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Sustainable Development Goal 7: Affordable and Clean Energy

Panel Data Analysis

Bachelor thesis

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain any other academic title.

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Prague, May 9, 2019

Alzbeta Krizkova

Abstract

This thesis analyses the seventh Sustainable Development Goal: Affordable and Clean Energy. Four empirical models are built, each for one indicator. They are then evaluated using panel data analysis for all member states of the UN. The research question it seeks to answer is: ”What characteristics have major impact on providing electric energy and other energy related benefits?” We found that in most of the cases, the proportion of urban population and the Human Development Index have a major impact on the indicators. Unlike any previous study dealing with similar topics, this paper analyses the whole goal with its four indicators, not just one particular energy aspect. That allows us to look for interconnection and common features between indicators and their influences.

JEL Classification	K32, O13, P48, Q42
Keywords	Clean Energy, Panel Data, Access to Electricity, Clean Fuels, Renewable Energy, Energy Intensity
Title	Sustainable Development Goal 7: Affordable and Clean Energy *Panel Data Analysis*

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Abstrakt

Tato bakalářská práce zkoumá sedmý Cíl udržitelného rozvoje: Dostupná a čistá energie. Zaměřuje se na všechny jeho čtyři indikátory. Pro každý z nich staví a vyhodnocuje empirický model za použití analýzy panelových dat všech členský země OSN. Výzkumná otázka, kterou si práce klade, je: ”Které ukazatele mají největší vliv na poskytování elektrické energie a dalších výhod plynoucích z dostupnosti elektrické energie?” Na základě našeho výzkumu můžeme prohlásit, že ve většině případů mají největší vliv podíl urbaniz ovaného obyvatelstva a index lidského rozvoje. Na rozdíl od dříve provedených výzkumů zabývajících se podobnými tématy, tato práce zkoumá všechny čtyři aspekty elektrické energie dohromady. To nám dává možnost hledat společné vlivy a propojení mezi indikátory.

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Acronyms

SDG Sustainable Development Goal

GDP Gross Domestic Product

HDI Human Development Index

MDG Millennium Development Goal

NGO Non-Governmental Organization

OLS Ordinary Least Squares

FD First Difference

RE Random Effects

FE Fixed Effects

WHO World Health Organization

IEA International Energy Agency

UNDP United Nations Development Programme

Bachelor’s Thesis Proposal

Author	Alžběta Křížková
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Proposed topic	Sustainable Development Goal 7: Affordable and Clean Energy *Panel Data Analysis*

Motivation The Sustainable Development Goals (SDGs) presented in 2015 by the United Nations contain of 17 goals to be achieved by 2030. They cover a wide range of topics in order to end poverty, protect the Earth and improve lives. Each goal is subsequently divided into specific targets, each quantified by one or two indicators.

SDGs follow and broaden previous Millennium Sustainable Goals, running from 2000 to 2015. In scientific circles it is still widely debated, whether and how much these Goals were overall successful and helpful. SDGs attempt to extend goals that were not achieved and add some more which are important for future development of the whole world.

In the thesis, I am going to focus on SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all. I am going to examine three core targets of this goal and their four indicators.

Research Question The research question I aspire to answer: ”On what characteristics is each indicator dependent?” I am going to refer to each indicator of the targets and analyze them using econometric methods.

Hypotheses

Hypothesis #1: Urban population and HDI play a major role in access to electricity.

Hypothesis #2: Urban population has a major effect on primary reliance on clean fuels and technology.

Hypothesis #3: HDI and school enrolment have a positive influence on a share of renewable energy.

Hypothesis #4: GDP has a negative impact on energy intensity, while urban population has a positive impact.

Methodology I am going to be focusing on these four indicators:

7.1.1 Proportion of population with access to electricity

7.1.2 Proportion of population with primary reliance on clean fuels and technology

7.2.1 Renewable energy share in the total final energy consumption

7.3.1 Energy intensity measured in terms of primary energy and GDP.

I am going to be working with data mainly from the Global Database of SGD Indicators by the United Nations Statistics Division and the World Bank. Using panel data analysis I am going to regress socio-economic characteristics on each indicator and find out which ones are statistically significant.

Expected Contribution My research is going to be covering the whole energy goal and its feasibility in general. Through my analysis, I can discover which targets need to be worked on the most. The conclusions can be useful for policymakers, in order to see if existing progress towards the fulfillment of each goal is sufficient. Also, my work can be further elaborated into recommendations for diplomats and policymakers.

Outline

1. Introduction
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7. Conclusion

Core bibliography

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Author Supervisor

Chapter 1

Introduction

What are the key determinants of access to energy and other benefits linked to energy across the world? What socio-economic areas should we focus on, in order to accomplish the Sustainable Development Goals (SDGs)? Those are the research questions we would like to answer with this thesis. The SDGs developed by the United Nations (UN) in collaboration with numerous NGOs and scientists aspire to end poverty and hunger, improve education, health and quality of life, promote gender equality, sustainability and many more. Altogether 17 goals are divided into 169 targets that are subsequently quantified using data based indicators.

The seventh SDG deals with affordable and clean energy, namely access to electricity, primary reliance on clean fuels and technology, share of renewable energy in the total consumption and energy intensity. Following the idea behind all the SDGs, the targets within each goal are set in ascending order, hence each country has a path to follow. Meaning, that poor countries should primarily aim at achieving the first target in order to secure basic human rights for their residents. Meanwhile, developed and rich countries, assuming having achieved the top target already, should focus on subsequent targets. This should ensure the whole world to jointly move towards sustainability.

The goal of the thesis is to shed light on characteristics standing behind each energy indicator. Proceeding from research papers already conducted and available, we built four empirical models, each analysing one indicator using various explanatory variables of socio-economic character. We worked with available data for member states of the UN using panel data analysis. The hypotheses we set for each indicator are following:

> Hypothesis #1: Urban population and HDI have major role in access to electricity.
>
> Hypothesis #2: Urban population has major effect on primary reliance on clean fuels and technology.
>
> Hypothesis #3: HDI and school enrolment have positive influence on share of renewable energy.
>
> Hypothesis #4: GDP has a negative impact on energy intensity, while urban population has a positive impact.

The thesis begins with Chapter 2 presenting previously conducted research papers in literature review that we based our analysis on. In Chapter 3 we present a short overview on Sustainable Development Goals and then focus on Goal 7: Affordable and Clean Energy. We examine each indicator, describe its objective and comment on the progress. Chapter 4 refers to the panel data approach and estimators we used throughout the analysis. In Chapter 5 we describe the data we work with and mention some interesting facts from summary statistics. The results and discussion of our empirical models can be found in Chapter 6. Finally, the last part of the thesis is dedicated to conclusion in Chapter 7, followed by Appendixes.

Chapter 2

Literature Review

Since SDGs are a relatively new concept, there is not much literature and research papers to be found about the topic, especially the ones analysing the subject using panel data analysis. However, one can look at the individual sections presented in the SDGs and look for works dealing with individual energy aspects.

The research that we relied on the most for the first indicator is by Magnani & Vaona (2016). They use data from 31 countries for the years 2010 and 2011 and regress *access to electricity* on various socio-economic characteristics: *borrowers from commercial banks, electricity production from renewable sources (excluding hydro power), electricity produced from fossil fuels, electricity production from hydroelectric sources, GDP per capita, rural population, total natural resources rents, lower secondary completion rate* and *urban population.* The strongest relations was found for *rural population* (negative sign) and *human capital* (positive sign). Other variables affecting dependent variables were *electricity production by renewable sources* and *total natural resources rents. GDP per capita* turned out to play a rather minor role. They also show that *quality of institution* has a positive impact. However, they could only show that for some of the countries from dataset, because of restricted data availability.

Another paper we drew on by Gualberti *et al.* (2013) who find a significant and positive impact of *official development finance for electricity production* and *gross fixed capital formation of the whole economy* on *installed base for electricity generation.* Nanka-Bruce (2010) focuses on sub-Saharan Africa and "finds *the Human Development Index, wealth distribution, institutional development* and *urban population size of a country* to have a significant impact on *rural electrification development.*" Onyeji *et al.* (2012) find *government effec-*

tiveness and *institutional quality* as significant and positively impacting *access to electricity* in sub-Saharan countries.

For the indicator focusing on access to clean fuels and technology, we could not find a research paper using panel data analysis to uncover causes at a country level. However, there are numerous papers analysing specifically one country and consumers' decisions regarding what fuels to use. For example Alem *et al.* (2013) use panel data from urban Ethiopia and find that *price of electricity and firewood* as well as *access to credit* are major determinants of *adoption of electric cook stove.* Other cause for adopting clean technology for cooking can be found in the report by World Bank (2018). It claims *urban population* to be a main determinant in countries' *primary reliance on clean fuels.*

Papers relating to the third indicator regarding renewable energy share in the total consumption usually focus on one-to-one causality between renewable energy share or use and another socio-economic characteristic. Menegaki (2011) was not able to show causality between *renewable energy consumption* and *GDP* for 27 European countries, while Marinaş Marius-Corneliu (2018) finds bi-directional causality between *renewable energy consumption* and *GDP* in Central and Eastern Europe. Akin *et al.* (2017) show causality between *renewable energy usage* and *HDI, income level* as well as *educational expenditure quality for middle income countries.*

The fourth model describing *energy intensity* is based on the following papers: Filipović *et al.* (2015) estimate model showing that *energy price, energy taxes* and *GDP* have a negative impact on *energy intensity* in EU member states, while the *growth of gross inland consumption* and *final energy consumption per capita* affect *energy intensity* positively. Bilgili *et al.* (2017) show significance of *urban population* on *energy intensity* for 10 Asian countries.

Other sources used for purposes of our research are documents intended mainly for policymakers and NGOs. They are annually released reports on progress in SDGs (e.g. the Policy Briefs in support of the first SDG7 Review at the UN High-level political Forum 2018 or the Report of the Secretary General, Sustainable Development Goals Report).

Chapter 3

Sustainable Development Goals

”Sustainable Development Goals” is an agenda and a resolution developed by the United Nations and adopted by all the UN member states in 2015. It consists of 17 goals each focused on a certain aspect of a continuous sustainable development of human population on Earth.

> ”They recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth—all while tackling climate change and working to preserve our oceans and forests.”United Nations (2018)

Diplomatic attempts for a worldwide framework on how to tackle sustainable development and environmental issues started in 1992 with the Agenda 21, which was ”a comprehensive plan of action to build a global partnership for sustainable development to improve human lives and protect the environment,” (United Nations 2018) implemented by more than 170 countries. This was followed by Millennial Development Goals unanimously agreed on by the UN in 2000. Eight goals targeting mainly at ending poverty, improving health and reducing inequality were meant to be achieved by 2015. Some of the critique the MDGs received was due to the fact that they were clearly built only for the poorest countries of the world, but claimed to be created for the whole world. At the time, MDGs were described as ”the most successful anti-poverty movement in history.” Their biggest achievement was halving the percentage of people suffering from hunger to 12.9 per cent in 2014. (UNDP 2015) However, the progress had been unbalanced and inequalities had still persisted.

When MDGs were coming to an end in 2015, the United Nations came up with an updated and extended version—the Sustainable Development Goals. The set of 17 goals attempting to cover the whole area of human sustainability on Earth are further divided into 169 targets. To be able to observe the progress, targets split into data based indicators with a specific figure (or rather a proportion) to be achieved by 2030. In contrast to the MDGs, targets in the SDGs are gradually scaled, so each country is able to find a target in each goal that it has not yet achieved.

One of the biggest issues the SDGs are still dealing with is data collection, since it is fundamental to be able to evaluate the progress. A global indicator framework to monitor the goals was adopted in 2018 on a voluntary basis. This has led many initiatives to develop new tools and frameworks for collecting and integrating new data, which is extremely important, because "data are increasingly disaggregated by income, sex, age, race, ethnicity, migratory status, disability, geographic location and other characteristics." (UN Statistics Division 2018b)

3.1 Goal 7: Affordable and Clean Energy

The seventh Sustainable Development Goal focuses on electrical energy and benefits resulting from connection to electricity, namely access to electric energy, clean fuels, renewable energy and overall improvement in technology, research and investment. The indicators are constructed in a way that every country has an aim to achieve. They are arranged from the most needed and the most elementary up to aspects intended rather for developed and rich countries, to promote sustainability and efficiency. As a result of interconnection between goals, achieving in the energy goal would mean significant improvement in other goals, too. The structure and the names declared in the resolution of the seventh goal are the following:

Sustainable Development Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all.
Target 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services.
Indicator 7.1.1: Proportion of population with access to electricity. *Indicator 7.1.2*: Proportion of population with primary reliance on clean fuels and technology.
Target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.
Indicator 7.2.1: Renewable energy share in the total final energy consumption.
Target 7.3 By 2030, double the global rate of improvement in energy efficiency.
Indicator 7.3.1: Energy intensity measured in terms of primary energy and GDP.
Target 7.a: By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
Indicator 7.a.1: International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems.
Target 7.b: By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support.
Indicator 7.b.1: Investments in energy efficiency as a proportion of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services.

Source: UN Statistics Division (2018a), `https://unstats.un.org/sdgs/metadata/`, accessed on 2019-03-25

3.1.1 Target 7.1: Universal access to energy services

The first target together with its two indicators deal with an overall access to electricity to every household and primary reliance on clean fuels and technology. Therefore the target is focusing primarily on developing countries and their poorest residents. It is aspiring to ensure basic needs for everybody.

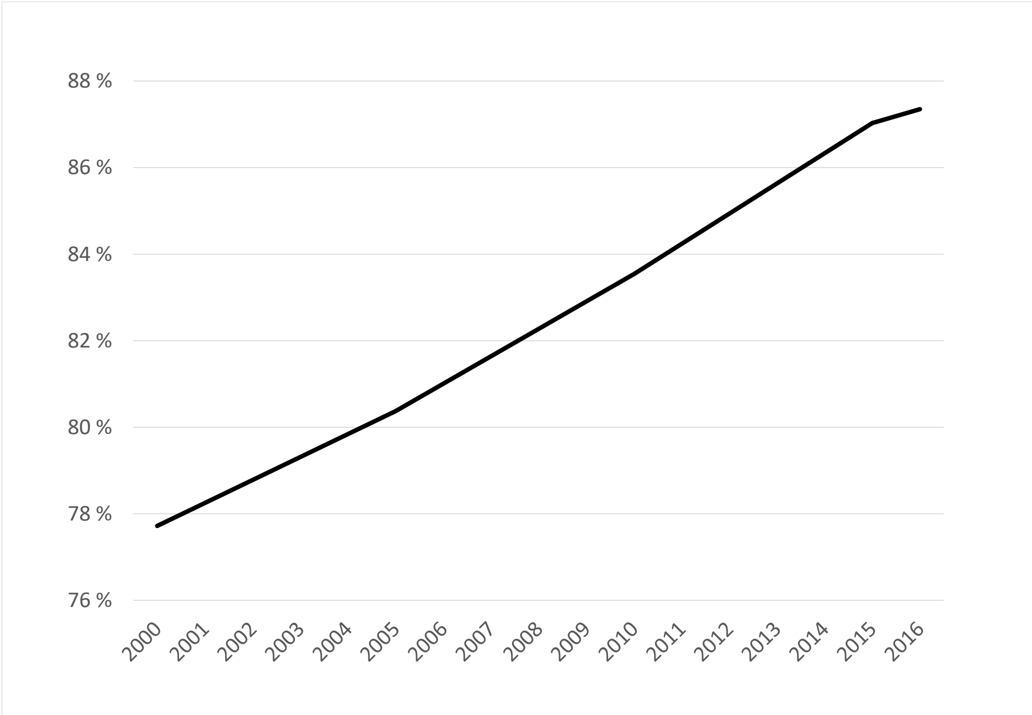
Indicator 7.1.1: Access to electricity

The first indicator measures the total share of population with access to electricity at household level. Moreover, there is also an emphasis on access to electricity for schools, health centres and local enterprises. That can be provided either by traditional and mainly used on-grid distribution of electricity but also by an off-grid solar energy solution. An off-grid distribution can expediently be used for sparsely populated and rural areas. Even though an off-grid solution is usually more expensive, it provides independence from energy supplier and distribution for a household. The consumer does not have to deal with the quality of supplied energy, as it is the case with on-grid connection. However, providing electricity connections to households is not the problem. Improvements in quality, reliability and affordability of the electricity provided still continues to be a problem in some parts of the world. According to the United Nations (2018),

> ”The biggest challenge still remains to be providing electricity to poor and remote households. Decentralized options seem to be the least-cost option for 60 per cent of people who lack access to electricity.”

Countries that have the lowest shares of population with access to electricity are located in sub-Saharan Africa and south Asia. One of the most successful countries in electrification is India. In 2018, there was a rapid increase in building electricity lines. 95 per cent of house were electrified (in 2018), compared to 86 per cent in 2017. Thanks to this effort and also to progress in other countries (e.g. Bangladesh, Ethiopia, Kenya and Tanzania), the number of people without access to electricity fell below 1 billion for the first time ever. (IEA and the World Bank 2017) Below can be found a figure illustrating world progress on the first indicator:

Figure 3.1: *Access to electricity*, world progress



Source: UN Statistics Division (2018a)

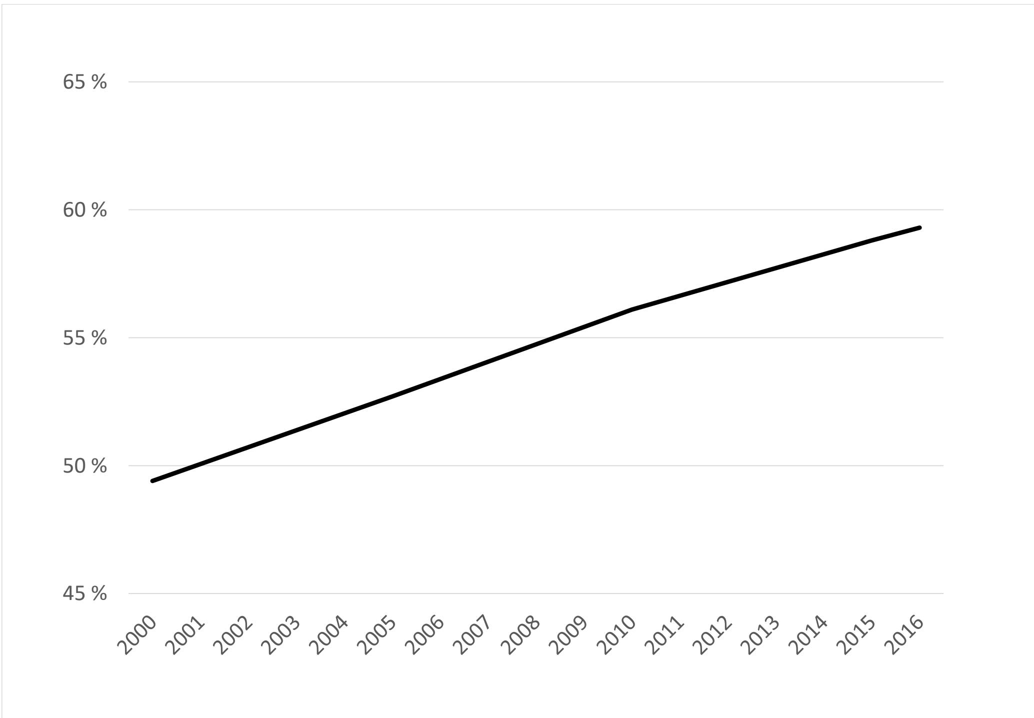
Indicator 7.1.2: Reliance on clean fuels and technology

The second indicator emphasizes primary reliance on clean cooking fuels and technology. It is measured as share of the total population with access to clean fuels and technologies for cooking. This issue involves around 40 per cent of the world's population, compared to 13 per cent without access to electricity. Around 85 per cent of the people without access to clean fuels and technology live in 20 countries only (e.g. India, China, Nigeria, Bangladesh). (United Nations 2018)

Air pollutants from traditional cook stoves and open fires inside the house fuelled by wood, coal, charcoal or animal waste are a leading cause of death in low-income households. Implementation of this indicator would also help other ten SDGs, since the problem is linked to health, gender equality, climate action and eliminating poverty. (United Nations 2018) The World Health Organization (WHO) estimates that around 4 million premature deaths each year are linked to inhaling emissions from biomass cook stoves and open fires. (WHO 2014) They also generate tons of CO_2 emissions contributing to climate change. Furthermore, replacing traditional cook stoves and transitioning to modern fuels could improve lives mainly of women and girls who spend significant amount of time gathering the wood and fuels and are also exposed to the resulting health risks inside their households more than men.

Electricity, gas, ethanol, solar and biomass stoves are examples of currently available options, that meet the most recent WHO Guidelines for indoor air quality. (WHO 2010) In order to benefit and provide the health benefits the WHO recommends to use these exclusively and discourage to use kerosene and unprocessed coal. (WHO 2014) However, the reality is often different and households frequently resort to stove stacking—combining modern and traditional cooking solution instead of completely transitioning to modern options. In addition, household should also obtain improved cook stoves with higher efficiency and lower emissions. Full transition is further conditioned by improvements in affordability and mainly in education and understanding of health, time and environmental impacts. A figure with the world progress on this indicator can be found below:

Figure 3.2: *Reliance on clean fuels*, world progress



Source: UN Statistics Division (2018a)

3.1.2 Target 7.2: Share of renewable energy

The second target focuses on substantially increasing the share of renewable energy in total final energy consumption. Unlike the previous target, all countries can make improvements in this target and none achieved 100 % share of renewable energy so far.

Indicator 7.2.1: Renewable energy share in the total consumption

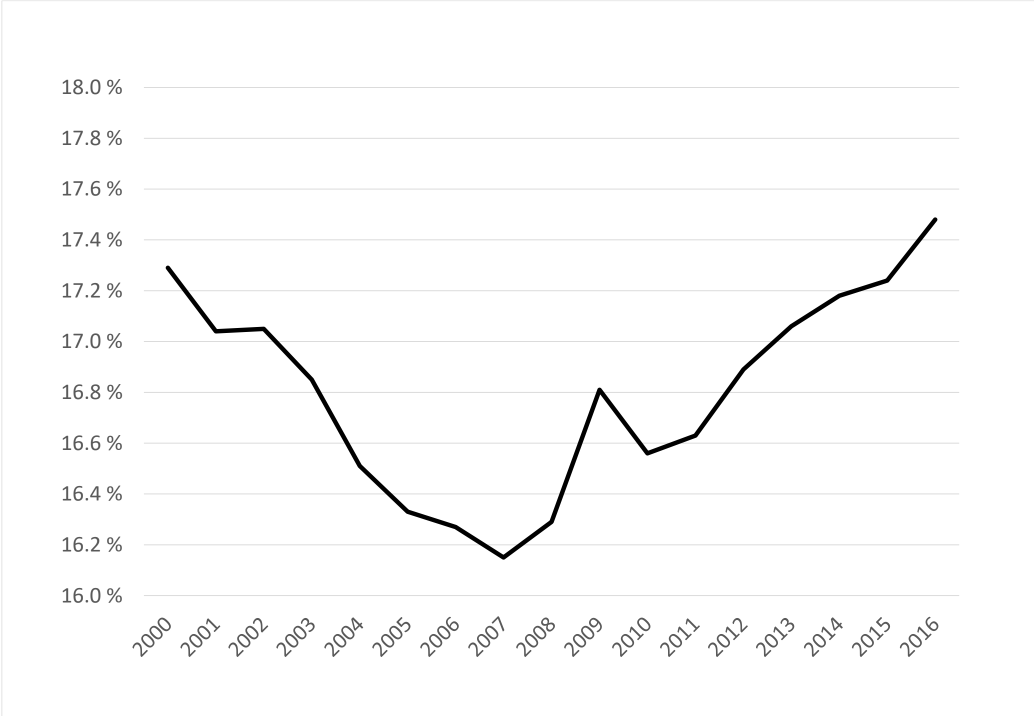
The target has only one indicator measuring share of renewable energy in the total energy mix. According to the International Energy Agency (IEA), the world should accelerate its efforts in order to achieve this goal. (IEA and the World Bank 2017) The improvements completed so far are not significant enough, the share of renewable energy in total final consumption grew from 16.6 per cent in 2010 to only 17.2 per cent in 2015. (UN Statistics Division 2018a) Favourably, research shows that the UN's plan for the share to grow to 60 per cent by 2030 is economically and technically feasible. For achieving the plan, strengthening of end-use sectors (buildings, industry and transport), improving flexibility and overall efficiency are needed. Increased focus should be directed towards improvements in smart technologies, especially production of batteries for transport and static storage. (United Nations 2018)

Different geographical and economical background of each country lead to the consequence that each country has to create its own plan of implementing the goal, taking into consideration restructuring the market design, policy and regulatory actions. On top of that, the whole energy sector needs to go through an efficient transformation heading towards a zero-carbon energy system. (United Nations 2018) The energy sector is esteemed to be accountable for two-thirds of the world's greenhouse gas emissions, thus it presents a major opportunity to combat climate change through a shift towards renewable energy. The United Nations (2018) adds more benefits:

> ”Increasing the share of renewables would lead to US$ 52 trillion in economic growth. The health, environmental and climate benefits would save up to 2-5 times more than the additional costs associated with reconfiguring the energy sector, while creating millions of jobs in the process, and improving the health and well-being of people, in line with the Sustainable Development Goals.”

A figure describing the world progress on the second target can be found below:

Figure 3.3: *Share of renewable energy*, world progress



Source: UN Statistics Division (2018a)

3.1.3 Target 7.3: Improvement in energy efficiency

Energy intensity expresses how a 'piece' of energy benefits the economy. It is calculated as a ratio of total primary energy use and GDP. The resulting value is used to express the efficiency of using the fuels and distributing them for each country.

Indicator: 7.3.1 Energy intensity

The scenario presented in the SDGs agenda is to double the rate of improvements in energy efficiency. This would result in fulfilment of the third target, enablement of the sustainable energy transition and stable position in achieving the Paris Agreement from 2015, that besides others aims to keep a global temperature raise below 2 degrees Celsius above pre-industrial level. (UN Climate Change 2018) Improvements in energy efficiency are crucial for achieving all the SDGs, e.g. less wasting electricity (SDG 12) would result in utility companies being able to supply electricity to more households without increasing producing capacity, keeping electricity affordable and reliable (SDG 1, 7 and 8), as well as in the possibility of storing more food and medicine (SDG 2 and

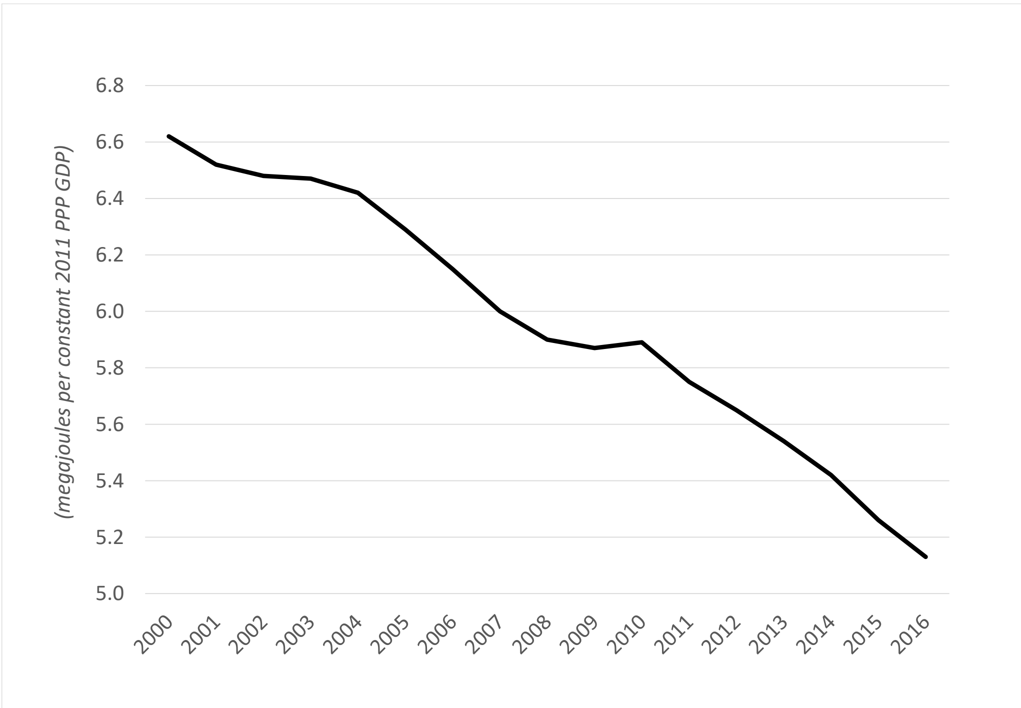
3), leading to more efficient businesses, better schools and hospitals. (United Nations 2018)

Recommendations published by the (United Nations 2018) for countries to improve their energy efficiency mention

> ”well-designed, -implemented, and -enforced policies and action plans, including building codes for residential and commercial facilities with energy performance requirements for new construction and major renovations, minimum energy performance standards and labels for electric and electronic products and vehicles.”

A figure depicting the world progress on the third target can be found below:

Figure 3.4: *Energy intensity*, world progress



Source: UN Statistics Division (2018a)

3.1.4 Additional Targets 7.a and 7.b

The additional targets 7.a and 7.b are different from the previous ones—they have no supporting data and no exact numbers have been assigned to these targets and their indicators. Therefore we will not be dealing with them in the research. They are meant to facilitate political decisions in the right direction and emphasize important topics in order to achieve SDG 7. Particularly, the first target and its indicator deal with international cooperation in clean energy, renewable energy and energy efficiency research and technology. They highlight the need of international financial flows to developing countries to support their research and investment. The second target together with its indicator focus on investments in the least developed countries in order to improve the energy efficiency. The Analysis of progress in SDGs implementation by United Nations (2018) of some countries in 2018 showed that

> ”...the doubling of financing from the current levels of US$ 500 billion to US$ 1 to 1.2 trillion a year until 2030 is needed in order to achieve SDG 7. Financing SDG 7 is, unfortunately, one of the least addressed areas.”

Chapter 4

Panel Data Analysis

For analysis of the indicators a panel data approach has been chosen, following mostly a framework presented in Wooldridge (2009). The panel data (or longitudinal data) combines cross-section and time series methods. It is a set following the same cross-sectional units over a certain period of time, resulting in the data being not independently distributed across time as pooled cross-sections. Using panel data analysis allows us to treat unobserved heterogeneity, it offers more variability and efficiency in estimation and less collinearity among dependent variables. The methods we chose to use were: Pooled OLS, First Difference, Random Effects and Fixed Effects Estimators.

The general model used for the analysis is as follows:

$$y_{i,t} = \alpha + \beta x_{i,t} + a_i + u_{i,t}$$

Index i is each observed unit (countries in our case) and index t denotes a time period. α is intercept, β represents the vector of coefficients we measure, $x_{i,t}$ is our explanatory variable, a_i represents fixed effects (also called individual heterogeneity) and $u_{i,t}$ is the idiosyncratic error representing unobserved factors that change over time and affects $y_{i,t}$.

A dataset is called balanced when we have collected observations for each individual and each time period. Vice versa, the dataset is unbalanced, when we miss certain observations from individuals across time. In the analysis of our data, we first worked with unbalanced data and then proceeded to balanced data.

4.1 Pooled OLS

For the Pooled OLS model we gather the data on different units with no assumption on individual differences. We have to assume that the fixed effect is uncorrelated with $x_{i,t}$, otherwise we get the heterogeneity bias.

4.2 First Difference

The First Difference (FD) estimator is used when we want to address the problem of omitted variables. Unfortunately, with FD we lose the first observation in our dataset. We must also assume that the errors $u_{i,t}$ are serially uncorrelated. The estimator is obtained by running a Pooled OLS model and taking the difference of adjacent time periods, where the earlier time period is subtracted from the later time period.

4.3 Random Effects

The Random Effects (RE) method should be used when we think the unobserved effect is uncorrelated with all the explanatory variables. If the assumptions of RE hold, the method is asymptotically more efficient than the other method we chose.

4.4 Fixed Effects

To eliminate the unobserved effect in our model, Fixed Effects (FE) method can be used. Wooldridge (2009) describes the method:

> "Compared with first differencing, the fixed effects estimator is efficient when the idiosyncratic errors are serially uncorrelated (as well as homoskedastic), and we make no assumptions about correlation between the unobserved effect a_i and the explanatory variables."

Using the Fixed Effects method we eliminate any explanatory variable constant over time. This can be especially helpful for removing the fixed effect a_i which could be correlated with explanatory variables. We get an unbiased estimator when the error term is uncorrelated with each explanatory variable across all time periods. We also need to have the errors homoskedastic and serially uncorrelated across t. (Wooldridge 2001)

Tested properties of our models performed throughout the analysis are presented in the table below:

Table 4.1: Overview of the tests

Tested property	*Null Hypothesis/Description*
Individual and time effects	no time or individual effects needed
Heteroskedasticity	homoskedasticity present
Serial Correlation	no serial correlation
Cross-Sectional Independence	no cross-sectional dependence
Stationarity	series has a unit root (non-stationary)
RE vs. Pooled OLS	OLS better than Random Effects
FE vs. Pooled OLS	OLS better than Fixed Effects
Hausmann Test (FE vs. RE)	RE efficient + consistent, FE inefficient

Source: Wooldridge (2009)

Chapter 5

Model Specification

5.1 Data Specification

The data we used for the analysis are from two main sources: the Statistics Division of the UN and the World Bank. Data for our dependent variables have been obtained from the Statistics Division of the UN. The Metadata Repository for SDG Indicators collects data for all indicators. Data for the first indicator 7.1.1 are available annually for the years from 2000 to 2016. For the analysis of the indicator 7.1.2 only five-yearly data (2000, 2005, 2010, 2015) were available. For the indicators 7.2.1 and 7.3.1 data from 2000 to 2015 are included in the analysis, because there are no observation in the repository for further years. Data for the *HDI* were found in the UNDP (United Nations Development Programme) Human Development Reports and were multiplied by 100, in order to match other variables in units. Data for all other explanatory variables are from the database of the World Bank. They were taken for the years corresponding to the data for indicators.

5.2 Model Specification

The following section presents a specification of the four empirical models using panel data analysis. The focus is to find an explanation for each of the four indicators from the seventh SDG. The explanatory variables used and tested in the models were chosen based on already existing papers and intuitive opinion of what could be the case behind the indicators. Each description of the models is accompanied with an overview table of used variables.

The first model focuses on overall access to electricity for all households.

The explanatory variables comprise *GDP per capita, primary school enrolment, urban population, share of renewable energy in the total final energy consumption*, as previously regressed by Magnani & Vaona (2016) and *HDI* studied by Nanka-Bruce (2010). Variables that could possibly be added to the model are: *foreign direct investment, GINI index and borrowers from bank*. Unfortunately, data for these attributes were either missing for a majority of observations or we were unable to obtain data at all.

Table 5.1: Variables for the model of indicator 7.1.1

Name	*Description*
acctoel	**Proportion of population with access to electricity (%)**
GDP	GDP per capita, PPP (current international $)
school	School enrolment, primary (% gross)
HDI	Human Development Index (%)
urban	Urban population (% of total)
renew	Renewable energy share in the total final energy consumption (%)

Source: Author's elaboration, based on World Bank (2019)

The next model tries to find an explanation for reliance on clean fuels and technology. When deciding which variables to use for this model, there was not any paper we could follow. Thus we only chose variables based on our intuition such as *GDP per capita, HDI, primary school enrolment, urban population, proportion of population with access to electricity* and *pump price for gasoline*. Data for *price of electricity* and *access to credit* that were established as major determinants in Ethiopia could not be obtained for majority of UN member states.

Table 5.2: Variables for the model of indicator 7.1.2

Name	*Description*
clfuels1	**Proportion of population with primary reliance on clean fuels and technology (%)**
GDP1	GDP per capita, PPP (current international $)
school1	School enrolment, primary (% gross)
HDI1	Human Development Index (%)
urban1	Urban population (% of total)
acctoel1	Proportion of population with access to electricity (%)
gasoline1	Pump price for gasoline (US$ per liter)

Source: Author's elaboration, based on World Bank (2019)

Subject of the third model is the share of renewable energy in the total mix of a country's consumption. Given the fact, that designing renewable energy construction is unique for each country and depends on a country's market design, geographic location and other characteristics, we put only fundamental variables into our model: *GDP per capita, HDI, primary school enrolment* and *urban population*, as suggested by Akin *et al.* (2017) and Marinaş Marius-Corneliu (2018). Our model could be possibly extended by adding variables such as *foreign direct investment, pump price for gasoline, renewable energy subsidies and taxes.*

Table 5.3: Variables for the model of indicator 7.2.1

Name	*Description*
renew2	**Renewable energy share in the total final energy consumption (%)**
GDP2	GDP per capita, PPP (current international $)
school2	School enrolment, primary (% gross)
HDI2	Human Development Index (%)
urban2	Urban population (% of total)

Source: Author's elaboration, based on World Bank (2019)

The final model considers the energy intensity of each country. The variables we chose to regress on are: *GDP per capita, primary school enrolment, HDI, urban population , share of renewable energy in the total final energy consumption* and *pump price for gasoline*, following Filipović *et al.* (2015) and Bilgili *et al.* (2017). Variables that could also be added to the model are *energy price and tax, gross inland consumption* or *final energy consumption.*

Table 5.4: Variables for the model of indicator 7.3.1

Name	*Description*
int3	**Energy intensity level of primary energy (megajoules per constant 2011 PPP GDP)**
GDP3	GDP per capita, PPP (current international $)
renew3	Renewable energy share in the total final energy consumption (%)
HDI3	Human Development Index (%)
school3	School enrolment, primary (% gross)
urban3	Urban population (% of total)
gasoline3	Pump price for gasoline (US$ per liter)

Source: Author's elaboration, based on World Bank (2019)

5.3 Missing Data

Treating missing data in a dataset is an important part of regressing. Regarding the unbalanced data, the observations are put into modelling in the form they were obtained. The software used (RStudio in our case) then omits missing observations. However, for balanced data, we have to find a way how to deal with missing observations.

First, we visually analyse whether the observations are missing randomly, or if there is a pattern. Data missing randomly can be ignored according to Wooldridge (2009). However, when there is some kind of connection between missing data and some other characteristics, it results in a non-random sample and violates MLR 2. (Wooldridge 2009)

Having these two particularities in mind, we move on to the actual treatment of missing data. In case there is a missing observation for a country in any year, the country is then excluded from the dataset for all the years. Observing the dataset, we were not able to establish a common feature of missing data. Time did not seem to be an issue, since all the missing data seemed to be distributed across all the years. Some of the world's poorest countries have difficulties reporting data and had to be excluded from the analysis. Looking through the datasets, we noticed that a lot of micro states missed all the observations and had to be omitted from the set as well. This should not bias our results, since some of the micro states are still present and it also does not have a big impact on the overall world area.

Another unusual phenomenon occurred to us with the data for indicator

7.1.2 regarding access to clean fuels and technology. Many of the developed and big countries (such as Australia, Canada or Spain) miss observations for all the years. A reason behind this could be that these countries do not deal with this problem, meaning that the whole population has an access to clean fuels and technology and the countries therefore do not need to collect information about this issue. This could cause shifts in the results, because some of the countries that have full access to clean fuels are omitted and countries with lower access get more space in the analysis.

To obtain a reasonably large dataset for the analysis of balanced data, the approach of the Last Observation Carried Forward method was chosen. The list of countries included in the research was derived from the list of member states of the United Nations, since the SDGs are focused primarily on those countries. Altogether there are 193 countries included in the dataset of unbalanced data. Detailed overview of countries included in each of the models for both unbalanced and balanced datasets is attached in the Appendix A.

5.4 Descriptive Statistics

The following figures and the table show some particularly interesting parts of the descriptive statistics of our data.

Firstly, the table depicting summary data for each dependent variable is attached below. We can see that access to electricity ranges from 0.01 per cent (Liberia, 2004) to 100 per cent, reflecting the differences and inequalities across the world. Looking at the maximum of indicator 7.2.1, our prediction about developed countries not reporting this issue although their reliance is 100 per cent shows to be probable. We can also see that there is no country in 2015 that would entirely rely on renewable energy. Even though the maximum of energy intensity (Uzbekistan, 2000) is quite high, the median shows a convergence to lower intensity in the course of time.

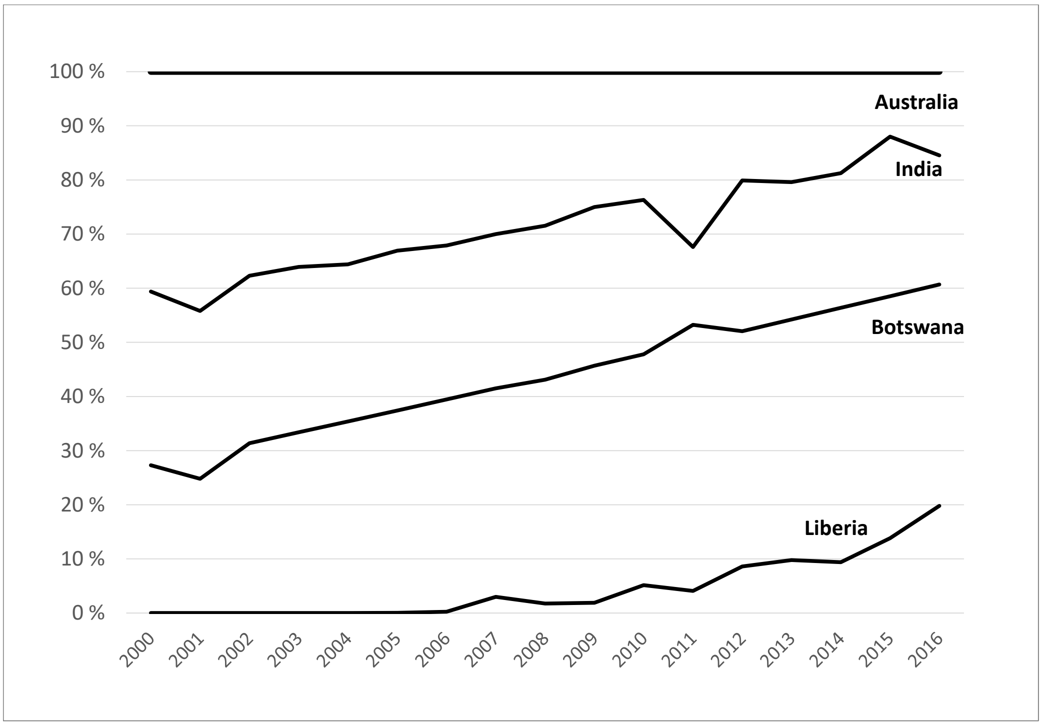
Table 5.5: Summary Statistics of each dependent variable

	acctoel	*clfuels1*	*renew2*	*int3*
Minimum	0.01	5	0.01	1.14
1st Quantile	53.9	30	7.11	3.78
Median	96.06	65	26.86	4.98
Mean	76.15	58.03	34.5	6.445
3rd Quantile	100	89.25	57.56	7.085
Maximum	100	95	98.34	34.51

Source: Author's elaboration; based on data from UN Statistics Division (2018a)

The next figure shows four countries chosen to represent different paths to achieve full access to electricity for everybody. Developed countries have usually already achieved the first target and should therefore focus on achieving the second and the third targets. Most of the countries grow at a steady pace from the middle of spectrum upwards. The country with the lowest access was Liberia with 0.01 per cent until 2004, when the proportion of population with access to electricity started to rise. Nowadays, Liberia has caught up with other poor countries and is moving upwards, too.

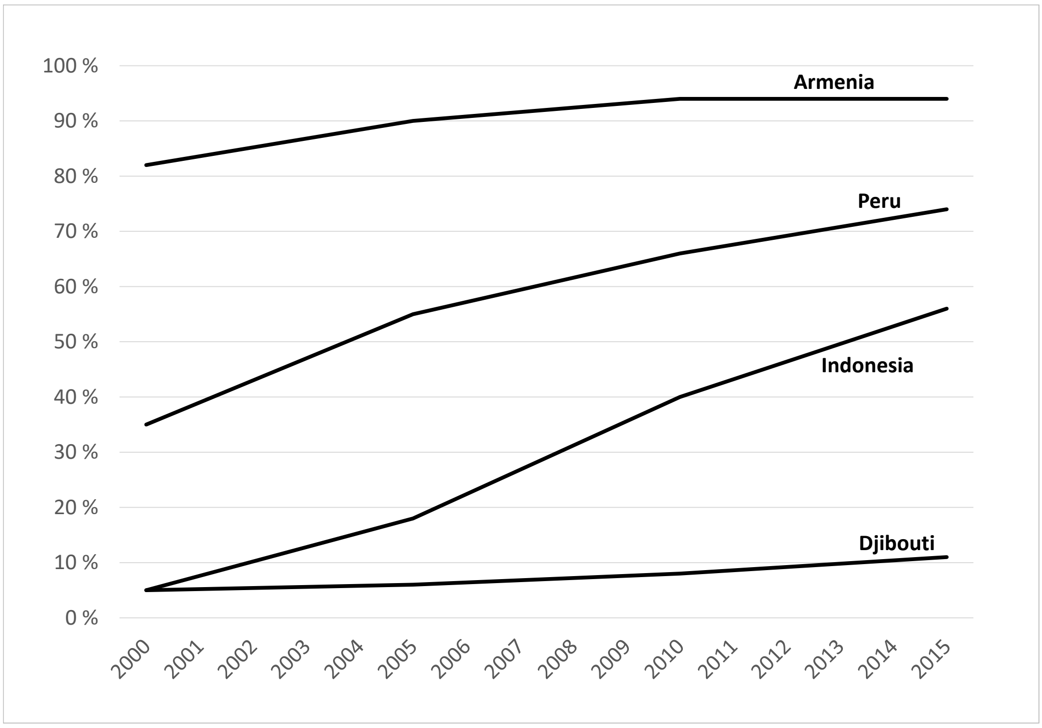
Figure 5.1: *Access to electricity*, comparison of selected countries



Source: Author's elaboration; based on data from (UN Statistics Division 2018a)

The following figure shows a few countries on their way to achieve the indicator 7.1.2: primary reliance on clean fuels and technology. Unlike the first indicator, not all countries aim to achieve full reliance, even though most of them are on the right track and are moving upwards.

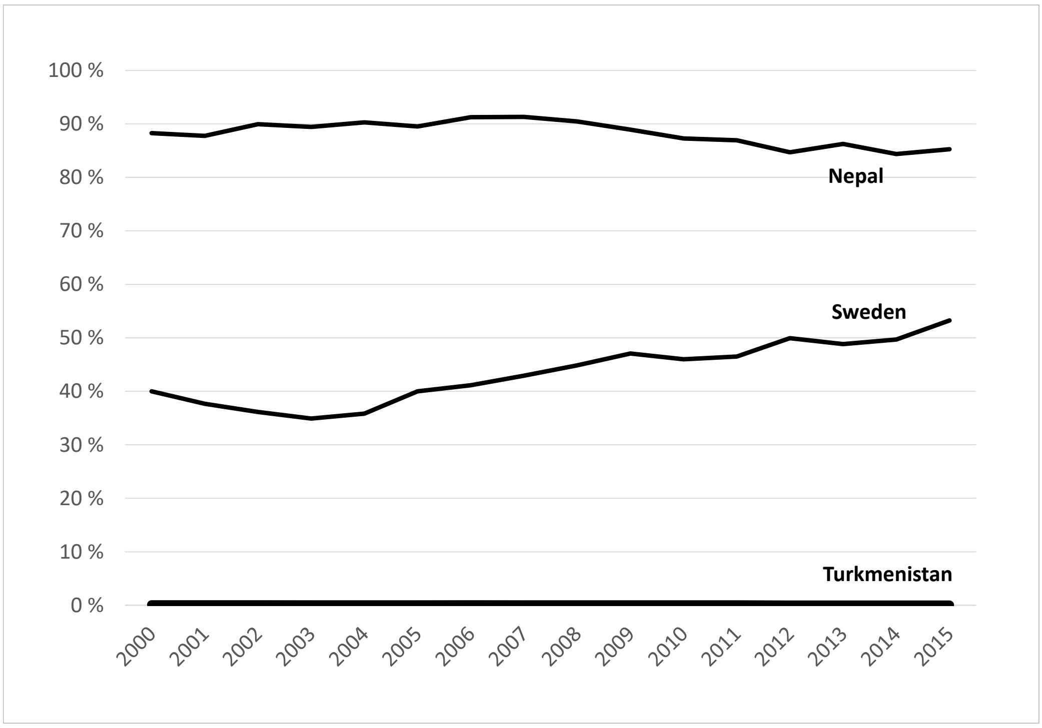
Figure 5.2: *Reliance on clean fuels*, comparison of selected countries



Source: Author's elaboration; based on data from (UN Statistics Division 2018a)

Progress regarding the second target about the share of renewable energy is very diverse. Some countries do not use renewable energy at all, usually the ones with large sources of oil, for example Turkmenistan or Saudi Arabia. There are also countries on the other side of the spectrum, with almost a 100 per cent share of renewable energy. One of them — Nepal is using mostly hydro, but also solar and wind energy. Most of the countries, however, find themselves in the middle, usually with less than half of the energy mix comprising renewable energy. The progress of these countries is rather slow, resulting in the fact, that the world overall is not on track to achieve this target.

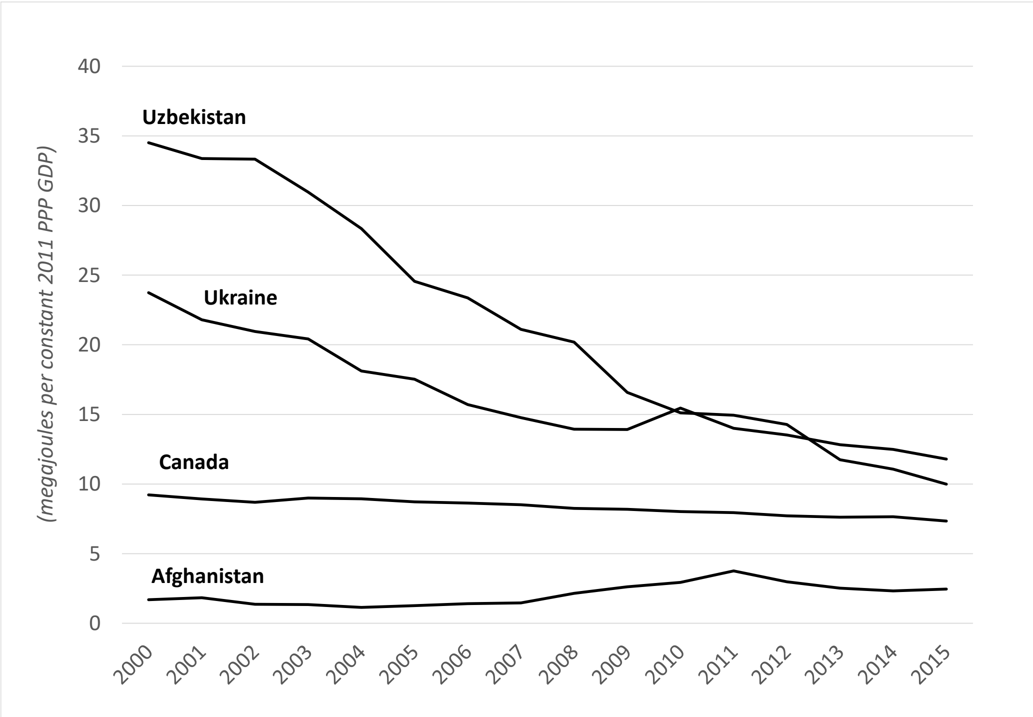
Figure 5.3: *Share of renewable energy*, comparison of selected countries



Source: Author's elaboration; based on data from UN Statistics Division (2018a)

The last figure depicts some of the countries on their way to lower their energy intensity. We can see that countries with high intensity managed to lower it quite rapidly at the beginning of our observed period. Nowadays, the lowering continues for majority of countries.

Figure 5.4: *Energy intensity*, comparison of selected countries



Source: Author's elaboration; based on data from UN Statistics Division (2018a)

Chapter 6

Interpretation of the Results

Presented below are the results of our four empirical models. Each dependant variable corresponds to one of the indicators of the seventh Sustainable Development Goal. Explanatory variables are factors that are believed to have an influence on dependant variables. They were chosen based on previously conducted research papers, the UN's opinions of what the explanation behind the indicators could be and also author's intuitive and subjective point of view. However, some of the variables mentioned by the UN or existing research papers could not be used in the analysis either because of too many missing observations or no suitable data.

We are going to present the results from the models using a balanced dataset and robust standard errors, since both heterogeneity and serial correlation have been detected in all the models. Results of the models for unbalanced data can be found in the Appendix B.

6.1 Indicator 7.1.1: Access to Electricity

The first model tries to uncover the reasons for various proportions of populations with access to electricity across different countries. The five explanatory variables included in the model are: *GDP per capita, primary school enrolment, HDI, urban population* and *share of renewable energy.*

A hypothesis for this model was set as: "Urban population and HDI play a major role in access to electricity."

The overall model used for the regression looks as follows:

$$acctoel_{i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 school_{i,t} + \beta_3 HDI_{i,t} + \beta_4 urban_{i,t} + \\ + \beta_5 renew_{i,t} + a_i + u_{i,t}$$

We regressed data for 173 countries for the years 2000 to 2016. Detailed overview of what countries were included can be found in the Appendix A. Results of the regression with robust standard errors in parentheses are presented in the table below.

Table 6.1: Regression results - *Access to electricity*, robust standard errors

	Dependent variable: acctoel			
	(Pooled OLS)	(FD)	(RE)	(FE)
GDP	-0.001^{***}	-0.0001^{***}	-0.0004^{***}	-0.0004^{***}
	(0.0001)	(0.00004)	(0.0001)	(0.0001)
school	-0.129^{*}	0.017	-0.023	-0.008
	(0.073)	(0.017)	(0.043)	(0.043)
HDI	1.896^{***}	0.144	1.419^{***}	1.228^{***}
	(0.131)	(0.090)	(0.136)	(0.165)
urban	0.122^{**}	0.579^{***}	0.407^{***}	0.467^{***}
	(0.059)	(0.164)	(0.103)	(0.169)
renew	-0.183^{***}	0.169^{***}	0.073	0.188^{*}
	(0.045)	(0.033)	(0.070)	(0.097)
constant	-28.866^{***}	0.450^{***}	-35.118^{***}	
	(8.228)	(0.084)	(9.791)	
Observations	2,941	2,768	2,941	2,941
Adjusted R^2	0.829	0.067	0.524	0.456
Note:				*p<0.1; **p<0.05; ***p<0.01

Firstly, heteroskedasticity and serial correlation, stationarity and cross-sectional dependence were all detected. Hausmann test regarding the selection of regression method favoured Fixed Effects Estimator.

As predicted, the *HDI* variable turned out to be statistically significant and to have the biggest positive impact out of all explanatory variables on *access to electricity* in our model. This was predicted based on the research papers previously reviewed. The estimate for *urban* is also statistically significant and has a positive sign. This is very easy to explain, since building a grid can be done easily and efficiently in cities and towns, while rural and sparse areas are the hardest to provide electricity to. Also the estimate for *GDP* turned out to be statistically significant in all the methods. Although, it is negative, the estimate is very close to zero. That shows that GDP has almost no or only a slightly negative effect on access to electricity. The *renew* estimate is not statistically significant in our favoured method and neither is the effect of *school*.

Overall, the results proved our hypothesis to be valid—HDI and urban population are the most important positive factors in access to electricity. GDP has unexpectedly a negative effect on access to electricity. However, magnitude of its estimate is very close to zero. Estimates for *enrolment into school* and *share of renewable energy* both turned out to be statistically insignificant. Out of all the models we ran the regression with, the Fixed Effect estimator showed to be consistent and most suitable to use.

6.2 Indicator 7.1.2: Clean Fuels and Technology

The dependant variable of the second model is the *proportion of population with primary reliance on clean fuels and technology.* As mentioned in the Chapter 5, some of the developed countries that have probably fully achieved the indicator do not report any numbers regarding the topic. This speculation turns out to be possible, since the maximum of the data for clean fuels is below 100 per cent. We should therefore take that into consideration when interpreting the results. The explanatory variables chosen for this model were: *pump price for gasoline, proportion of population with access to electricity, GDP per capita, HDI, school enrolment* and *urban population.*

The model regressed was:

$$clfuels_{i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 school_{i,t} + \beta_3 HDI_{i,t} + \beta_4 urban_{i,t} + \\ + \beta_5 acctoel_{i,t} + \beta_6 gasoline_{i,t} + a_i + u_{i,t}$$

We used data for 102 countries for the years 2000, 2005, 2010 and 2015.

The main hypothesis we wanted to test was: "Urban population has a major effect on primary reliance on clean fuels and technology." The results of the regressions can be found in the table below.

Table 6.2: Regression results - *Primary reliance on clean fuels*, robust standard errors

	Dependent variable: clfuels			
	(Pooled OLS)	(FD)	(RE)	(FE)
GDP1	-0.00001	-0.0003^{**}	0.00002	-0.00001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
school1	-0.161^{*}	-0.070^{**}	-0.194^{***}	-0.175^{***}
	(0.087)	(0.029)	(0.058)	(0.066)
HDI1	1.111^{***}	-0.035	1.027^{***}	0.809^{***}
	(0.274)	(0.214)	(0.207)	(0.246)
urban1	0.320^{**}	0.210	0.385^{***}	0.302
	(0.136)	(0.226)	(0.122)	(0.243)
acctoel1	0.403^{***}	0.043	0.228^{***}	0.148^{*}
	(0.092)	(0.053)	(0.075)	(0.085)
gasoline1	-6.339^{**}	0.492	-0.945	2.831^{*}
	(2.743)	(0.925)	(1.298)	(1.633)
constant	-39.382^{***}	4.526^{***}	-25.452^{***}	
	(12.302)	(0.879)	(8.079)	
Observations	408	306	408	408
Adjusted R^2	0.731	0.035	0.561	0.307
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Out of all the methods, the Fixed Effects proved to be the most suitable again. Heteroskedasticity, serial correlation and cross-sectional dependence were detected in the data. We were not able to reject the null hypothesis of the Augmented Dickey-Fuller test regarding stationarity.

The results of the regressions show that our main hypothesis was invalid. *HDI* and *school* showed to have major effects on *reliance on clean fuels*. Unexpectedly, the estimator for *school* has a negative sign. This is not in line with the UN emphasizing the importance of education and is probably caused by the fact that the majority of developed countries had to be omitted from this regression due to missing observations. In both Pooled OLS and RE methods, the estimates for *acctoel* and *urban* are statistically significant and positive. Other variables turned out to be statistically insignificant.

Considering the most suitable method—Fixed Effects, the estimate for *HDI* seems to have a major positive impact on primary reliance on clean fuels and technology. *Urban population* turned out to be statistically insignificant, contrary to the hypothesis. Estimator of the variable for *school* is negative, which is not supported by our previous research. In conclusion, the quality of this model is probably affected by omitting developed countries from our dataset. Improving the regression would require more detailed inspection and reparation of the data.

6.3 Indicator 7.2.1: Share of Renewable Energy

The next model is trying to find a relationship between the *share of renewable energy* and *GDP per capita, HDI, primary school enrolment, urban population.* The model

$$renew_{i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 school_{i,t} + \beta_3 HDI_{i,t} + \beta_4 urban_{i,t} + a_i + u_{i,t}$$

was regressed using data for 172 countries for the years from 2000 to 2015. The hypothesis we wanted to confirm was: "HDI and school enrolment have a positive influence on a share of renewable energy." Results of the regression are presented in the following table:

Table 6.3: Regression results - *Share of renewable energy*, robust standard errors

	Dependent variable: renew			
	(Pooled OLS)	(FD)	(RE)	(FE)
GDP2	0.0004**	0.00000	0.0003***	0.0003***
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
school2	0.244***	−0.033**	−0.033	−0.041
	(0.089)	(0.014)	(0.028)	(0.028)
HDI2	−1.629***	−0.249***	−0.490***	−0.434***
	(0.174)	(0.079)	(0.127)	(0.134)
urban2	−0.096	−0.559***	−0.406***	−0.395**
	(0.106)	(0.207)	(0.128)	(0.154)
constant	116.921***	0.113	87.759***	
	(9.837)	(0.085)	(6.810)	
Observations	2,752	2,580	2,752	2,752
Adjusted R^2	0.556	0.015	0.213	0.139
Note:		*p<0.1; **p<0.05; ***p<0.01		

Based on the results of the tests performed on our regression, heteroskedasticity, serial correlation and cross-sectional dependence are present. Again, we were not able to reject the null hypothesis of the Augmented Dickey-Fuller Test regarding stationarity.

The effect of *HDI* is the most significant. The coefficient is statistically significant and negative in all models. The estimator for *urban* is negative in all of them, as well. The explanation behind this could be that both *HDI* and *urban population* are linked to industrialization and exploiting natural resources in order to achieve the best results in production. From our data we can see that many poor countries (e.g. Nepal) have a high share of renewable energy. By contrast many developed and rich countries (e.g. Australia) have relatively low share of renewable energy in the final energy mix. Also, use and production of renewable energy depend rather on individual policy decisions and geographical location of country. Even though *GDP* also turned out to be statistically significant, it is very close to zero in magnitude. *School* turned out to be statistically insignificant in our model.

The results from the Fixed Effects estimator show, that HDI and urban population seem to have a major negative impact on the share of renewable energy. This is in contrary to our previously stated hypothesis. However, looking through the data, we suggested that exploitation of natural resource in order to achieve the fastest growth might be one of the reasons behind that. The estimator for *GDP* is statistically significant, but very close to zero, and the estimate for variable *school* is not even statistically significant.

6.4 Indicator 7.3.1: Energy Intensity

Next, we try to explain the *intensity level of primary energy* using *GDP per capita, primary school enrolment, HDI, urban population, renewable energy share in the total final energy consumption* and *pump price for gasoline.* Using data for 158 countries for the time period from 2000 to 2015 we estimated the following model:

$$int_{i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 school_{i,t} + \beta_3 HDI_{i,t} + \beta_4 urban_{i,t} + \\ + \beta_5 renew_{i,t} + +\beta_6 gasoline_{i,t} + a_i + u_{i,t}$$

The hypothesis we were going to test was: "GDP has a negative impact on energy intensity, while urban population has a positive impact." Results with robust standard errors in the parentheses are attached below:

Table 6.4: Regression results - *Energy Intensity*, robust standard errors

	Dependent variable: int			
	(Pooled OLS)	(FD)	(RE)	(FE)
GDP3	-0.00000	-0.0001^{***}	0.00001	0.00000
	(0.00002)	(0.00003)	(0.00002)	(0.00003)
school3	-0.032^{*}	-0.004	-0.009	-0.007
	(0.019)	(0.004)	(0.011)	(0.011)
HDI3	-0.011	0.0002	-0.204^{***}	-0.233^{***}
	(0.042)	(0.068)	(0.056)	(0.062)
urban3	-0.002	-0.015	0.042^{*}	0.047
	(0.019)	(0.037)	(0.024)	(0.038)
renew3	0.043^{**}	-0.011	-0.013	-0.016
	(0.020)	(0.011)	(0.020)	(0.023)
gasoline3	-1.889^{***}	0.023	-0.431^{*}	-0.249
	(0.551)	(0.063)	(0.228)	(0.276)
constant	10.986^{***}	-0.072^{**}	19.525^{***}	
	(3.145)	(0.033)	(4.083)	
Observations	2,528	2,370	2,528	2,528
Adjusted R^2	0.153	0.022	0.196	0.154
Note:		$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

Yet again, the tests showed presence of heteroskedasticity, serial correlation and cross-sectional dependence. We were not able to reject the null hypothesis of the Augmented Dickey-Fuller Test regarding stationarity.

Results of Hausmann test favoured the Fixed Effects method. However, the p-value is very close to 0.01, therefore we could use Random Effects estimator for a supplementary interpretation. The only estimate that resulted to be statistically significant is of the variable *HDI*. Bearing in mind that lowering energy intensity is desirable, a minus sign shows a negative effect of HDI. Both variables from the hypothesis *GDP* and *urban population* are statistically insignificant in our models. Also *school, renew* and *gasoline* seem to have no effect on lowering energy intensity. In summary, our hypothesis turned out to be invalid with neither GDP, nor urban to be statistically significant in our models. However, HDI has a negative effect on energy intensity, showing that higher HDI contributes to a desirable lowering of energy intensity. Yet again, in this model FE is the most favourable estimator to use for interpreting the results.

Looking at the models we presented, four explanatory variables were present in all of them: *school, HDI, GDI* and *urban.* They were also main components of our hypotheses. Looking at the results, we can say that most energy issues are strongly and positively related with the Human Development Index and also urban population. On the contrary, relation between energy benefits and school enrolment or GDP could not be proven, since majority of the estimates in our models were statistically significant or very close to zero.

Chapter 7

Conclusion

This thesis analyses the seventh Sustainable Development Goal and aims to uncover the socio-economic characteristics that have major impacts on promoting energy in countries all over the world. Using panel data analysis, we built four empirical models, each having one indicator as a dependent variable. We used Pooled OLS, First Difference, Random Effects and Fixed Effects Estimators for the analysis. In all of our models, after conducting necessary tests, FE estimator was selected as the most favourable. Heteroskedasticity and serial correlation were present in our models, for which we controlled using robust standard errors.

The first model was aspiring to explain access to electricity with GDP, school enrolment, HDI, urban population and share of renewable energy. Our hypothesis set as "Urban population and HDI play a major role in access to electricity", turned out to be valid. The estimates for variables *HDI, urban population* and *GDP* turned out to be statistically significant. However, the estimate for *GDP* was very close to zero, so we can ignore its effect and state HDI and urban population to have major positive impact on access to electricity.

The next model focused on primary reliance on clean fuels; it was regressed on GDP, HDI, school enrolment, urban population, pump price of gasoline and access to electricity. In this case, hypothesis "Urban population has a major effect on primary reliance on clean fuels and technology" turned out to be invalid. Only *school* and *HDI* were statistically significant. In contrary to our expectation, both estimates were negative, showing negative impact of school and HDI on reliance on clean fuels. This probably indicates that we worked with an incomplete and damaged dataset. We had to omit many developed countries, because of missing observations. It seems as if these countries rather do not report these numbers, even though they probably have full reliance on clean fuels and technology. For more reliable results, deeper analysis of data would be necessary, which is unfortunately beyond the scope of this thesis.

In the third model we regressed the share of renewable energy on GDP, HDI, school enrolment and urban population. Hypothesis "HDI and school enrolment have a positive influence on a share of renewable energy" turned out to be invalid. We were not able to show an influence of school enrolment, since its estimate was not statistically significant. The estimates for variable *HDI*, together with *GDP* and *urban population* showed to be statistically significant and have negative impact. We explained this by the fact, that the use of renewable energy is dependent on each country's market design, geographic location but also political decisions. Additionally, growth of GDP and urban population can be connected to higher demand for energy and thus using every source of energy possible, despite its unsustainability. Yet again, the estimate for *GDP* was very close to zero, leaving HDI and urban estimates as main negative causes of share of renewable energy.

In the last model, we focused on energy intensity. The explanatory variables we chose to analyse were: *GDP, HDI, urban population, school enrolment, share of renewable energy* and *pump price of gasoline*. The hypothesis "GDP has a negative impact on energy intensity, while urban population has a positive impact", turned out to be completely invalid. The only estimate that was statistically significant (and positive) was *HDI*. The impact of GDP and urban population could not be shown. Both estimates were statistically insignificant.

We can see that four explanatory variables were present in all of our models: *GDP, HDI, urban population* and *school enrolment*. From all the results we can gather that majority of energy issues rely strongly on the Human Development Index and also on proportion of urban population. However, they are not very strongly connected with GDP or school enrolment.

In case of extending our research, we would recommend focusing on more detailed work with the data, especially for indicator 7.1.2, where we found a discrepancy. Our empirical models could also be examined more precisely, adding more variables to find the best ones. The results can be used by policymakers and diplomats, in order to correctly and efficiently decide on what aspect of energy implementation to focus the most.

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Appendix A

List of countries in each model

Table A.1: Countries included in each model

Country	*UnB*	*7.1.1*	*7.1.2*	*7.2.1*	*7.3.1*
Afghanistan	✓	✓	✓	✓	✓
Albania	✓	✓	✓	✓	✓
Algeria	✓	✓	✓	✓	✓
Andorra	✓				
Angola	✓	✓	✓	✓	✓
Antigua and Barbuda	✓	✓		✓	✓
Argentina	✓	✓	✓	✓	✓
Armenia	✓	✓	✓	✓	✓
Australia	✓	✓		✓	✓
Austria	✓	✓		✓	✓
Azerbaijan	✓	✓	✓	✓	✓
Bahamas, The	✓	✓		✓	✓
Bahrain	✓				
Bangladesh	✓	✓	✓	✓	✓
Barbados	✓	✓		✓	✓
Belarus	✓	✓	✓	✓	✓
Belgium	✓	✓		✓	✓
Belize	✓	✓	✓	✓	✓
Benin	✓	✓	✓	✓	✓
Bhutan	✓	✓	✓	✓	✓
Bolivia	✓	✓	✓	✓	✓
Bosnia and Herzegovina	✓				

Botswana	✓	✓	✓	✓	✓
Brazil	✓	✓	✓	✓	✓
Brunei Darussalam	✓	✓		✓	✓
Bulgaria	✓	✓	✓	✓	✓
Burkina Faso	✓	✓	✓	✓	✓
Burundi	✓	✓		✓	✓
Cabo Verde	✓	✓	✓	✓	✓
Cambodia	✓	✓	✓	✓	✓
Cameroon	✓	✓	✓	✓	✓
Canada	✓	✓		✓	✓
Central African Republic	✓	✓		✓	✓
Chad	✓	✓		✓	✓
Chile	✓	✓	✓	✓	✓
China	✓	✓	✓	✓	✓
Colombia	✓	✓	✓	✓	✓
Comoros	✓	✓		✓	
Congo	✓	✓	✓	✓	✓
Congo, DR	✓	✓		✓	✓
Costa Rica	✓	✓	✓	✓	✓
Cote d'Ivoire	✓	✓	✓	✓	✓
Croatia	✓	✓	✓	✓	✓
Cuba	✓				
Cyprus	✓	✓		✓	✓
Czech Republic	✓	✓	✓	✓	✓
Denmark	✓	✓		✓	✓
Djibouti	✓	✓	✓	✓	✓
Dominica	✓	✓		✓	
Dominican Republic	✓	✓	✓	✓	✓
Ecuador	✓	✓	✓	✓	✓
Egypt	✓	✓	✓	✓	✓
El Salvador	✓	✓	✓	✓	✓
Equatorial Guinea	✓	✓		✓	
Eritrea	✓	✓	✓	✓	✓
Estonia	✓	✓	✓	✓	✓
Eswatini	✓	✓	✓	✓	✓
Ethiopia	✓	✓		✓	✓
Fiji	✓	✓	✓	✓	✓

Finland	✓	✓		✓	✓
France	✓	✓		✓	✓
Gabon	✓	✓	✓	✓	✓
Gambia, The	✓	✓		✓	✓
Georgia	✓	✓	✓	✓	✓
Germany	✓	✓		✓	✓
Ghana	✓	✓	✓	✓	✓
Greece	✓	✓	✓	✓	✓
Grenada	✓	✓	✓	✓	✓
Guatemala	✓	✓	✓	✓	✓
Guinea	✓	✓		✓	✓
Guinea—Bissau	✓	✓		✓	
Guyana	✓	✓	✓	✓	✓
Haiti	✓				
Honduras	✓	✓	✓	✓	✓
Hungary	✓	✓		✓	✓
Iceland	✓	✓		✓	✓
India	✓	✓	✓	✓	✓
Indonesia	✓	✓	✓	✓	✓
Iran, Islamic Rep.	✓	✓	✓	✓	✓
Iraq	✓	✓	✓	✓	✓
Ireland	✓	✓		✓	✓
Israel	✓	✓		✓	✓
Italy	✓	✓		✓	✓
Jamaica	✓	✓	✓	✓	✓
Japan	✓	✓		✓	✓
Jordan	✓	✓		✓	✓
Kazakhstan	✓	✓	✓	✓	✓
Kenya	✓	✓	✓	✓	✓
Kiribati	✓	✓		✓	
Korea, Dem. People's Rep.	✓				
Korea, Rep.	✓	✓		✓	✓
Kuwait	✓	✓			
Kyrgyz Republic	✓	✓	✓	✓	✓
Lao PDR	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	✓	✓
Lebanon	✓	✓		✓	✓

Lesotho	✓	✓	✓	✓	✓
Liberia	✓	✓		✓	✓
Libya	✓	✓		✓	✓
Liechtenstein	✓				
Lithuania	✓	✓		✓	✓
Luxembourg	✓	✓		✓	✓
Macedonia, FYR					
Madagascar	✓	✓		✓	✓
Malawi	✓	✓		✓	✓
Malaysia	✓	✓	✓	✓	✓
Maldives	✓	✓	✓	✓	✓
Mali	✓	✓		✓	✓
Malta	✓	✓		✓	✓
Marshall Islands	✓	✓	✓		
Mauritania	✓	✓	✓	✓	✓
Mauritius	✓	✓	✓	✓	✓
Mexico	✓	✓	✓	✓	✓
Micronesia, Fed. Sts.	✓	✓		✓	
Moldova	✓	✓	✓	✓	✓
Monaco	✓				
Mongolia	✓	✓	✓	✓	✓
Montenegro	✓	✓	✓	✓	✓
Morocco	✓	✓	✓	✓	✓
Mozambique	✓	✓		✓	✓
Myanmar	✓	✓	✓	✓	✓
Namibia	✓	✓	✓	✓	✓
Nauru	✓				
Nepal	✓	✓	✓	✓	✓
Netherlands	✓	✓		✓	✓
New Zealand	✓	✓		✓	✓
Nicaragua	✓	✓	✓	✓	✓
Niger	✓	✓		✓	✓
Nigeria	✓	✓		✓	✓
Norway	✓	✓		✓	✓
Oman	✓		✓		
Pakistan	✓	✓	✓	✓	✓
Palau	✓				

Panama	✓	✓	✓	✓	✓
Papua New Guinea	✓	✓	✓	✓	✓
Paraguay	✓	✓	✓	✓	✓
Peru	✓	✓	✓	✓	✓
Philippines	✓	✓	✓	✓	✓
Poland	✓	✓		✓	✓
Portugal	✓	✓		✓	✓
Qatar	✓		✓		
Romania	✓	✓	✓	✓	✓
Russian Federation	✓	✓	✓	✓	✓
Rwanda	✓	✓		✓	✓
Samoa	✓	✓	✓	✓	✓
San Marino	✓				
Sao Tome and Principe	✓	✓		✓	
Saudi Arabia	✓	✓	✓	✓	✓
Senegal	✓	✓	✓	✓	✓
Serbia	✓	✓	✓	✓	✓
Seychelles	✓	✓		✓	
Sierra Leone	✓	✓		✓	✓
Singapore	✓	✓			
Slovak Republic	✓	✓	✓	✓	✓
Slovenia	✓	✓	✓	✓	✓
Solomon Islands	✓	✓		✓	
Somalia	✓				
South Africa	✓	✓	✓	✓	✓
South Sudan					
Spain	✓	✓		✓	✓
Sri Lanka	✓	✓	✓	✓	✓
St. Kitts and Nevis	✓				✓
St. Lucia	✓	✓	✓	✓	✓
St. Vincent and the Grenadines	✓	✓		✓	
Sudan	✓	✓	✓	✓	✓
Suriname	✓	✓	✓	✓	✓
Sweden	✓	✓		✓	✓
Switzerland	✓	✓		✓	✓
Syrian Arab Republic	✓				
Tajikistan	✓	✓	✓	✓	✓

Tanzania	✓	✓		✓	✓
Thailand	✓	✓	✓	✓	✓
Timor—Leste	✓	✓	✓	✓	
Togo	✓	✓	✓	✓	✓
Tonga	✓	✓		✓	
Trinidad and Tobago	✓	✓		✓	✓
Tunisia	✓	✓	✓	✓	✓
Turkey	✓	✓		✓	✓
Turkmenistan	✓	✓		✓	✓
Tuvalu	✓				
Uganda	✓	✓		✓	✓
Ukraine	✓	✓	✓	✓	✓
United Arab Emirates	✓	✓		✓	✓
United Kingdom	✓	✓		✓	✓
United States	✓	✓		✓	✓
Uruguay	✓	✓		✓	✓
Uzbekistan	✓	✓	✓	✓	✓
Vanuatu	✓	✓		✓	
Venezuela, RB	✓	✓		✓	✓
Vietnam	✓	✓	✓	✓	✓
Yemen, Rep.	✓	✓	✓	✓	✓
Zambia	✓	✓	✓	✓	✓
Zimbabwe	✓		✓	✓	✓

Appendix B

Results of unbalanced dataset with robust standard errors

Table B.1: Regression results - *Access to electricity*, unbalanced data, robust standard errors

	Dependent variable: acctoel			
	(Pooled OLS)	(FD)	(RE)	(FE)
uGDP	-0.001^{***}	-0.0002^{***}	-0.0004^{***}	-0.0003^{***}
	(0.0001)	(0.00004)	(0.0001)	(0.0001)
uschool	-0.150^{**}	0.012	-0.045	-0.031
	(0.075)	(0.019)	(0.034)	(0.034)
uHDI	1.844^{***}	0.340^{***}	1.265^{***}	1.154^{***}
	(0.150)	(0.110)	(0.159)	(0.186)
uurban	0.062	0.717^{***}	0.265^{***}	0.390^{**}
	(0.062)	(0.204)	(0.094)	(0.167)
urenew	-0.253^{***}	-0.045	-0.264^{***}	-0.238^{***}
	(0.048)	(0.031)	(0.068)	(0.091)
Constant	-16.639^{*}	0.372^{***}	-4.506	
	(9.629)	(0.086)	(9.917)	

Note: *p<0.1; **p<0.05; ***p<0.01

Table B.2: Regression results - *Primary reliance on clean fuels*, unbalanced data, robust standard errors

	Dependent variable: clfuels			
	(Pooled OLS)	(FD)	(RE)	(FE)
uGDP1	0.001	-0.0005^{***}	0.0001	-0.0002
	(0.0005)	(0.0002)	(0.0003)	(0.0004)
uschool1	-0.246^{**}	-0.168^{***}	-0.242^{***}	-0.292^{***}
	(0.104)	(0.040)	(0.077)	(0.091)
uHDI1	0.606	0.858^{***}	1.169^{***}	1.859^{***}
	(0.433)	(0.189)	(0.397)	(0.596)
uurban1	0.497^{***}	-0.077	0.555^{***}	0.221
	(0.123)	(0.262)	(0.137)	(0.355)
ugasoline1	-6.081^{**}	5.508^{***}	0.548	3.116^{**}
	(2.713)	(1.229)	(1.522)	(1.537)
uacctoel1	0.394^{***}	-0.040	0.193^{*}	-0.010
	(0.123)	(0.065)	(0.100)	(0.132)
Constant	-12.288	6.457^{***}	-38.079^{***}	
	(15.627)	(1.284)	(12.647)	
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table B.3: Regression results - *Share of renewable energy*, unbalanced data, robust standard errors

	Dependent variable: renew			
	(Pooled OLS)	(FD)	(RE)	(FE)
uGDP2	0.001^{***}	-0.00001	0.0004^{***}	0.0004^{***}
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
uschool2	0.220^{***}	-0.019	-0.003	-0.015
	(0.077)	(0.015)	(0.028)	(0.028)
uHDI2	-1.645^{***}	-0.301^{***}	-0.487^{***}	-0.395^{**}
	(0.181)	(0.095)	(0.148)	(0.161)
uurban2	-0.165	-0.560^{***}	-0.496^{***}	-0.511^{***}
	(0.104)	(0.188)	(0.142)	(0.182)
Constant	122.577^{***}	0.174^{*}	88.420^{***}	
	(8.981)	(0.093)	(6.887)	
Note:		*p<0.1; **p<0.05; ***p<0.01		

Table B.4: Regression results - *Energy intensity*, unbalanced data, robust standard errors

	Dependent variable: int			
	(Pooled OLS)	(FD)	(RE)	(FE)
uGDP3	0.00000	−0.00002	0.00003	0.00003
	(0.00002)	(0.00002)	(0.00002)	(0.00003)
uHDI3	−0.020	-0.103^{**}	-0.224^{***}	-0.312^{***}
	(0.044)	(0.048)	(0.064)	(0.083)
uschool3	−0.028	−0.005	−0.003	0.006
	(0.021)	(0.006)	(0.015)	(0.015)
uurban3	0.0001	0.019	0.056^{***}	0.098^{**}
	(0.022)	(0.037)	(0.021)	(0.039)
urenew3	0.034	−0.002	−0.015	−0.021
	(0.025)	(0.012)	(0.022)	(0.025)
ugasoline3	-1.427^{***}	0.052	-0.562^{**}	−0.160
	(0.410)	(0.097)	(0.246)	(0.329)
Constant	10.801^{***}	-0.144^{**}	19.406^{***}	
	(3.759)	(0.068)	(4.581)	
Note:				*p<0.1; **p<0.05; ***p<0.01