita means a decrease in energy use/capita, meaning that there should be more energy available for export. This stands in direct conflict with a statement made earlier in this chapter during the analysis of the energy use and raises the question of the robustness of the MLR methodology adopted. This discrepancy is taken seriously by the author. The reader is hereby made aware of this fact and it is left up to them to decide how to deal with this inconsistency.

Unfortunately, the results allow no correlation to be stated between electricity sector reforms in Iran and the electric T&D losses to be confirmed. However, it can be said that as the electric power consumption per capita increases, so do the T&D losses. Furthermore, as the total CO_2 emissions from electricity and heat production decrease, the T&D losses increase. The author is at a loss to explain these two phenomena and advises the reader to search in available literature for relationships between these two sets of variables.

The only deduction that can be made concerning the correlation between the SIRRE indicator and the electrification rate is that the lower the market shares of the strongest company in every electricity sector segment are, the higher the access to electricity of the Iranian population is. However, since the electrification rate of Iran was over 99.3% in 2013, the electrification of the rest of the population is not a main priority for the Iranian policy makers. Being an oil and gas exporter, the policy makers have other things to worry about and should focus more on implementing energy efficiency measures and decreasing or mitigating the increase in energy demand.

Furthermore, the results show that as the electric power consumption per capita increases, so does the electrification rate. This statement could be turned around to read: as the electrification rate increases, the electric power consumption increases. This is logical since a person cannot consume electricity when he has no access to it. A further correlation exists between the energy intensity and the electrification rate, namely that as the energy intensity increases, so does the electrification rate. However, this means that the higher the percentage of the population that has access to electricity is, the more energy inefficient the country is. This does not necessarily infer causation, as the phenomenon can simply be explained by the fact that the energy intensity and the access to electricity have been steadily increasing since 1990. This does not primarily point to the causation of these variables, as it may be a coincidence that they possess the same slope. This is similarly true for all obtained results and the reader is asked to be aware of this fact while reading this thesis.

The only effect the electricity sector reforms have had on the corruption in Iran comes from the market structure sub-indicator. As the market shares of the largest company in the respective electricity sector segment increase, the corruption also increases. This is logical since a corrupt desire to maintain power implies keeping as much of the sector under your control. To counter and battle corruption, Iran could decide to further pursue the implementation of sectoral reforms or widen the application of these reforms to other sectors of the economy. Privatization and the sale of state-owned assets could prove invaluable for stamping out corruption however hard the process may be. The results imply that the higher the inflation rate in Iran is, the more corruption can be found in Iran. One explanation is that poor yet honest citizens are forced to become corrupt, by accepting bribes e.g., in order to provide for their families. This is not directly related to the deregulation of the electricity sector and the author does not wish to go into depth with such issues since it definitely lies outside the scope of this thesis.

6 Comparison and Discussion of Results

Apart from analyzing each country separately, invaluable knowledge can be derived from the comparison of the different case-studies. The following seven tables were created to summarize the obtained results of each country for the seven different impact indicators in a simple and clear way to attain a proper overview. This way, new conclusions and universally valid policy recommendations can be drawn.

For the following seven tables, ● represents a negative correlation between the dependent variable and the SIRRE sub-indicator or the control variable. The number of black circles, ●, ●● and ●●●, stands for the statistical significance of the p-values < 0.1, < 0.05 and < 0.01, respectively. On the other hand, o represents a positive correlation between the dependent variable and the SIRRE sub-indicator or the control variable. The number of white circles, o, oo or ooo, stands for the statistical significance of the p-values < 0.1, < 0.05 and < 0.01, respectively. Since the SIRRE sub-indicators were analyzed twice, namely in methodology phases I and II, it is possible that they correlated more than once. In such a case, the results are separated with a comma. Where the fields have been left blank no statistical significance was proven since the p-value obtained there was above 0.1. If N.A. is found in a field, it means that that specific SIRRE sub-indicator was not analyzed and no result was obtained.

The individual results of the Shannon's diversity index are displayed in Table 6-1 below. The first noticeable fact is that when the total CO2 emissions from the electricity and heat production correlate with the Shannon's diversity index, it is always a positive correlation. This leads to the conclusion that as the total CO2 emissions increase for Turkey, Chile and India, the power generations fuel mix increases in diversity. Let it be known to the reader that all these countries had a strong hydropower percentage in the energy mix that steadily decreased throughout the timeline.

The SIRRE sub-indicator impact on the Shannon's diversity index is very ambivalent with the analyzed countries. In general, it can be said that a high correlation exists, however, this is at times negative and at other times positive, which complicates this discussion. Therefore, no clear conclusion can be drawn regarding all developing countries in general and each case needs to be observed and discussed separately. While Turkey's power generation mix becomes less diversified with increasing deregulation, the opposite is true for Ghana and Chile while an ambivalent nature exists for the different SIRRE sub-indicators of India and Iran. Furthermore, the net inflow of foreign direct investment did not correlate with the Shannon's diversity index for any of the analyzed countries, which was counterintuitive to the author. It was expected that the higher the inflow of foreign investment, the more diversified the energy mix will become. This could not be proven with the results obtained in this thesis.

Shannon's Diversity Index	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation	●	○○○	●, ●●	●●, ●●●	
Public Ownership	○○○	●●●	○○○	N.A.	N.A.
Vertical Integration		●●			○○
Market Structure	○, ○○○	●●		●●●, ●●	●●
Electric power consumption (kWh per capita)	●●		●●		
GDP/capita (current US$ per capita)			○○○		
GHGs/capita (kt of CO2 equivalent per capita)	○○				
Energy imports, net (% of energy use)		○○		●●	
Foreign direct investment, net inflows (% of GDP)					
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	○○○	○○○		○○○	

Table 6-1 Comparison of Results: Shannon's Diversity Index

Table 6-2 summarizes the results obtained for all analyzed countries regarding the energy intensity impact indicator. The results in this table are a lot more homogenous than the ones displayed in Table 6-1. It is interesting to note that the entry regulation SIRRE sub-indicator never correlated with any country although it was analyzed ten times[14]. The same is true for public ownership although that indicator was only analyzed four times. Nonetheless, vertical integration correlated in four out of five analyses and when it did, the correlation was positive. This is an important conclusion and means that as the electricity reforms in a country begin to increasingly separate the different vertically integrated electricity sector segments, the energy intensity decreases and the country becomes more energy efficient, able to wring more GDP out of every unit of energy. The decreasing of the market shares of the largest company in the electricity sector has the same effect, although this time it is restricted to the case-study of Ghana.

The clearly homogeneous results among all analyzed countries for this dependent variable is an indicator of success for this methodology. The correlation explanations of access to electricity, GDP/capita, energy use and inflation rate will not be further discussed in this chapter since they have been widely elaborated on in the individual country result discussions.

Energy Intensity	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation					
Public Ownership		N.A.		N.A.	N.A.
Vertical Integration		○	○○○, ○○	○○○	○○
Market Structure				○○○, ○○	
Europe Brent Spot Price (US$ per Barrel)		●●			
Access to electricity (% of population)		●		●●●	
GDP/capita (current US$ per capita)			●●	●●	●●
GHGs/capita (kt of CO2 equivalent per capita)					●
Energy imports, net (% of energy use)			●●●	○○	○○○
Energy use (kg of oil equivalent per capita)	○	○○○	○	○○○	○○○
Unemployment, total (% of total labor force)		○○			
Inflation, consumer prices (annual %)		○○○			○○○

Table 6-2 Comparison of Results: Energy Intensity

All the attained results for the energy use impact indicator are summarized in Table 6-3 below. The strong positive correlation between the electric power consumption per capita and the GHG emissions per capita with the energy use per capita comes as no surprise and has been explained previously. However, the impact of electricity sector reforms, quantified by the SIRRE sub-indicators, is ambiguous of nature and does not allow a concise conclusion that is valid across all of the case-studies to be drawn. Some sub-indicators have different coefficient signs across countries while others such as vertical integration in the case of Chile even have different coefficient signs for methodology phases I and II. Going into detail for the explanation of the individual country results has already been done previously and will not be repeated at this stage.

[14] Five countries times two methodology phases equals ten phases.

Energy Use	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation		○○○		●●, ●●	●, ●
Public Ownership	○○○	●●●, ●●●	●, ○○	N.A.	N.A.
Vertical Integration	○○	●●●, ○○○	●●	●	
Market Structure	●●	●●●, ●●●		○○○, ○○○	
Electric power consumption (kWh per capita)	○○○	○○○	○○○	○○○	○○○
GDP/capita (current US$ per capita)		○○○	○○	●●	●
GHGs/capita (kt of CO2 equivalent per capita)		○○○	○○	○○○	○○○
Energy imports, net (% of energy use)				●●●	○○○

Table 6-3 Comparison of Results: Energy Use

Table 6-4 depicts the results of all the case-study analyses for the net energy imports impact indicator below. Several conclusions can be derived although some ambiguities exist like the public ownership and vertical integration SIRRE sub-indicators e.g. that have opposite coefficient signs for the countries in which they proved statistically significant. Although some SIRRE sub-indicators are coherent among different countries, when each country is taken by itself, like Chile and Ghana, the impact of electricity sector reforms is contradictory. While deregulation in entry regulations may lead to the decrease of net energy imports, deregulation in the market structure increases them. No correlation could be obtained between the net energy imports impact indicators and any SIRRE sub-indicator of India and Iran.

The policy maker reading this is hereby warned of the different impacts of electricity reforms and depending on the priorities of his agenda can choose which area of the electricity sector to deregulate and which to maintain regulated. If a policy maker wants to decrease the net energy imports of his country e.g. he would have to decrease the market share of the largest company but not allow third-party access to the transmission grid or the establishment of a liberalized wholesale electricity market. Being able to solve this apparent contradiction depends on the skill of the policy maker.

Net Energy Imports	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation		○○○		○○○, ○	
Public Ownership	○○○	●●●	●	N.A.	N.A.
Vertical Integration		○○○		●●, ●●●	
Market Structure		●●●		●●●	
Electric power consumption (kWh per capita)	○○○				○○○
Energy mix diversification (Shannon's H)					
GDP/capita (current US$ per capita)	●●		○	●●●	
GHGs/capita (kt of CO2 equivalent per capita)		○○○			●●●
Foreign direct investment, net inflows (% of GDP)				○	

Table 6-4 Comparison of Results: Net Energy Imports

All the results for the different case-study analyses describing the impacts on the electric T&D losses are displayed in Table 6-5 below. The only control variable with a homogenous coefficient sign for the countries of correlation is GDP/capita. The electric T&D losses decrease with increasing GDP/capita. The GDP/capita is an economic indicator measuring the wealth of a country and sometimes even the country's development. The observation is logical because as a country develops and its economy grows, its electrical grid will become more efficient and the T&D losses will decrease.

Regarding the SIRRE sub-indicators, the obtained results are similar to the previous impact indicator, yet different. The ambiguity surrounding the vertical integration and market structure for the different countries hinders the formulation of a conclusion spanning over all developing countries. However, this is different for the other two sub-indicators. Public ownership correlates positively with the T&D losses every time it is analyzed. This signifies that the higher the shares owned by the government of the largest company in the sector are, the higher the T&D losses are. This is a strong argument for deregulation and more specifically for privatization. If a policy maker wishes to decrease the T&D losses in the electricity system, he should endorse privatization and sell state-owned company assets to private firms.

The negative correlation of entry regulation challenges the afore-mentioned statement by implying that increased deregulation would increase T&D losses. This is no contradiction however, since different parts of deregulation can have contradicting impacts on the same dependent variable. Nonetheless, this means that as third-party access to the transmission grid is granted and a liberalized wholesale electricity market is established, the T&D losses increase – or at least for Chile and India.

Electric T&D losses	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation		●●●, ●	●●		
Public Ownership	○○○	○○○	○○○, ○○	N.A.	N.A.
Vertical Integration		●●	○○	●●	●
Market Structure	○○	○○○, ○○		●●●, ●●	
Electric power consumption (kWh per capita)	○○○		●		○○○
Energy mix diversification (Shannon's H)			○○	●●●	
GDP/capita (current US$ per capita)	●●●			●●●	
CO2 emissions from electricity and heat production, total (% of total fuel combustion)			○○○	○○○	●●●
Electricity production from renewable sources, excluding hydroelectric (kWh)	●		○○○	●●	

Table 6-5 Comparison of Results: Electric T&D Losses

Table 6-6 depicts the results of the analysis of the access to electricity dependent variable below. In general, the table below is characterized by a lack of statistical significance of the control variables except for the case-study of Ghana. Nonetheless, important conclusions can be extracted regarding one control variable in addition to the impact of electricity sector reforms.

Having a positive correlation for four out of five analyzed countries allows the conclusion to be drawn that as the electric power consumption per capita increases, the electrification rate increases and more percent of the population gain access to electricity. Although it does not have to be that one causes the other, the correlation relationship between these two variable sets is interesting to note.

If Table 6-6 is looked at from a distance, a definitive majority of black circles exists in the top four rows of the table compared to white circles. This signifies that with increasing deregulation, the access to electricity also increases. This is found to be the case for most analyzed countries and therefore it is stated as a universally applicable altruism for developing countries: As the deregulation of the electricity sector increases, the electrification rate increases. This is a key policy recommendation for any developing country with a low percentage of the population having access to electricity and that has the increase of this indicator as a priority on its agenda: deregulate your electricity sector!

Access to electricity	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation		●●		●●●	
Public Ownership	○○○, ○○	N.A.		N.A.	N.A.
Vertical Integration			●	●●, ●	
Market Structure	●●	●●●		●●●, ○○	●●
Electric power consumption (kWh per capita)	○○○	○○○		○○	○○○
Energy mix diversification (Shannon's H)				○○○	
GDP/capita (current US$ per capita)				●●	
CO2 emissions from electricity and heat production, total (% of total fuel combustion)	○			●●	
Europe Brent Spot Price (US$ per Barrel)	●				
Energy intensity (MJ/$2011 PPP GDP)				●●●	○○
Foreign direct investment, net inflows (% of GDP)					

Table 6-6 Comparison of Results: Access to Electricity

Table 6-7 depicts the obtained results for all countries analyzing the corruption perception index. The table below is characterized by a lack of circles in the rows for the control variables, which shows the lack of statistical significance thereof and the inability to impact the corruption of a country. During the case-study analysis of India and Ghana, no control variable and only one SIRRE sub-indicator each showed signs of being statistically significant. The obtained results disallow the deduction of any conclusion or policy recommendation for all developing countries due to the lack of homogeneity among the analyzed countries. Nevertheless, the results obtained for the case-study of Turkey are very expressive and have previously been explained and discussed. Unfortunately, they are relevant only for Turkey and cannot be widely applied for all developing countries.

Corruption Perception Index	*Turkey*	*Chile*	*India*	*Ghana*	*Iran*
Entry Regulation	○, ○○			●●●	
Public Ownership	●●●, ●●●	N.A.		N.A.	N.A.
Vertical Integration	●●	○○	●		
Market Structure	●●●	●●●			○○○, ○○
GDP/capita (current US$ per capita)					
GHGs/capita (kt of CO2 equivalent per capita)					
Unemployment, total (% of total labor force)		○			
Inflation, consumer prices (annual %)					○○
Energy intensity (MJ/$2011 PPP GDP)		●			
Foreign direct investment, net inflows (% of GDP)					

Table 6-7 Comparison of Results: Corruption Perception Index

7 Conclusion and Recommendations

This thesis analyzed the impacts of electricity sector deregulation in developing countries. This was done following a complex procedure that was guided by a clear methodology all the way through until the final results were obtained. First of all, the countries to-be-analyzed had to be defined, which was done following a guideline that prescribed that the countries must be heterogenous in a wide range of indicators and indices, such as democracy, population, geographic location and most importantly degree of electricity sector regulation. A very diverse group of countries was found by choosing Turkey, Chile, India, Ghana and Iran.

Consulting the available literature on the topic of electricity sector deregulation impacts, the data for the SIRRE indicator was found provided by the OECD for the entire timeline of Turkey, Chile and only for two years for India. The methodology to obtain this SIRRE indicator was therefore consulted in order to fill out the missing data for India and calculate the scores for the SIRRE sub-indicators for Ghana and Iran. The timeline of the overall SIRRE indicator scores for the analyzed case-studies is depicted in Figure 7.1 below.

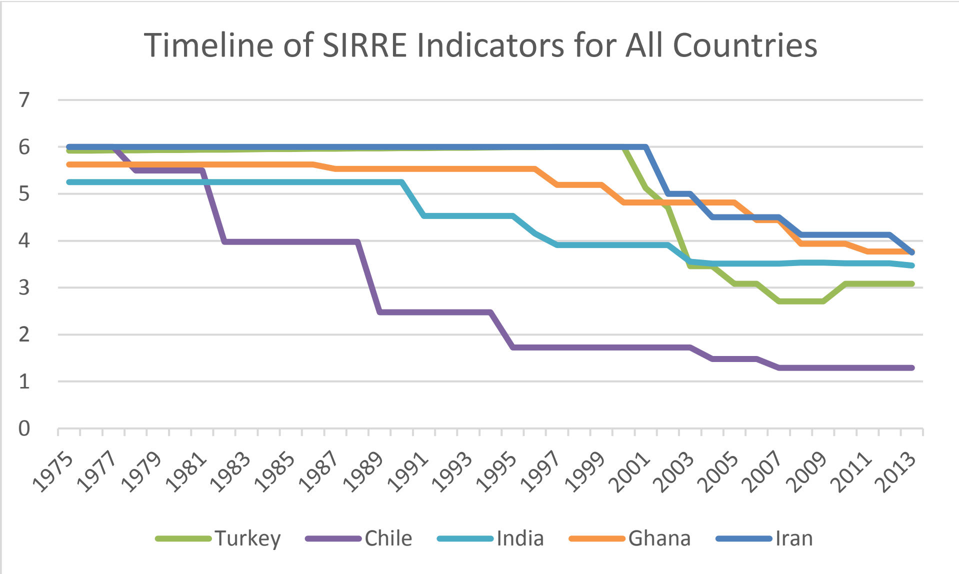

Figure 7.1 Overall SIRRE Indicators vs. Time

Figure 7.1 highlights the difference in deregulation experiences among the analyzed countries. A mere look at the figure shows that Chile was the first country to begin deregulation and Iran the last. Furthermore, although India began electricity reforms a considerable time before Iran, their overall SIRRE indicator score was nearly equal in 2013. Turkey shows a strange behavior since its overall SIRRE indicator increased twice, i.e. from 1975-1996 and then again in 2010, which is unparalleled in all the other analyzed countries.

After calculating the SIRRE sub-indicator for all analyzed countries, the impact indicators[15] and the corresponding control variables[16] were defined. Although the task of finding all this data was tedious and wearisome, it was rewarded with the ability of performing a quantitative analysis describing the relationship between electricity sector deregulation and the chosen impact indicators. This was performed in the first methodology phase, in which correlations between SIRRE sub-indicators and the impact indicators were deduced for each country. In the second phase of the methodology, the control variables defined for each

[15] The impact indicators are Shannon's diversity index, energy intensity, energy use, electric power T&D losses, access to electricity and the corruption perception index.

[16] The control variables include electric power consumption, total CO_2 emissions from electricity and heat production, electricity from renewable non-hydro sources, GDP/capita, GHGs/capita, net inflows of foreign direct investment, inflation of consumer prices, unemployment rate and lastly the Brent spot oil price.

respective impact indicator were added to the MLR equation to render the results more realistic and be able to predict future trends more precisely by increasing the R-squared value.

If a SIRRE sub-indicator or a control variable boasted a p-value of below 0.05 in the results, thereby proving statistical significance, it was discussed and explanations were sought for the observed phenomenon. This was done separately for each country and interesting conclusions were drawn that enabled further policy recommendations. Thereafter, the results were displayed in tables for subsequent comparison and contrast in order to obtain universally applicable conclusions for all developing countries. These conclusions and policy recommendations will not be repeated here but the reader is hereby reminded to look at the Derived New Knowledge and Discussion of Results chapter available after the presentation of results for each country as well as the Comparison and Discussion of Results chapter.

Although this thesis is particularly interesting for policy makers of the analyzed countries, the conclusions drawn can have a wider sphere of influence due to the heterogeneous nature of the group of analyzed countries. A different developing country can simply see which one of the analyzed case-studies it is closest to and use the conclusions and policy recommendations of that country or even combine the derived results of different case-studies to formulate its own policies for electricity sector reform. The discussion of the results contains two types of information: warnings of undesired impacts on the one hand and possible potential positive impacts on the other that occur in the case of deregulation. Both are important for offering high-quality advice and recommendations to key policymakers in order for them to make discerning decisions depending on the priorities on their country's agenda. Furthermore, the results obtained include a linear equation in the form of coefficients, which enables predicting future trends of the observed impact indicator using the knowledge of the statistically significant SIRRE impact indicators and control variables.

This thesis was concerned with the problem of supplying reliable electricity while simultaneously promoting competition by allowing third-party access to the transmission grid and establishing a wholesale electricity market, which faces many policy makers worldwide. The effects of the reforms have been analyzed and have been found to be more positive than negative in most case studies, which is a clear argument for the implementation of sector reforms.

Although most of the differences between the analyzed case-studies can be taken from the chapters dedicated to each individual country, some key dissimilarities were derived after the results were obtained. Both Ghana and Iran showed strong statistical significance between the net energy imports and energy use, despite the coefficient signs being opposite. While an increase in the Ghanaian energy use leads to a decrease in net energy imports, an increase in the Iranian energy use leads to an increase in net energy imports or a synonymous decrease in net energy exports. This is due to the fact that Ghana is in the process of transformation from being a net energy importer to a net energy exporter, while Iran has always been an energy exporter but with the ever-increasing national energy demand, less resources are available for export. Furthermore, the net energy imports of India and Iran do not correlate at all with any deregulation processes, while the opposite is true for Chile and Ghana. The reader is hereby notified that India and Iran both had vertically integrated, state-owned regional electricity companies managing the electricity system, while these responsibilities were concentrated in one company, utility or authority in the case of Chile and Ghana.

The obtained results lead to interesting conclusions. It is key to mention the fact that the electric power consumption variable has a strong statistical significance with the energy use of each of the analyzed case-studies adds robustness to and increases trust in the results. Additionally, it is shown that the GHGs/capita have a strong impact on the energy use or the other way around, the energy use has a strong impact on the GHGs/capita, which seems to be more logical since the GHGs are produced through the usage of energy. This brings us back to the main limitation of the MLR methodology used in this thesis, namely that it cannot be distinguished what is the cause and what the effect of the variables, but simply that a correlation exists between the two variable sets. Moreover, the strong correlation between the electric power consumption and the access to electricity is noteworthy for all of the analyzed case-studies, except for the one in which it would matter the most, i.e. India. Although the results demonstrate that increasing the electrification rate automatically increases the electric power consumption, no statistical significance could be extracted for India, the country home to the most unelectrified households in the world.

After discussing and explaining the obtained results, a few key insights can be noted down especially interesting for policy makers of developing countries.

- Deregulatory reforms in the areas of entry regulation and public ownership have no impact on the energy intensity of a developing country, whereas strong correlation exists between vertical separation of electricity sector segments and a decrease in energy intensity and thereby increased energy efficiency.
- If a developing country has a strong hydro power generation base load, increasing CO2 emissions from electricity and heat production is an indicator for an increasingly diversified fuel source generation mix.
- An increase in the GDP/capita and electrification rate decreases the energy intensity and renders the country more energy efficient while the opposite is true for an increase in energy use, unemployment and inflation.
- Electricity sector deregulation reforms can have contradictory impacts and depending on the priorities of the policy maker's agenda, they can choose which area of the electricity sector to deregulate and which to maintain regulated. If a policy maker wants to decrease the net energy imports of his country e.g. he would have to decrease the market share of the largest company but not allow third-party access to the transmission grid or the establishment of a liberalized wholesale electricity market.
- Likewise, if a policy maker wants to decrease the electric T&D losses of their country, they would have to decrease the percentage of the shares owned by the government of the largest company but not allow third-party access to the transmission grid or the establishment of a liberalized wholesale electricity market.
- As the deregulation of the electricity sector increases, the electrification rate increases. This is key for any developing country with a low percentage of the population having access to electricity and that has the increase of this indicator as a priority on its agenda: deregulate your electricity sector!
- The deregulation of the Turkish electricity sector decreased the corruption perception index of the country. Although this conclusion is only valid for the case-study of Turkey and not for all developing countries, Turkish policy makers should continue deregulating the sector if they wish to battle corruption within their country.

Finally, it must be stated that the electricity sector cannot ever be fully deregulated. There are certain bottlenecks in the transmission and distribution electricity sector segments that force monopolistic actor behavior where regulation is crucial and even necessary. The real question is how to make the system work efficiently with parts of it remaining regulated. Nevertheless, most developing countries are far from perfect deregulation and are located in the upper part of the 0-6 SIRRE scale. As shown through this thesis, improved energy efficiency[17], sinking electric T&D losses[18], increased electrification rate and lower corruption[19] are only a few of the many benefits electricity sector deregulation has to offer. Although many problems, which are also described in this thesis, may be encountered on the way, accelerated electricity reforms should be a priority for any policy maker of a developing country plagued by problems such as frequent blackouts, insufficient funds for capacity expansions and high T&D as well as non-technical losses.

[17] Energy efficiency improvement is used synonymously with energy intensity decrease.
[18] T&D losses decrease with the decreasing percentage of state-owned assets in the largest firm in the sector.
[19] Lower corruption applies to the specific case of Turkey and is not generally applicable to all developing countries.

8 Outlook and Suggested Future Work

Apart from the analyzed indicators, the deregulation of the electricity sector can have significant impacts on other areas of the society, politics or economics of a country. Of them, the most important to mention is the impact on electricity cuts or more precisely, GDP lost due to power outages. It is expected that there is a significant causation effect between electricity sector deregulatory measures and power outages. However, due to the lack of sufficient data, this connection was not able to be measured quantitively and is therefore left open for future work on this subject. Many developing countries are plagued with an unreliable electricity system that causes huge losses in the total GDP of the country. An in-depth study that is able to prove correlation between electricity cuts and electricity sector reforms will have a big influence on the policy makers of developing countries encountering this problem.

For the analyzed countries, electricity price data availability was unsatisfactory. Turkey e.g. only had available data as of 2007 and due to the fact that the deregulation of the electricity system commenced in the 1980's, this data was insufficient. Numerous studies have already been conducted on this connection but most focus on the negative examples such as the electricity price peak in California due to deregulation measures in the early 2000's. However, an analysis of the impact of electricity sector deregulatory measures on electricity prices in developing countries is still among the outstanding works regarding this subject. In addition, due to the lack of complete information from 1975-2013, the oil price could only be used as a control variable for energy intensity and access to electricity.

Eight unique control variables along with the Brent oil price were added to the MLR equation to make the results more realistic in the second methodology phase. Although this does improve the results, it is suggested that some of the impact indicators depend on other factors that were not taken into consideration. A few control variables were pondered on, but finally disregarded for different reasons such as the lack of data availability for all analyzed case-studies. Examples of such control variables are capacity utilization (%), private investment in the energy sector (current US$), the consumer price index and finally the GINI index. The GINI index could prove to be interesting, since it measures inequality by quantifying the disparity and distribution of the population's income and/or wealth.

Often, a country's development goes hand in hand with the deregulation of numerous sectors of the economy. It is expected that this is no different for the electricity sector. The will to show this was definitely present in this thesis, however the Human Development Index (HDI) lacks historical data dating back to the time of deregulation in the countries analyzed. A note-worthy correlation relationship could therefore not be made. The author is aware that there are other ways to measure development with the existence of a myriad of indicators[20]. This was however not the primary objective and therefore outside the scope of this thesis. The author hopes that this will be analyzed soon as it could have significant policy implications in many developing countries.

The analyzed timeline ends in 2013 since no more up-to-date information is available for all case-studies of interest. This is quite unfortunate since in many developing countries, the deregulatory reforms of the electricity system are quite recent, such as in Iran where electricity reforms began in 2002. A further example is the Turkish electricity stock market that was introduced in 2015, whose impacts were not analyzed in this thesis. Further work on this topic could simply include updating the information and data used for this analysis to include deregulation reforms, law amendments and policies that came into effect post 2013.

Although the five analyzed countries in this thesis were heterogenous in a variety of aspects, the limited number of case-studies does not allow complete generalization of the conclusions. In order to further enhance the robustness of the results, a bigger selection of countries can be taken into account that would subsequently increase the statistical significance. Increasing both the timeline of the analysis as well as the number of analyzed countries would substantially strengthen the validity of the results obtained in this thesis.

---

[20] The GDP/capita is often used to measure development and was utilized in this thesis as a control variable for all analyzed impact indicators.

The Shannon's diversity index was utilized to measure the diversification of the electricity generating technology mix. Obviously, electricity sector reforms have grand ramifications on the number of companies and their shares in the different electricity sector branches, i.e. generation, transmission and distribution. This has not been specifically analyzed in this thesis[21] but could definitely be of interest. The author suggests using the Shannon's diversity index to quantify the evenness and diversity of the companies present in an electricity sector branch - possibly an area of future research.

The Corruption Perception Index was included in this thesis although it is not directly related to the electricity sector but to society in general. A relationship between a country's corruption and the deregulation of the electricity system has been attempted to be made. The author is fully aware that corruption depends on more than only deregulation, with a number of other variables playing a role that were not analyzed in this thesis. Although a few control variables were included to make the results more realistic, numerous variables that are thought to have an impact were excluded for lack of data availability. It would have been beneficial to include the control variable of total government expenditure on education (% of GDP) in the equation predicting the CPI, since it is assumed that education does in fact influence corruption. [114] This was unfortunately not possible due to insufficient data. The World Bank [14] does provide data, the set is however incomplete over the time-span in question and is therefore of little use. Future work could additionally include control variables such as the index for gender inequality, economic freedom and ease of doing business.

[21] This thesis investigates the percentage of government-owned shares of the largest company in the public ownership sub-indicator and the market share of the largest company in the market structure sub-indicator.

9 Appendix A: Impact Indicators

Turkey	*Shannon's Diversity Index*	*Energy intensity (MJ/$2011 PPP GDP)*	*Energy Use (kg of oil equivalent per capita)*	*Net Energy Imports (% of energy use)*	*Electric T&D losses (% of output)*	*Access to electricity (% of population)*	*Corruption Perception Index*
1975	1.146	..	682.81	39.22	10.47	..	..
1976	1.101	..	726.09	42.95	9.36	..	..
1977	1.121	..	778.43	46.93	10.10	..	..
1978	1.107	..	758.03	44.61	10.07	..	..
1979	1.095	..	704.89	42.42	11.38	..	..
1980	1.076	..	716.29	45.51	12.13	..	4.1
1981	1.054	..	705.60	43.04	11.88	..	4.1
1982	1.014	..	732.66	43.73	12.49	..	4.1
1983	1.083	..	757.97	45.95	12.51	..	4.1
1984	1.071	..	770.96	45.43	12.22	..	4.1
1985	1.067	..	799.56	44.41	11.53	..	4.1
1986	1.139	..	843.95	44.49	13.72	..	4.1
1987	1.162	..	917.98	46.72	12.44	..	4.1
1988	1.031	..	907.14	47.56	13.13	..	4.1
1989	1.258	..	925.30	47.79	12.00	..	4.1
1990	1.233	3.831	976.34	51.03	11.61	88.15	4.1
1991	1.234	3.750	946.57	50.68	12.55	88.80	4.1
1992	1.239	3.684	960.86	50.86	13.36	89.46	4.1
1993	1.201	3.630	1003.19	53.99	13.89	90.11	3.5
1994	1.239	3.762	975.73	53.21	15.12	90.75	3.5
1995	1.249	3.820	1052.05	56.99	15.96	91.39	3.5
1996	1.238	3.867	1125.65	59.47	16.71	92.02	3.5
1997	1.268	3.782	1165.81	60.29	17.99	92.63	3.2
1998	1.273	3.767	1169.59	59.48	18.73	93.23	3.4
1999	1.286	3.828	1130.94	60.98	18.50	93.81	3.6
2000	1.283	3.865	1201.09	65.96	19.02	94.38	3.8
2001	1.274	3.790	1094.35	65.24	19.01	94.93	3.6
2002	1.282	3.772	1139.69	67.51	18.49	95.48	3.2
2003	1.233	3.760	1178.90	69.71	17.11	96.02	3.1
2004	1.226	3.564	1205.34	70.13	15.42	96.56	3.2
2005	1.178	3.430	1240.95	71.58	14.85	97.11	3.5
2006	1.158	3.549	1355.83	71.71	14.07	97.67	3.8
2007	1.151	3.640	1438.54	72.73	13.91	98.24	4.1
2008	1.160	3.570	1403.26	70.64	13.85	98.81	4.6
2009	1.160	3.716	1372.29	69.04	14.88	99.33	4.4
2010	1.172	3.713	1475.01	69.62	14.31	100.00	4.4
2011	1.169	3.632	1543.94	71.61	14.11	99.92	4.2
2012	1.204	3.704	1579.48	74.02	14.89	99.99	4.9
2013	1.226	3.517	1534.14	73.07	15.46	100.00	5.0

Table 9-1 Timeline of Analyzed Impact Indicators: Turkey

Chile	*Shannon's Diversity Index*	*Energy intensity (MJ/$2011 PPP GDP)*	*Energy Use (kg of oil equivalent per capita)*	*Net Energy Imports (% of energy use)*	*Electric T&D losses (% of output)*	*Access to electricity (% of population)*	*Corruption Perception Index*
1975	0.820	..	732.42	34.69	11.34	..	..
1976	0.861	..	763.56	35.87	10.89	..	..
1977	0.863	..	779.39	37.05	11.33	..	..
1978	0.888	..	795.23	38.75	10.73	..	..
1979	0.938	..	828.66	45.33	11.41	..	..
1980	0.943	..	843.70	38.80	12.27	..	6.5
1981	0.933	..	844.62	35.47	11.13	..	6.5
1982	0.819	..	763.20	28.04	12.21	..	6.5
1983	0.807	..	777.50	28.95	14.50	..	6.5
1984	0.834	..	805.69	29.71	13.48	..	6.5
1985	0.736	..	791.40	28.96	13.73	..	6.5
1986	0.718	..	813.75	29.95	13.21	..	6.0
1987	0.673	..	826.26	31.54	14.75	..	6.0
1988	0.807	..	919.89	38.03	14.82	..	5.5
1989	0.994	..	1014.23	43.24	11.37	..	5.5
1990	1.145	4.828	1066.06	43.41	10.58	92.26	5.5
1991	0.985	4.573	1072.71	41.72	11.17	94.08	5.5
1992	0.853	4.404	1141.81	44.29	10.61	94.56	5.5
1993	0.872	4.219	1152.22	48.16	12.00	94.81	6.8
1994	0.988	4.291	1220.28	51.28	10.96	95.17	6.8
1995	0.965	4.168	1292.22	54.74	10.44	95.52	6.8
1996	1.097	4.298	1411.22	59.00	8.56	95.62	6.8
1997	1.119	4.514	1558.79	63.24	8.11	96.19	6.1
1998	1.274	4.528	1592.83	65.58	8.18	97.24	6.8
1999	1.365	4.848	1670.70	68.20	5.78	96.79	6.9
2000	1.258	4.665	1659.01	65.91	7.29	97.94	7.4
2001	1.212	4.430	1608.07	63.24	7.36	97.34	7.5
2002	1.207	4.489	1644.79	64.51	6.18	97.60	7.5
2003	1.215	4.363	1642.37	66.85	6.09	98.78	7.4
2004	1.302	4.382	1728.85	68.91	7.88	98.11	7.4
2005	1.260	4.279	1762.11	67.08	8.65	98.38	7.3
2006	1.223	4.266	1813.51	67.41	8.86	99.37	7.3
2007	1.394	4.208	1860.10	69.41	8.43	98.93	7.0
2008	1.336	4.035	1822.00	67.93	8.51	99.22	6.9
2009	1.398	3.969	1754.17	65.46	10.55	99.59	6.7
2010	1.440	3.921	1812.96	70.15	8.22	99.74	7.2
2011	1.475	4.037	1953.90	70.61	7.13	99.59	7.2
2012	1.447	4.237	2139.76	64.99	5.02	99.98	7.2
2013	1.411	4.238	2201.57	61.29	6.69	99.60	7.1

Table 9-2 Timeline of Analyzed Impact Indicators: Chile

India	*Shannon's Diversity Index*	*Energy intensity (MJ/$2011 PPP GDP)*	*Energy Use (kg of oil equivalent per capita)*	*Net Energy Imports (% of energy use)*	*Electric T&D losses (% of output)*	*Access to electricity (% of population)*	*Corruption Perception Index*
1975	1.020	..	276.53	7.30	16.91	..	..
1976	1.001	..	281.09	8.57	17.20	..	..
1977	0.982	..	282.60	8.78	16.71	..	..
1978	1.000	..	280.04	7.48	17.58	..	..
1979	1.016	..	286.22	9.90	17.79	..	..
1980	1.021	..	286.87	9.46	17.71	..	3.7
1981	0.992	..	294.49	7.81	17.83	..	3.7
1982	0.980	..	298.87	6.55	18.12	..	3.7
1983	1.005	..	301.53	4.82	18.22	..	3.7
1984	1.006	..	306.93	4.00	18.16	..	3.7
1985	0.973	..	315.81	6.32	18.38	..	3.7
1986	0.965	..	319.81	5.30	18.28	..	3.3
1987	0.909	..	324.85	5.95	19.03	..	3.3
1988	0.909	..	335.27	6.18	18.22	..	2.9
1989	0.910	..	343.75	7.62	19.59	..	2.9
1990	0.959	8.292	351.15	8.26	19.31	45.06	2.9
1991	0.942	8.548	358.48	8.80	19.24	46.54	2.9
1992	0.952	8.400	364.22	11.05	18.26	48.03	2.9
1993	0.910	8.211	365.67	11.98	18.02	50.90	2.6
1994	0.949	7.994	372.41	12.20	17.80	50.98	2.6
1995	0.949	7.858	386.31	13.06	18.73	52.44	2.6
1996	0.958	7.530	390.65	14.26	20.56	53.90	2.6
1997	0.991	7.524	398.61	14.93	20.72	55.34	2.8
1998	1.031	7.256	400.71	17.23	22.13	56.76	2.9
1999	1.047	7.051	416.20	20.06	25.68	60.10	2.9
2000	1.037	6.950	418.51	20.45	27.22	59.56	2.8
2001	1.025	6.725	417.22	20.08	28.24	55.80	2.7
2002	1.021	6.672	422.48	20.35	26.68	62.30	2.7
2003	1.059	6.334	425.50	19.66	26.74	63.69	2.8
2004	1.055	6.181	440.95	21.38	25.66	64.40	2.8
2005	1.064	5.878	451.06	22.05	25.17	66.43	2.9
2006	1.068	5.662	467.50	23.47	23.66	67.90	3.3
2007	1.089	5.508	486.55	24.97	22.77	69.21	3.5
2008	1.041	5.562	503.07	25.79	21.26	70.62	3.4
2009	1.077	5.647	546.22	27.45	21.13	75.00	3.4
2010	1.083	5.353	563.16	28.35	19.86	76.30	3.3
2011	1.095	5.233	579.31	29.38	19.39	67.60	3.1
2012	1.004	5.200	600.19	31.50	18.90	79.90	3.6
2013	0.970	4.989	606.43	32.48	18.46	77.74	3.6

Table 9-3 Timeline of Analyzed Impact Indicators: India

Ghana	Shannon's Diversity Index	Energy intensity (MJ/$2011 PPP GDP)	Energy Use (kg of oil equivalent per capita)	Net Energy Imports (% of energy use)	Electric T&D losses (% of output)	Access to electricity (% of population)	Corruption Perception Index
1975	0.055	..	372.24	22.86	3.54	..	..
1976	0.061	..	365.40	20.37	3.53	..	..
1977	0.063	..	381.52	22.51	3.94	..	..
1978	0.073	..	374.55	21.98	3.37	..	..
1979	0.062	..	370.54	17.96	3.59	..	..
1980	0.045	..	372.47	17.86	5.19	..	..
1981	0.039	..	378.63	19.78	4.69	..	..
1982	0.035	..	376.71	21.04	2.44	..	..
1983	0.053	..	308.66	10.38	4.32	..	..
1984	0.090	..	318.74	15.06	3.22	..	..
1985	0.057	..	342.26	18.38	10.74	..	..
1986	0.041	..	345.37	16.18	7.72	..	..
1987	0	..	363.85	19.50	6.22	..	..
1988	0	..	346.47	14.76	7.72	..	..
1989	0	..	363.60	17.57	6.00	..	..
1990	0	7.889	361.70	17.00	3.15	23.88	..
1991	0	7.754	363.97	15.30	3.18	26.00	..
1992	0	7.731	366.52	14.73	3.27	28.13	..
1993	0.023	7.726	373.52	16.30	2.14	30.60	..
1994	0.029	7.782	378.39	17.07	2.55	32.36	..
1995	0.021	7.824	386.09	18.83	3.34	34.47	..
1996	0.003	7.738	389.93	19.17	2.85	36.57	..
1997	0.032	7.761	398.23	20.78	2.86	38.65	..
1998	0.533	7.835	411.54	26.80	2.59	42.60	3.3
1999	0.446	7.794	417.76	26.56	1.99	42.77	3.3
2000	0.291	6.142	333.41	28.96	19.48	44.81	3.5
2001	0.438	5.944	327.39	32.36	18.56	46.83	3.4
2002	0.617	5.653	317.28	36.57	22.16	48.85	3.9
2003	0.641	5.085	292.57	37.02	28.83	48.30	3.3
2004	0.378	4.812	284.89	36.77	27.12	52.87	3.6
2005	0.457	4.504	275.14	37.58	24.57	54.89	3.5
2006	0.637	4.510	285.62	42.45	20.68	56.92	3.3
2007	0.691	4.323	278.34	45.53	23.30	58.95	3.7
2008	0.569	3.961	271.28	42.05	22.87	60.50	3.9
2009	0.555	4.091	286.40	44.88	23.63	63.06	3.9
2010	0.822	4.135	304.59	45.91	23.22	65.12	4.1
2011	0.814	3.871	317.17	5.31	23.12	64.06	3.9
2012	0.850	3.833	334.98	2.88	21.53	69.26	4.5
2013	0.872	3.737	342.17	-7.49	21.54	70.70	4.6

Table 9-4 Timeline of Analyzed Impact Indicators: Ghana

Iran	*Shannon's Diversity Index*	*Energy intensity (MJ/$2011 PPP GDP)*	*Energy Use (kg of oil equivalent per capita)*	*Net Energy Imports (% of energy use)*	*Electric T&D losses (% of output)*	*Access to electricity (% of population)*	*Corruption Perception Index*
1975	1.026	..	813.72	-969.62	4.42	..	..
1976	1.023	..	898.30	-933.97	4.39	..	..
1977	1.048	..	974.61	-785.97	5.69	..	..
1978	1.031	..	913.31	-743.07	7.25	..	..
1979	1.067	..	999.22	-361.62	5.55	..	..
1980	1.067	..	984.23	-112.19	7.06	..	..
1981	1.063	..	1065.88	-85.33	10.03	..	..
1982	1.090	..	1197.64	-158.56	11.74	..	..
1983	0.982	..	982.00	-210.56	9.85	..	..
1984	0.965	..	1096.55	-140.47	10.91	..	..
1985	0.880	..	1137.40	-127.74	9.52	..	..
1986	0.944	..	1100.39	-87.84	10.10	..	..
1987	1.052	..	1079.75	-132.94	10.50	..	..
1988	1.026	..	1064.54	-149.93	10.55	..	..
1989	1.012	..	1210.41	-149.87	10.53	..	..
1990	0.948	5.079	1234.29	-170.93	10.27	96.15	..
1991	0.962	4.996	1341.57	-160.83	10.54	96.35	..
1992	0.988	5.091	1391.75	-165.64	8.83	96.55	..
1993	0.963	5.563	1481.10	-161.58	12.48	96.74	..
1994	0.888	6.283	1625.24	-139.21	14.10	96.93	..
1995	0.896	6.421	1677.94	-134.81	14.20	97.11	..
1996	0.881	5.824	1592.43	-140.95	11.92	97.28	..
1997	0.834	6.431	1750.19	-117.80	13.64	97.44	..
1998	0.729	6.416	1749.05	-116.77	14.06	97.58	..
1999	0.707	7.135	1948.45	-93.57	14.91	97.70	..
2000	0.668	6.570	1868.22	-106.18	15.82	97.90	..
2001	0.698	6.962	1997.72	-86.07	15.85	97.91	3.1
2002	0.712	6.663	2039.31	-83.96	16.87	98.00	3.0
2003	0.683	6.338	2082.07	-97.06	16.76	98.08	3.0
2004	0.690	6.624	2244.40	-88.11	17.19	98.17	2.9
2005	0.747	7.055	2462.39	-79.91	18.16	98.26	2.9
2006	0.814	6.975	2544.48	-78.83	18.55	98.40	2.7
2007	0.800	6.764	2662.25	-76.69	18.98	98.47	2.5
2008	0.617	7.182	2821.14	-65.06	17.54	98.59	2.3
2009	0.662	7.006	2783.49	-63.62	15.61	98.72	1.8
2010	0.675	6.575	2751.16	-67.53	14.19	98.86	2.2
2011	0.803	6.463	2770.71	-65.93	14.54	99.00	2.7
2012	0.823	7.200	2846.08	-37.20	14.47	99.15	2.8
2013	0.924	7.484	2864.00	-34.83	14.50	99.29	2.5

Table 9-5 Timeline of Analyzed Impact Indicators: Iran

10 Appendix B: Control Variables

Turkey	*Electric power consump-tion (kWh per capita)*	*Energy sector related CO2 emissions (% of total fuel combustion)*	*non-Hydro renewable electricity production (kWh)*	*GDP/capita (current US$ per capita)*	*GHGs/capita (kt of CO2 equivalent per capita)*	*Foreign direct investment, net inflows (% of GDP)*	*Inflation, consumer prices (annual %)*	*Unemploy-ment (% of total labor force)*
1975	359.42	24.62	220000000	1139.03	0.00322	0.255	19.20	..
1976	421.51	24.27	161000000	1278.78	0.00341	0.020	17.36	..
1977	462.67	24.18	218000000	1430.44	0.00357	0.046	27.08	..
1978	480.51	23.98	137000000	1552.85	0.00350	0.052	45.28	..
1979	489.46	25.03	145000000	2083.18	0.00331	0.084	58.69	..
1980	496.34	23.17	136000000	1566.75	0.00335	0.026	110.17	..
1981	519.80	25.09	110000000	1580.89	0.00335	0.134	36.58	..
1982	543.68	24.40	0	1403.24	0.00346	0.085	30.84	10.90
1983	555.42	25.42	0	1310.28	0.00347	0.075	31.40	12.10
1984	613.36	27.03	22000000	1246.20	0.00354	0.188	48.38	11.90
1985	659.16	30.73	6000000	1367.17	0.00357	0.147	44.96	11.20
1986	697.89	34.42	44000000	1508.91	0.00373	0.165	34.62	..
1987	770.14	29.23	58000000	1703.63	0.00378	0.132	38.85	..
1988	808.05	24.69	69000000	1742.93	0.00381	0.390	73.67	8.04
1989	873.53	31.06	63000000	2019.04	0.00400	0.619	63.27	8.26
1990	928.44	30.74	80000000	2790.58	0.00416	0.454	60.31	7.50
1991	964.10	31.56	119000000	2732.27	0.00413	0.540	65.97	8.42
1992	1043.20	33.10	117000000	2839.20	0.00426	0.533	70.07	8.16
1993	1114.14	32.04	134000000	3177.18	0.00432	0.353	66.10	8.50
1994	1144.62	36.36	130000000	2268.58	0.00418	0.465	106.26	8.15
1995	1226.57	34.01	308000000	2896.09	0.00446	0.522	88.11	7.29
1996	1327.72	34.17	260000000	3052.50	0.00468	0.398	80.35	6.40
1997	1439.46	35.75	377000000	3143.26	0.00480	0.424	85.73	6.74
1998	1519.72	38.15	331000000	4389.72	0.00482	0.349	84.64	6.70
1999	1556.13	40.60	235000000	4009.13	0.00474	0.314	64.87	7.66
2000	1652.75	37.23	275000000	4215.16	0.00500	0.368	54.92	6.51
2001	1613.24	41.97	336000000	3053.87	0.00464	1.710	54.40	8.84
2002	1667.87	37.10	283000000	3570.55	0.00476	0.465	44.96	10.86
2003	1772.61	35.60	229000000	4586.81	0.00490	0.562	25.30	10.55
2004	1892.90	35.57	227000000	5855.54	0.00498	0.710	10.58	10.28
2005	2015.16	37.55	187000000	7117.23	0.00512	2.077	10.14	10.26
2006	2180.72	37.68	278000000	7727.27	0.00549	3.802	9.60	8.72
2007	2349.88	40.09	606000000	9309.29	0.00584	3.407	8.76	8.87
2008	2425.27	43.19	1151000000	10382.15	0.00567	2.718	10.44	9.71
2009	2316.64	43.71	2183000000	8624.17	0.00568	1.397	6.25	12.55
2010	2492.20	42.60	3916000000	10111.19	0.00585	1.244	8.57	10.66
2011	2692.37	43.28	5760000000	10538.72	0.00591	2.089	6.47	8.80
2012	2761.71	41.74	7351000000	10539.37	0.00595	1.684	8.89	8.15
2013	2744.84	42.71	9800000000	10800.54	0.00600	1.504	7.49	8.73

Table 10-1 Timeline of Control Variables: Turkey

Chile	Electric power consump-tion (kWh per capita)	Energy sector related CO2 emissions (% of total fuel combustion)	non-Hydro renewable electricity production (kWh)	GDP/capita (current US$ per capita)	GHGs/capita (kt of CO2 equivalent per capita)	Foreign direct investment, net inflows (% of GDP)	Inflation, consumer prices (annual %)	Unemploy-ment (% of total labor force)
1975	743.24	27.24	51000000	693.48	0.00400	0.692	374.74	14.69
1976	781.26	28.17	73000000	931.34	0.00400	-0.010	211.92	12.75
1977	806.88	27.58	80000000	1243.14	0.00378	0.157	91.95	11.83
1978	847.92	27.50	91000000	1411.77	0.00382	1.175	40.09	14.26
1979	891.04	30.50	94000000	1872.57	0.00394	1.177	33.39	13.63
1980	917.63	29.81	105000000	2454.29	0.00391	0.773	35.14	..
1981	933.73	29.12	110000000	2863.46	0.00367	1.173	19.69	..
1982	900.76	27.48	137000000	2103.82	0.00329	1.648	9.94	19.60
1983	919.26	27.30	208000000	1683.73	0.00329	0.683	27.26	14.65
1984	979.58	28.55	201000000	1613.29	0.00332	0.406	19.86	13.91
1985	1000.28	27.17	195000000	1361.52	0.00316	0.875	30.70	11.72
1986	1039.97	24.78	280000000	1440.36	0.00318	1.780	19.48	8.71
1987	1065.84	24.34	271000000	1671.17	0.00318	4.260	19.88	9.27
1988	1133.09	27.50	327000000	1937.71	0.00356	3.928	14.68	6.23
1989	1220.95	32.40	321000000	2195.54	0.00396	4.522	17.03	5.29
1990	1250.19	36.05	963000000	2401.53	0.00416	2.095	26.04	5.63
1991	1327.84	29.51	1033000000	2727.57	0.00396	2.259	21.78	5.23
1992	1473.51	24.28	1743000000	3277.67	0.00408	2.105	15.43	4.35
1993	1533.02	23.13	1750000000	3461.44	0.00424	2.169	12.73	4.49
1994	1608.95	27.10	1786000000	3942.97	0.00445	4.682	11.44	5.87
1995	1768.35	27.20	1879000000	5026.72	0.00468	4.144	8.23	4.70
1996	1952.14	32.42	1738000000	5263.19	0.00511	6.354	7.36	5.39
1997	2096.60	31.89	1743000000	5674.15	0.00565	6.366	6.13	5.34
1998	2204.81	37.18	1161000000	5367.21	0.00620	5.830	5.11	7.16
1999	2422.08	40.23	1010000000	4872.69	0.00648	12.002	3.34	8.92
2000	2527.62	34.05	941000000	5229.18	0.00596	6.126	3.84	8.34
2001	2655.68	31.38	2075000000	4709.92	0.00592	5.806	3.57	7.89
2002	2752.41	33.22	1951000000	4566.52	0.00587	3.592	2.49	7.81
2003	2919.97	35.35	1814000000	4948.75	0.00599	5.534	2.81	7.39
2004	3084.06	39.13	2038000000	6323.76	0.00628	7.128	1.05	7.78
2005	3112.22	38.26	1797000000	7728.61	0.00631	5.614	3.05	6.94
2006	3237.22	37.48	1438000000	9500.84	0.00626	4.719	3.39	6.01
2007	3353.16	41.80	2705000000	10513.54	0.00687	7.241	4.41	7.21
2008	3350.79	43.36	3121000000	10791.02	0.00667	8.434	8.72	7.48
2009	3307.55	42.00	4353000000	10217.31	0.00656	7.495	0.07	8.62
2010	3316.18	40.03	2579000000	12785.05	0.00672	7.229	1.41	7.12
2011	3590.31	43.12	5011000000	14582.17	0.00684	9.346	3.34	6.60
2012	3810.12	47.86	5263000000	15253.33	0.00694	10.729	3.01	6.05
2013	3878.91	46.88	6323000000	15764.76	0.00704	6.988	1.79	5.67

Table 10-2 Timeline of Control Variables: Chile

India	*Electric power consump-tion (kWh per capita)*	*Energy sector related CO2 emissions (% of total fuel combustion)*	*non-Hydro renewable electricity production (kWh)*	*GDP/capita (current US$ per capita)*	*GHGs/capita (kt of CO2 equivalent per capita)*	*Foreign direct investment, net inflows (% of GDP)*	*Inflation, consumer prices (annual %)*	*Unemploy-ment (% of total labor force)*
1975	114.82	26.91	0	161.17	0.00133	-0.010	5.74	..
1976	124.41	28.40	0	164.29	0.00134	-0.007	-7.63	..
1977	126.55	27.45	0	189.92	0.00134	-0.029	8.32	..
1978	136.24	25.03	0	209.79	0.00131	0.013	2.52	..
1979	136.07	26.94	0	228.48	0.00133	0.031	6.25	..
1980	142.06	31.02	0	271.92	0.00133	0.042	11.37	..
1981	152.27	32.09	0	275.92	0.00137	0.047	13.12	..
1982	158.52	33.56	0	279.66	0.00138	0.035	7.89	..
1983	166.14	35.27	0	297.16	0.00142	0.003	11.87	..
1984	183.82	34.48	0	282.32	0.00146	0.009	8.32	..
1985	194.10	38.09	0	302.51	0.00146	0.045	5.56	..
1986	208.59	39.82	2000000	316.85	0.00150	0.046	8.73	..
1987	220.88	42.35	3000000	347.43	0.00147	0.075	8.80	..
1988	240.75	42.11	6000000	361.45	0.00156	0.030	9.38	..
1989	257.82	43.01	6000000	353.26	0.00160	0.084	3.26	..
1990	272.90	43.75	32000000	375.15	0.00159	0.072	8.97	4.00
1991	291.80	45.29	39000000	309.33	0.00162	0.027	13.87	4.00
1992	305.39	46.79	88000000	323.52	0.00164	0.094	11.79	3.90
1993	321.57	49.40	99000000	307.41	0.00165	0.194	6.36	4.06
1994	342.32	48.78	200000000	353.29	0.00168	0.292	10.21	3.70
1995	359.90	51.62	530000000	381.53	0.00172	0.585	10.22	3.97
1996	360.95	52.46	924000000	408.24	0.00174	0.607	8.98	3.95
1997	376.65	51.53	1039000000	424.09	0.00177	0.845	7.16	4.39
1998	387.03	52.73	1129000000	421.82	0.00174	0.615	13.23	4.12
1999	393.21	53.74	2421000000	451.09	0.00189	0.464	4.67	4.22
2000	394.80	55.21	2964000000	452.41	0.00179	0.752	4.01	4.31
2001	394.95	55.87	3983000000	460.83	0.00175	1.038	3.68	3.78
2002	411.82	54.93	5178000000	480.62	0.00176	0.994	4.39	4.32
2003	431.71	56.26	6862000000	557.90	0.00178	0.595	3.81	3.93
2004	452.90	56.89	8547000000	640.60	0.00186	0.752	3.77	3.89
2005	469.37	55.56	11025000000	729.00	0.00185	0.871	4.25	4.40
2006	510.70	55.53	15353000000	816.73	0.00192	2.110	6.15	4.33
2007	543.36	55.45	19258000000	1018.13	0.00202	2.100	6.37	3.72
2008	562.94	53.62	23259000000	991.52	0.00204	3.657	8.35	4.15
2009	600.25	52.29	30514000000	1090.36	0.00214	2.688	10.88	3.91
2010	642.11	51.50	34065000000	1345.72	0.00225	1.654	11.99	3.55
2011	698.43	51.76	42495000000	1461.38	0.00227	2.002	8.86	3.54
2012	724.49	53.44	52150000000	1446.77	0.00238	1.313	9.31	3.62
2013	765.00	52.32	59494000000	1451.53	0.00248	1.516	10.91	3.57

Table 10-3 Timeline of Control Variables: India

Ghana	Electric power consump-tion (kWh per capita)	Energy sector related CO2 emissions (% of total fuel combustion)	non-Hydro renewable electricity production (kWh)	GDP/capita (current US$ per capita)	GHGs/capita (kt of CO2 equivalent per capita)	Foreign direct investment, net inflows (% of GDP)	Inflation, consumer prices (annual %)	Unemploy-ment (% of total labor force)
1975	377.36	6.49	0	285.83	0.00210	2.522	29.82	0.90
1976	390.78	6.38	0	275.88	0.00211	-0.660	56.08	1.00
1977	401.48	5.98	0	313.00	0.00236	0.603	116.45	1.00
1978	331.16	5.53	0	353.71	0.00203	0.265	73.09	1.00
1979	399.69	5.88	0	381.04	0.00211	-0.070	54.44	0.90
1980	425.94	5.94	0	411.52	0.00243	0.351	50.07	1.20
1981	418.44	4.80	0	379.80	0.00212	0.385	116.50	1.00
1982	376.65	5.19	0	351.32	0.00224	0.404	22.30	0.70
1983	165.61	4.00	0	341.09	0.00192	0.059	122.87	0.70
1984	93.49	4.97	0	358.40	0.00189	0.045	39.67	0.40
1985	163.81	5.26	0	354.22	0.00173	0.124	10.31	0.40
1986	259.31	4.48	0	437.09	0.00174	0.075	24.57	0.50
1987	288.64	2.59	0	376.46	0.00178	0.093	39.82	..
1988	305.07	3.35	0	375.23	0.00166	0.096	31.36	..
1989	308.87	3.03	0	369.00	0.00176	0.286	25.22	..
1990	326.76	2.76	0	402.59	0.00202	0.251	37.26	6.08
1991	339.70	3.51	0	438.52	0.00165	0.303	18.03	6.08
1992	355.04	2.99	0	414.56	0.00185	0.351	10.06	4.70
1993	340.29	2.94	0	375.07	0.00174	2.095	24.96	5.25
1994	340.71	3.74	0	333.22	0.00171	4.280	24.87	6.20
1995	354.81	2.80	0	385.73	0.00182	1.647	59.46	7.80
1996	367.98	2.28	0	403.92	0.00178	1.730	46.56	8.51
1997	394.28	0.83	0	392.25	0.00179	1.187	27.89	7.71
1998	276.20	22.53	0	416.33	0.00726	2.238	14.62	8.20
1999	362.86	20.14	0	419.89	0.00514	3.157	12.41	10.10
2000	334.02	11.45	0	264.70	0.00572	3.329	25.19	10.36
2001	340.01	17.70	0	275.47	0.00541	1.681	32.91	7.57
2002	313.07	29.60	0	311.62	0.00469	0.956	14.82	9.19
2003	222.70	27.61	0	375.88	0.00532	1.792	26.67	6.48
2004	221.40	11.15	0	426.16	0.00341	1.568	12.62	5.32
2005	247.60	18.59	0	501.72	0.00529	1.351	15.12	4.93
2006	298.93	31.35	0	929.73	0.00474	3.116	10.92	3.60
2007	245.96	31.47	0	1099.02	0.00476	5.587	10.73	9.43
2008	266.35	24.74	0	1234.08	0.00537	9.517	16.52	5.59
2009	265.13	18.70	0	1095.50	0.00442	9.133	19.25	8.43
2010	282.76	29.67	0	1323.10	0.00438	7.855	10.71	4.20
2011	320.96	24.21	0	1587.19	0.00430	8.208	8.73	3.98
2012	348.25	24.35	0	1641.83	0.00422	7.855	9.16	4.09
2013	382.31	26.74	3000000	1827.10	0.00412	6.750	11.61	5.20

Table 10-4 Timeline of Control Variables: Ghana

Iran	*Electric power consump-tion (kWh per capita)*	*Energy sector related CO2 emissions (% of total fuel combustion)*	*non-Hydro renewable electricity production (kWh)*	*GDP/capita (current US$ per capita)*	*GHGs/capita (kt of CO2 equivalent per capita)*	*Foreign direct investment, net inflows (% of GDP)*	*Inflation, consumer prices (annual %)*	*Unemploy-ment (% of total labor force)*
1975	458.47	25.57	0	1581.89	0.00618	0.955	12.88	..
1976	490.56	24.58	0	2017.10	0.00671	-0.149	11.26	..
1977	514.24	22.95	0	2315.15	0.00669	0.429	27.29	..
1978	511.68	22.55	0	2167.86	0.00625	1.166	11.72	..
1979	555.39	22.37	0	2426.19	0.00537	0.182	10.49	..
1980	537.91	20.66	0	2440.31	0.00433	0.086	20.64	..
1981	557.31	19.96	0	2499.42	0.00407	0.028	24.20	..
1982	613.01	20.04	0	3008.64	0.00479	-0.108	18.69	..
1983	682.38	19.72	0	3585.49	0.00504	-0.050	19.74	..
1984	717.67	20.64	0	3572.09	0.00465	0.026	12.54	..
1985	750.38	20.88	0	3810.12	0.00470	-0.021	4.39	..
1986	759.53	22.39	0	4249.41	0.00432	-0.054	18.43	..
1987	808.31	21.64	0	2619.83	0.00417	-0.230	28.57	..
1988	802.78	22.89	0	2320.27	0.00421	0.049	28.67	..
1989	861.68	22.07	0	2201.44	0.00439	-0.016	22.35	..
1990	944.18	24.45	0	2222.09	0.00505	-0.290	7.63	11.10
1991	1001.36	23.47	0	1874.52	0.00541	0.012	17.13	11.10
1992	1077.08	22.22	0	1621.85	0.00566	0.164	25.81	12.28
1993	1130.74	26.01	0	1083.86	0.00558	0.326	21.20	11.01
1994	1178.75	24.25	0	1207.39	0.00612	0.003	31.45	10.26
1995	1206.14	25.19	0	1598.50	0.00614	0.018	49.66	11.74
1996	1299.19	25.81	0	1963.96	0.00629	0.022	28.94	12.77
1997	1344.09	26.07	0	1824.86	0.00645	0.047	17.35	11.72
1998	1387.94	26.51	0	1733.48	0.00645	0.022	17.87	11.69
1999	1467.31	29.94	35000000	1757.45	0.00657	0.031	20.07	11.65
2000	1541.18	29.16	37000000	1664.26	0.00680	0.177	14.48	11.78
2001	1635.03	29.62	34000000	1899.02	0.00690	0.322	11.27	12.31
2002	1734.65	29.92	30000000	1900.05	0.00714	2.736	14.34	12.80
2003	1877.69	30.03	27000000	2240.81	0.00753	1.874	16.47	12.19
2004	1998.78	30.76	47000000	2649.91	0.00797	1.653	14.76	10.30
2005	2068.89	31.23	71000000	3135.19	0.00822	1.314	13.43	12.10
2006	2209.66	30.59	125000000	3646.84	0.00874	0.896	11.94	11.25
2007	2294.93	30.22	143000000	4705.39	0.00908	0.598	17.21	10.60
2008	2408.88	32.32	196000000	5476.16	0.00943	0.498	25.55	10.48
2009	2490.62	32.14	227000000	5437.82	0.00917	0.748	13.50	11.97
2010	2642.37	32.87	173000000	6299.92	0.00940	0.780	10.14	13.52
2011	2661.91	33.67	239000000	7874.48	0.00962	0.722	20.63	12.30
2012	2762.06	34.70	230000000	7710.51	0.00985	0.794	27.36	12.21
2013	2806.21	34.99	397000000	6631.30	0.01008	0.596	39.27	10.44

Table 10-5 Timeline of Control Variables: Iran

11 List of Figures

Figure 2.1 Lebanese Electricity Generation, Demand and Deficit, source [9] 13
Figure 4.1 OECD Methodology for Calculation of ETCR Indicator, source [4] 20
Figure 4.2 OECD Methodology for Calculation of the Sectoral Indicator of Regulatory Reform: Electricity, source [4] 20
Figure 4.3 Electricity Grid Structure, adapted from [45] 25
Figure 4.4 Electricity Access World Map, data from 2010 source: [48] 26
Figure 5.1 Turkish Electricity System Illustration, source: [61] 33
Figure 5.2 SIRRE Sub-Indicators vs. Time: Turkey 34
Figure 5.3 Turkish Electricity Power T&D Losses Between 1975 – 2013 38
Figure 5.4 SIRRE Sub-Indicators vs. Time: Chile 44
Figure 5.5 SIRRE Sub-Indicators vs. Time: India 54
Figure 5.6 Entry Regulation vs. Time: India 54
Figure 5.7 Public Ownership vs. Time: India 56
Figure 5.8 Access to Electricity [%] vs. Time: India 61
Figure 5.9 Structure of the Ghanaian Electricity Sector 2010, source [96] 65
Figure 5.10 SIRRE Sub-Indicators vs. Time: Ghana 66
Figure 5.11 Entry Regulation vs. Time: Ghana 67
Figure 5.12 Vertical Separation vs. Time: Ghana 68
Figure 5.13 Structure of the Iranian Electricity Sector in 2013, source: [35] 78
Figure 5.14 SIRRE Sub-Indicators vs. Time: Iran 79
Figure 5.15 Entry Regulation vs. Time: Iran 80
Figure 5.16 Timeline of Gross Power Generation in Iran 81
Figure 7.1 Overall SIRRE Indicators vs. Time 95

12 List of Tables

Table 2-1 Impact Indicators 14
Table 4-1 Sector Regulation (NMR) Methodology: Electricity, source [37] 22
Table 4-2 Shannon's Diversity Index Variable Explanation 22
Table 4-3 Control Variables 28
Table 4-4 Country Selection Parameters 31
Table 5-1 Shannon’s Diversity Index Impact Results: Turkey 35
Table 5-2 Shannon's Diversity Index Impact Results (with control variables): Turkey 35
Table 5-3 Energy Intensity Impact Results: Turkey 35
Table 5-4 Energy Intensity Impact Results (with control variables): Turkey 36
Table 5-5 Energy Use Impact Results: Turkey 36
Table 5-6 Energy Use Impact Results (with control variables): Turkey 37
Table 5-7 Net Energy Import Impact Results: Turkey 37
Table 5-8 Net Energy Import Impact Results (with control variables): Turkey 38
Table 5-9 Electric Power T&D Losses Impact Results: Turkey 39
Table 5-10 Electric Power T&D Losses Impact Results (with control variables): Turkey 39
Table 5-11 Access to Electricity Impact Results: Turkey 40
Table 5-12 Access to Electricity Impact Results (with control variables): Turkey 40
Table 5-13 Corruption Perception Index Impact Results: Turkey 41
Table 5-14 Corruption Perception Index Impact Results (with control variables): Turkey 41
Table 5-15 Shannon’s Diversity Index Impact Results: Chile 45
Table 5-16 Shannon’s Diversity Index Impact Results (with control variables): Chile 45
Table 5-17 Energy Intensity Impact Results: Chile 46
Table 5-18 Energy Intensity Impact Results: Chile (without Public Ownership) 46
Table 5-19 Energy Intensity Impact Results (with control variables): Chile 46
Table 5-20 Energy Use Impact Results: Chile 47
Table 5-21 Energy Use Impact Results (with control variables): Chile 47
Table 5-22 Net Energy Import Impact Results: Chile 47
Table 5-23 Net Energy Import Impact Results (with control variables): Chile 48
Table 5-24 Electric Power T&D Losses Impact Results: Chile 48
Table 5-25 Electric Power T&D Losses Impact Results (with control variables): Chile 49
Table 5-26 Access to Electricity Impact Results: Chile 49
Table 5-27 Access to Electricity Impact Results: Chile (without Public Ownership) 50
Table 5-28 Access to Electricity Impact Results (with control variables): Chile 50
Table 5-29 Corruption Perception Index Impact Results: Chile 50
Table 5-30 Corruption Perception Index Impact Results (with control variables): Chile 51
Table 5-31 Shannon’s Diversity Index Impact Results: India 57
Table 5-32 Shannon’s Diversity Index Impact Results (with control variables): India 57
Table 5-33 Energy Intensity Impact Results: India 58
Table 5-34 Energy Intensity Impact Results (with control variables): India 58
Table 5-35 Energy Use Impact Results: India 58
Table 5-36 Energy Use Impact Results (with control variables): India 59
Table 5-37 Net Energy Import Impact Results: India 59
Table 5-38 Net Energy Import Impact Results (with control variables): India 60
Table 5-39 Electric Power T&D Losses Impact Results: India 60
Table 5-40 Electric Power T&D Losses Impact Results (with control variables): India 61
Table 5-41 Access to Electricity Impact Results: India (corrected) 62
Table 5-42 Access to Electricity Impact Results (with control variables): India 62
Table 5-43 Corruption Perception Index Impact Results: India 62
Table 5-44 Corruption Perception Index Impact Results (with control variables): India 63

Table 5-45 Shannon's Diversity Index Impact Results: Ghana (with Public Ownership) 69
Table 5-46 Shannon's Diversity Index Impact Results: Ghana (without Public Ownership) 69
Table 5-47 Shannon's Diversity Index Impact Results (with control variables): Ghana 70
Table 5-48 Energy Intensity Impact Results: Ghana (without Public Ownership) 70
Table 5-49 Energy Intensity Impact Results (with control variables): Ghana 71
Table 5-50 Energy Use Impact Results: Ghana 71
Table 5-51 Energy Use Impact Results (with control variables): Ghana 71
Table 5-52 Net Energy Import Impact Results: Ghana 72
Table 5-53 Net Energy Import Impact Results (with control variables): Ghana 72
Table 5-54 Electric Power T&D Losses Impact Results: Ghana 72
Table 5-55 Electric Power T&D Losses Impact Results (with control variables): Ghana 73
Table 5-56 Access to Electricity Impact Results: Ghana 73
Table 5-57 Access to Electricity Impact Results (with control variables): Ghana 74
Table 5-58 Corruption Perception Index Impact Results: Ghana 74
Table 5-59 Corruption Perception Index Impact Results (with control variables): Ghana 75
Table 5-60 Shannon's Diversity Index Impact Results: Iran 82
Table 5-61 Shannon's Diversity Index Impact Results (with control variables): Iran 82
Table 5-62 Energy Intensity Impact Results: Iran 83
Table 5-63 Energy Intensity Impact Results (with control variables): Iran 83
Table 5-64 Energy Use Impact Results: Iran 84
Table 5-65 Energy Use Impact Results (with control variables): Iran 84
Table 5-66 Net Energy Import Impact Results: Iran 84
Table 5-67 Net Energy Import Impact Results (with control variables): Iran 85
Table 5-68 Electric Power T&D Losses Impact Results: Iran 85
Table 5-69 Electric Power T&D Losses Impact Results (with control variables): Iran 86
Table 5-70 Access to Electricity Impact Results: Iran 86
Table 5-71 Access to Electricity Impact Results (with control variables): Iran 86
Table 5-72 Corruption Perception Index Impact Results: Iran 87
Table 5-73 Corruption Perception Index Impact Results (with control variables): Iran 87
Table 6-1 Comparison of Results: Shannon's Diversity Index 90
Table 6-2 Comparison of Results: Energy Intensity 91
Table 6-3 Comparison of Results: Energy Use 92
Table 6-4 Comparison of Results: Net Energy Imports 92
Table 6-5 Comparison of Results: Electric T&D Losses 93
Table 6-6 Comparison of Results: Access to Electricity 94
Table 6-7 Comparison of Results: Corruption Perception Index 94
Table 9-1 Timeline of Analyzed Impact Indicators: Turkey 100
Table 9-2 Timeline of Analyzed Impact Indicators: Chile 101
Table 9-3 Timeline of Analyzed Impact Indicators: India 102
Table 9-4 Timeline of Analyzed Impact Indicators: Ghana 103
Table 9-5 Timeline of Analyzed Impact Indicators: Iran 104
Table 10-1 Timeline of Control Variables: Turkey 105
Table 10-2 Timeline of Control Variables: Chile 106
Table 10-3 Timeline of Control Variables: India 107
Table 10-4 Timeline of Control Variables: Ghana 108
Table 10-5 Timeline of Control Variables: Iran 109

13 List of Equations

Equation 4-1 Shannon's Diversity Index 22
Equation 4-2 Equitability (Evenness) 22
Equation 4-3 Multiple Linear Regression, Methodology Phase I 29
Equation 4-4 Multiple Linear Regression, Methodology Phase II 29
Equation 4-5 Test Statistic 30
Equation 5-1 Market-Share in [%] 44

Bibliography

[1] F. P. Sioshansi and W. Pfaffenberger, "Chapter 1: Why Restructure Electricity Markets?," in *Electricity Market Reform, An International Perspective*, Walnut Creek and Bremen, Elsevier Global Energy Policy and Economics Series, 2006.

[2] L. S. Belyaev, Electricity Market Reforms, Irkutsk, Russia: Springer, 2011.

[3] C. Woo, M. Ming, A. Tishler and L. Chow, "Costs of electricity deregulation," *Energy,* vol. 31, pp. 747-768, 2006.

[4] I. Koske, I. Wanner, R. Bitetti and O. Barbiero, "The 2013 update of the OECD's database on product market regulation: Policy Insights for OECD and non-OECD countries," OECD Publishing, Paris, 2015.

[5] P. L. Joskow, "Introduction to Electricity Sector Liberalization: Lessons Learned from Cross-Country Studies," in *Electricity Market Reform, An International Perspective*, Cambridge, USA, Elsevier Global Energy Policy and Economics Series, 2006.

[6] I. Dyner, S. Arango and E. R. Larsen, "Chapter 17: Understanding The Argentinean and Colombian Electricity Markets," in *Electricity Market Reform, An International Perspective*, Medellin, Elsevier Global Energy Policy and Economics Series, 2006.

[7] A. Kairouz, J. El Hokayem and U. El Hage, "Sustainability of Public Management in the Developing Countries: the Case of Lebanon," *Procedia - Social and Behavioral Sciences,* vol. 221, pp. 378-387, 2016.

[8] Electricité du Liban, "About EDL," Electricité du Liban (EDL), [Online]. Available: http://www.edl.gov.lb/aboutedl.htm#2. [Accessed 8 May 2017].

[9] E. Bouri and J. El Assad, "The Lebanese Electricity Woes: An Estimation of the Economical Costs of Power Interruptions," *Energies,* vol. 9, no. 583, pp. 1-12, 2016.

[10] F. Fardoun, O. Ibrahim, R. Younes and H. Louahlia-Gualous, "Electricity of Lebanon: Problems and Recommendations," *Energy Procedia,* vol. 19, pp. 310-320, 2012.

[11] R. El-Fadel, G. Hammond, H. Harajli, C. Jones, V. Kabakian and A. Winnett, "The Lebanese electricity system in the context of sustainable development," *Energy Policy,* vol. 38, pp. 751-761, 2010.

[12] Working Group III Technical Support Unit, "Climate Change 2014 Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge University Press, Cambridge, 2014.

[13] E. Asane-Otoo, "Competition policies and environmental quality: Empirical analysis of the electricity sector in OECD countries," *Energy Policy,* vol. 95, pp. 212-223, 2016.

[14] The World Bank, "World Development Indicators," The World Bank Group, 2017. [Online]. Available: http://data.worldbank.org/data-catalog/world-development-indicators. [Accessed 31 May 2017].

[15] E. Erdogdu, "A cross-country analysis of electricity market reforms: Potential contribution of New Institutional Economics," vol. 39, pp. 239-251, 2013.

[16] R. Raineri, "Chapter 3, Chile: Where It All Started," in *Electricity Market Reform*, Santiago, Elsevier Global Energy Policy and Economics Series, 2006, pp. 77-1008.

[17] F. P. Sioshansi and W. Pfaffenberger, Electricity Market Reform, An International Perspective, Elsevier Global Energy Policy and Economics Series, 2006.

[18] S. Littlechild, "Foreword: The Market versus Regulation," in *Electricity Market Reform, An International Perspective*, Elsevier Global Energy Policy and Economics Series, 2006.

[19] G. Razeghi, B. Shaffer and S. Samuelsen, "Impact of electricity deregulation in the state of California," vol. 103, pp. 105-115, 2017.

[20] J. D. Craig, "Motivations for market restructuring: Evidence from U.S.," *Energy Economics,* vol. 60, pp. 162-167, 2016.

[21] C. R. Knittel, "The Adoption of State Electricity Regulation: The Role of Interest Groups," *The Journal of Industrial Economics,* vol. LIV, no. 2, pp. 201-222, June 2006.

[22] J. D. Craig and S. J. Savage, "Market Restructuring, Competition and the Efficiency of Electricity Generation: Plant-level Evidence from the United States 1996 to 2006," University of Colorado, Boulder, 2009.

[23] D. L. Kaserman, J. W. Mayo and P. L. Pacey, "The Political Economy of Deregulation: The Case of Intrastate Long Distance," *Journal of Regulatory Economics,* vol. 5, pp. 49-63, 1993.

[24] R. S. Kroszner and P. E. Strahan, "What Drives Deregulation? Economics and Politics of the Relaxation of Bank Branching Restrictions," *The Quarterly Journal of Economics,* pp. 1437-1467, 1999.

[25] N. Gal, I. Milstein, A. Tishler and C. Woo, "Fuel cost uncertainty, capacity investment and price in a competitive electricity market," *Energy Economics,* vol. 61, pp. 233-240, 2017.

[26] T. J. Considine and A. N. Kleit, "Comparing Electricity Deregulation in California and Pennsylvania: Implication for the Appalachian Region," Appalachian Regional Commission, University Park, 2002.

[27] Y. Wu, "Deregulation and growth in China's energy sector: a review of recent development," *Energy Policy,* vol. 31, pp. 1417-1425, August 2002.

[28] M. Nakada, "Deregulation in an energy market and its impact on R&D for low-carbon energy technology," *Resource and Energy Economics,* vol. 27, pp. 306-320, 2005.

[29] S. van Koten and A. Ortmann, "Structural versus behavioral remedies in the deregulation of electricity markets: An experimental investigation motivated by policy concerns," *European Economic Review,* vol. 64, pp. 256-265, 2013.

[30] A. Clements, A. Hurn and Z. Li, "Strategic bidding and rebidding in electricity markets," *Energy Economics,* vol. 59, pp. 24-36, 2016.

[31] A. Afful-Dadzie, E. Afful-Dadzie, A. Iddrisu and J. Kwaku Banuro, "Power generation capacity planning under budget constraint in developing countries," *Applied Energy,* vol. 188, pp. 71-82, 2017.

[32] H. Nagayama and T. Kashiwagi, "Evaluating electricity sector reforms in Argentina: lessons for developing countries?," *Journal of Cleaner Production,* vol. 15, pp. 115-130, 2007.

[33] J. N. Swisher and M. C. McAlphin, "Environmental impact of electricity deregulation," *Energy,* vol. 31, pp. 1067-1083, 2006.

[34] P. Conway and G. Nicoletti, "Product Market Deregulation in the Non-Manufacturing Sectors of OECD Countries: Measurement and Highlights," Organisation for Economic Co-operation and Development, 2006.

[35] R. M. Dyllick-Brenzinger and M. Finger, "Review of electricity sector reform in five large, oil- and gas-exporting MENA countries: Current status and outlook," *Energy Strategy Reviews,* vol. 2, pp. 31-45, 2013.

[36] T. Slocum, "The Failure of Electricity Deregulation: History, Status and Needed Reforms," Public Citizen's Energy Program, March 2007.

[37] Organisation for Economic Co-operation and Development, "Indicators of Sectoral Regulation (NMR)," 2017. [Online]. Available: http://www.oecd.org/gov/regulatory-policy/indicators-sectoral-regulation.htm. [Accessed 31 May 2017].

[38] C. E. Shannon, The Mathematical Theory of Communication, 1948.

[39] M. Beals, L. Gross and S. Harrell, "Diversity Indices: Shannon's H and E," The University of Tennessee Knoxville, 2000. [Online]. Available: http://www.tiem.utk.edu/~gross/bioed/bealsmodules/shannonDI.html. [Accessed 30 May 2017].

[40] United Nations, "Sustainable Development Knowledge Program," the United Nations, Department of Economic and Social Affairs, [Online]. Available: https://sustainabledevelopment.un.org/natlinfo/indicators/isdms2001/isd-ms2001economicB.htm. [Accessed 31 May 2017].

[41] International Energy Agency, "What is Energy Security?," OECD/IEA, [Online]. Available: https://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/. [Accessed 1 June 2017].

[42] M. Howells, *Energy and Environment Lecture,* Stockholm: Division of Energy System Analysis, 2015.

[43] Republic of Turkey, Ministry of Foreign Affairs, "Turkey's Energy Profile and Strategy," Republic of Turkey, Ministry of Foreign Affairs, 2011. [Online]. Available: http://www.mfa.gov.tr/turkeys-energy-strategy.en.mfa. [Accessed 1 June 2017].

[44] J. Jewell, "The IEA Model of Short-term Energy Security (MOSES): Primary Energy Sources and Secondary Fuels," International Energy Agency, Paris, 2011.

[45] N. Eyre, Artist, *Grid System Analysis.* [Art]. 2017.

[46] International Energy Agency, "Energy Poverty," OECD / IEA, 2017. [Online]. Available: https://www.iea.org/topics/energypoverty/. [Accessed 31 May 2017].

[47] United Nations, The World Bank, "Sustainable Energy for All," United Nations, The World Bank, [Online]. Available: http://www.se4all.org/our-mission. [Accessed 31 May 2017].

[48] J. Hanania, K. Stenhouse and J. Donev, "Energy Education: Access to Electricity," University of Calgary, [Online]. Available: http://energyeducation.ca/encyclopedia/Access_to_electricity. [Accessed 6 June 2017].

[49] Transparency International, "What is Corruption?," Transparency International, 2016. [Online]. Available: https://www.transparency.org/what-is-corruption/. [Accessed 6 June 2017].

[50] Transparency International, "Transparency International: Corruption Perception Index," 1996-2015. [Online]. Available: https://www.transparency.org/country/TUR. [Accessed 6 June 2017].

[51] The Global Economy, "Ghana: Unemployment rate," 2017. [Online]. Available: http://www.theglobaleconomy.com/Ghana/Unemployment_rate/. [Accessed 24 June 2017].

[52] The Global Economy, "India: Unemployment Rate," 2017. [Online]. Available: http://www.theglobaleconomy.com/India/Unemployment_rate/. [Accessed 24 June 2017].

[53] The Global Economy, "Iran: Unemployment rate," 2017. [Online]. Available: http://www.theglobaleconomy.com/Iran/Unemployment_rate/. [Accessed 24 June 2017].

[54] U.S. Energy Information Administration, "Petroleium & Other Liquids: Europe Brent Spot Price FOB," [Online]. Available: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=A. [Accessed 26 June 2017].

[55] G. Avgerinopoulos, *Introduction to Econometrics and Development Economics,* Stockholm: KTH Division of Energy System Analysis, 2016.

[56] Yale University, "Multiple Linear Regression," Yale University, [Online]. Available: http://www.stat.yale.edu/Courses/1997-98/101/linmult.htm. [Accessed 31 May 2017].

[57] PennState Eberly College of Science, "Lesson 5: Multiple Linear Regression," PennState Eberly College of Science, [Online]. Available: https://onlinecourses.science.psu.edu/stat501/node/283. [Accessed 31 May 2017].

[58] Minitab Inc., "Regression Analysis: How Do I Interpret R-squared and Assess the Goodness-of-Fit?," 2017. [Online]. Available: http://blog.minitab.com/blog/adventures-in-statistics-2/regression-analysis-how-do-i-interpret-r-squared-and-assess-the-goodness-of-fit. [Accessed 26 June 2017].

[59] L. Nielsen, "Classifications of Countries Based on Their Level of Development: How it is Done and How it Could be Done," International Monetary Fund, 2011.

[60] The Heritage Foundation, "Index of Economic Freedom," 2017. [Online]. Available: http://www.heritage.org/index/ranking. [Accessed 26 June 2017].

[61] K. Mapila and H. A. Abdo, "Creating Markets in Turkey's Power Sector," in *EM Compass: Fresh Ideas About Business in Emerging Markets*, 2017.

[62] M. Yazıcıoğlu, "Turkish Energy Market: An Investor's guide," EPDK Energy Market Regulatory Authority, Ankara, 2012.

[63] N. Bagdadioglu and N. Odyakmaz, "Turkish Electricity Reform," *Utilities Policy,* vol. 17, pp. 144-152, 2009.

[64] Ö. Özkyvrak, "Electricity Restructuring in Turkey," *Energy Policy,* vol. 33, pp. 1339-1350, 2005.

[65] E. Erdogdu, "Regulatory reform in Turkish energy industry: An analysis," *Energy Policy,* vol. 35, pp. 984-993, 2007.

[66] A. Hepbasli, "Development and restructuring of Turkey's electricity sector: a review," *Renewable and Sustainable Energy Reviews,* vol. 9, pp. 311-343, 2005.

[67] G. Kocaslan, "International Energy Security Indicators and Turkey's Energy Security Risk Score," *International Journal of Energy Economics and Policy,* vol. 4, no. 4, pp. 735-743, 2014.

[68] UNDP, "Human Development Report," United Nations Development Programme, 2007/2008.

[69] OECD, "Chile's accession to the OECD," Organisation for Economic Co-operation and Development, 2017. [Online]. Available: http://www.oecd.org/chile/chilesaccessiontotheoecd.htm. [Accessed 13 June 2017].

[70] V. J. Martinez and F. Flatow, "Chilean Experience in Developing Electric Powre Infrastructure," 27 Augst 2015. [Online]. Available: http://aperc.ieej.or.jp/file/2015/10/19/Chile.pdf. [Accessed 13 June 2017].

[71] Central Energía, "Central de información y discusión de energía en Chile," Central Energía, [Online]. Available: http://www.centralenergia.cl/en/. [Accessed 13 June 2017].

[72] M. G. Pollitt, "Electricity Reform in Chile: Lessons for Developing Countries," University of Cambridge, Cambridge, 2005.

[73] B. Nagel and C. Barrientos, "Country Nuclear Power Profiles 2016 Edition: Chile," Chilean Nuclear Energy Commission (CCHEN), 2016. [Online]. Available: http://www-pub.iaea.org/MTCD/Publications/PDF/cnpp2016/countryprofiles/Chile/Chile.htm. [Accessed 13 June 2017].

[74] Central Energía, "Central de información y discusión de energía en Chile," Central Energía, [Online]. Available: http://www.centralenergia.cl/en/electric-market-regulation-chile/electric-market-legislation/. [Accessed 13 June 2017].

[75] I. N. Kessides, "The Impacts of Electricity Sector Reforms in Developing Countries," *The Electricity Journal,* vol. 25, no. 6, pp. 79-88, 2012.

[76] ENDESA, "ENDESA 1998 Annual Report," Empresa Nacional de Electricidad, S. A. Chile, Santiago, 1998.

[77] R. Lynch, "An Energy Overview of Chile," Global Energy Network Institute, 4 October 2002. [Online]. Available: http://www.geni.org/globalenergy/library/national_energy_grid/chile/EnergyOverviewofChile.shtml. [Accessed 12 June 2017].

[78] J. Montero, I. Aguilo, J. P. Reitze and J. Michael, "Endesa Chile," December 2007. [Online]. Available: http://www.enelgeneracion.cl/ES/ACCIONISTAS/PRESENTACIONES/Documents/PresentacionesCorporativas/Endesa%20Chile%20YE%202007%20IR%20Presentation.pdf. [Accessed 12 June 2017].

[79] A. Tripathi, "Power Plus Distribution," Power Plus Consultants, Hyderabad, 2013.

[80] L. K. Joseph, "The politics of power: Electricity reform in India," *Energy Policy,* vol. 38, no. 1, pp. 503-511, 2010.

[81] T. Arun and F. Nixson, "The Reform of the Power Sector in India: 1991-1997," *Journal of International Development,* vol. 10, pp. 417-426, 1998.

[82] Ministry of Law and Justice, *The Electricity Act,* New Delhi, 2003.

[83] T. Thakur, S. Kaushik, S. Deshmukh and S. Tripathi, "Indian Electricity Act 2003: implications for the generation, transmission and distribution sectors," in *Electric Utility Deregulation, Restructuring and Power Technologies*, Hong Kong, 2004.

[84] G. o. I. M. o. Power, "About Ministry," 13 June 2017. [Online]. Available: http://www.powermin.nic.in/en/content/about-ministry. [Accessed 14 June 2017].

[85] Government of India: Ministry of Power, "Central Electricity Authority - An Introduction," 13 February 2017. [Online]. Available: http://www.cea.nic.in/aboutus.html. [Accessed 14 June 2017].

[86] Indian Power Sector, "Opening the Doors: Open Access," [Online]. Available: http://indianpowersector.com/home/tag/serc/. [Accessed 14 June 2017].

[87] NTPC, "NTPC Overview," 2015. [Online]. Available: http://www.ntpc.co.in/en/about-us/ntpc-overview. [Accessed 14 June 2017].

[88] Power Grid Corporation of India Limited, "Company Overview," 14 June 2017. [Online]. Available: https://www.powergridindia.com/company-overview-0. [Accessed 14 June 2017].

[89] United Nations, "Electricity, net installed capacity of electric power plants," [Online]. Available: http://data.un.org/Data.aspx?d=EDATA&f=cmID%3AEC. [Accessed 14 June 2017].

[90] NTPC, "History," 2015. [Online]. Available: http://www.ntpc.co.in/en/about-us/history. [Accessed 14 June 2017].

[91] S. G. Banerjee, D. Barnes, B. Singh, K. Mayer and H. Samad, "Power for All: Electricity Access Challenge in India," World Bank Group, Washington, 2015.

[92] M. Opam, "Institution Building in the Enegy Sector of Africa: A Case Study of the Ghana Power Sector Reform Programme," in *Africa Regional Conference on Mineral and Energy Resources Development and Utilisation*, Accra, 1995.

[93] K. A. Awotwi and K. S. Ofori-Atta, "Ghana: 20 Years of of Power Sector Reform," Accra, 2015.

[94] Energy Sector Management Assistance Program, "Ghana: Sector Reform and the Pattern of the Poor," ESMAP, Washington, 2006.

[95] Northern Electricity Distribution Company, "Abous Us," 2013. [Online]. Available: http://nedco.com.gh/about_us.php. [Accessed 15 June 2017].

[96] J. Kapika and A. Eberhard, "Chapter 6: Ghana," in *Power Sector Reform and Regulation in Africa*, Capte Town, HSRC Press, 2013, pp. 130-140.

[97] GRIDCo: Backbone to Power Delivery, "Overview," 2011. [Online]. Available: http://www.gridcogh.com/en/about-us/overview.php. [Accessed 15 June 2017].

[98] E. Kusi, "Ghana's Experience with Power Sector Reform: Legislative and Policy Issues," Parliamentary Forum on Energy Legislation and Sustainable Development, Cape Town, 2005.

[99] Energy Commission, *Energy Commission Act 1997 (Act 541),* Accra, 1997.

[100] Public Utilities Regulatory Commission, *The Public Utitlies Regulatory Comission Act, 1997 (Act 538),* Accra, 1997.

[101] International Atomic Energy Agency, "Country Nuclear Power Profiles: Ghana," 2012. [Online]. Available: http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2012_CD/countryprofiles/Ghana/Ghana.htm. [Accessed 16 June 2017].

[102] Electricity Company of Ghana Limited, "About the Power Sector in Ghana," 2016. [Online]. Available: http://www.ecgonline.info/index.php/about-the-power-sector-in-ghana.html. [Accessed 15 June 2017].

[103] Energy Commission, "Licensing and Permits in the Electricity Sector," 10 May 2017. [Online]. Available: http://www.energycom.gov.gh/licensing/licensing-electricity-natural-gas. [Accessed 16 June 2017].

[104] Global Investment & Business Center, Doing Business and Investing in Ghana Handbook: Strategic, Practical Information, Regulations, Contacts, International Business Publications, 2017.

[105] Volta River Authority, "Profile of the Volta River Authority," 2017. [Online]. Available: http://www.vra.com/about_us/profile.php. [Accessed 15 June 2017].

[106] Ghana Grid Company Limited, "2010 Electricity Supply Plan," GridCo, Accra, 2010.

[107] Ghana Grid Company Limited, "2014 Electricity Supply Plan," GridCo, Accra, 2014.

[108] N. N. Shahri, "Power market reforms and privatization of the electricity industry in the Iranian energy sector; an uphill struggle?," Munich Personal RePEc Archive, Dundee, 2011.

[109] M. Pourhossein, N. Nahavandi and M. K. Sheikh-El-Eslami, "Transition in Iran's Electricity Market Considering the Policies on Elimination of Electricity Subsidies: System Dynamics Application," *International Journal of Industrial Engineering & Production Research,* vol. 25, no. 4, pp. 263-270, 2014.

[110] Tavanir, "Electric Power Industry Statistics," Tavanir Org., [Online]. Available: http://amar.tavanir.org.ir/en/pages/introduction.php. [Accessed 19 June 2017].

[111] Iran Grid Management Company, "Our History," 2017. [Online]. Available: http://www.igmc.ir/en/. [Accessed 20 June 2017].

[112] M. A. M. Azad, M. P. Covich and S. Sojoodi, "The Impact of Electricity Competitive Market Establishment on Technical Efficiency of Thermal Power Plants in Iran," *International Journal of Energy Economics and Policy,* vol. 5, no. 4, pp. 1010-1015, 2015.

[113] Tavanir Holding Group, "Statistical Report on 49 Years of Activities of Iran Electric Power Industry (1967-2015)," Islamic Republic of Iran Ministry of Energy, Tavanir Holding Group, Tehran, 2016.

[114] M. Kaffenberger, "The Effect of Educational Attainment on Corruption Participation in Sub-Saharan Africa," Graduate School of Vanderbilt University, Nashville, 2012.