EMISSION REDUCTION VS EXPLOITATION OF DOMESTIC FOSSIL SOURCES: IS CLIMATE CHANGE MITIGATION COMPATIBLE WITH USING DOMESTIC COAL

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ABSTRACT

EMISSION REDUCTION VS EXPLOITATION OF DOMESTIC FOSSIL SOURCES: IS CLIMATE CHANGE MITIGATION COMPATIBLE WITH USING DOMESTIC COAL

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Energy policy of a country today deals with provision of secure, cheap and clean energy. Among the three, secure and cheap energy has general dominance over clean energy. Countries shape their energy policies accordingly and Turkey is no different example. Strategy Plan 2015 – 2019 of Ministry of Energy and Natural Resources emphasizes exploitation of domestic coal for energy security while Turkey intends to curb her emissions by 21% until 2030. These two targets contradict in terms of climate change mitigation. Therefore, Turkey has to establish a consistent policy that secures energy but, at least, does not exacerbate greenhouse gas emissions. This study aims to seek the role of coal, wind and solar power in such an energy policy making through panel econometrics and scenario analyses. Panel data estimates reveal that coal does not contribute to global energy security. Scenario analyses show that Turkey's use of domestic coal is vital but at the expense of climate change mitigation. On the other hand, both wind and solar contribute to country's efforts in energy security and climate change mitigation.

Keywords: Energy Security, Climate Change Mitigation, Electricity, Panel Data, Turkey

ÖZ

EMİSYON AZALTIMI VEYA YEREL FOSİL KULLANIMI: İKLİM DEĞİŞİKLİĞİ İLE MÜCADELEDE YEREL KÖMÜR KULLANIMI ANLAMLI MI

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Günümüzde bir ülkenin enerji politikası güvenli, ucuz ve temiz enerji sağlamayı hedefler. Bu üç unsurdan, güvenli ve ucuz enerjiye, temiz enerjiye göre genellikle öncelik verilir. Ülkeler enerji politikalarını bu yönde şekillendirir ve Türkiye farklı değildir. Enerji ve Tabii Kaynaklar Bakanlığı'nın 2015 – 2019 Strateji Plan'ı enerji güvenliği açısından kömür kullanımına vurgu yapmaktadır. Bunun yanında Türkiye 2030 yılına kadar karbon emisyonlarını %21 azaltma niyetini belirtmiştir. Bu iki hedef özellikle iklim değişikliği ile mücadele açısından karşıtlık göstermektedir. Bu sebeple Türkiye enerji güvenliğini sağlarken en azından sera gazı salınımını çok fazla arttırmayacak bir enerji politikası geliştirmek zorundadır. Bu çalışma böyle bir enerji politikası yapımında kömür, rüzgar ve güneş enerjilerinin rollerini araştırmaktadır. Çalışmada panel ekonometrisi ve senaryo analizleri kullanılmıştır. Panel veri kestirimleri kömürün küresel enerji güvenliğine katkısı olmadığını ortaya koymuştur. Senaryo analizleri Türkiye için yerel kömürün kullanımının önemli olduğu göstermektedir ancak bu iklim değişikliği ile mücadele konusunu sekteye uğratmaktadır. Diğer taraftan, rüzgar ve güneş enerjileri Türkiye'nin enerji güvenliğinin sağlanması ve iklim değişikliği ile mücadele çabalarına olumlu katkı yapmaktadır.

Anahtar Kelimeler: Enerji Güvenliği, İklim Değişikliği ile Mücadele, Elektrik, Panel Veri, Türkiye

In memory of Mr. Zahit TOROSLU

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AR5	Fifth Assessment Report of IPCC
BAU	Business-as-Usual
CCPP	Combined Cycle Power Plant
CCS	Carbon Capture and Sequestration
CTP	Coal Thermal Power
EU	European Union
ETKB	Turkish Ministry of Energy and Natural Resources
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTP	Gas Thermal Power
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel for Climate Change
IRENA	International Renewable Energy Agency
KT	Kilo tons
KTOE	Kilo tons oil equivalent
LM	Lagrange Multiplier
MT	Million tons
MTOE	Million tons oil equivalent
LNG	Liquified Natural Gas
NP	Nuclear Power
NPP	Nuclear Power Plant
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries
PE	Panel Equation
PV	Photovoltaic
RES	Renewable Energy Sources
SP	Solar Power
TEİAŞ	Turkish Electricity Transmission Corporation
TPES	Total Primary Energy Supply
TUIK	Turkish Statistical Institute
TWh	Tera watt hours

US	United States
WDI	World Development Indicators database of the World Bank Group
WP	Wind Power

CHAPTER 1

INTRODUCTION

Contemporary energy policies are to consider all energy sources and a wide variety of risks ranging from natural to political. In that sense, energy policies need scrupulous and wide analysis of energy security (Jewell, 2011). (The World Bank Group, 2005) identifies different energy security policies or targets for different groups of countries. Energy importing countries aim to ensure energy supply, diversify energy sources, secure energy infrastructure, and reduce import dependency. Additional concerns for developing countries are meeting constantly growing demand and meeting people's basic needs. Concerns of exporting countries are sustaining long-term markets with affordable prices and ensuring energy demand, diversification of markets, and investing in resource and infrastructure development. Based on these, there are two key issues for global energy security: meeting growing global demand in the long-run and managing volatile energy, specifically oil, prices. Global rising demand is mainly a problem because of rapid development of countries like China and India since this requires continuous investment on resources and infrastructure and puts more stress on sources and competition among nations, both importing and exporting. Price volatility is considered because it is a threat for economic growth and will have varying impacts on citizens and countries based on their income level. In other words, high dependence on energy systems require understanding the risks and prerequisites for energy security, and it is different than only energy supply since it needs consideration of the integrity of the whole chain from field to final consumer (Yergin, 2012).

Evolution of the term 'energy security' is the result of the changing global energy system after the World War II that is shaped by growing dependence on oil. Members of Organization for Economic Cooperation and Development (OECD) had become heavily reliant on Middle East fossil supply. During 1970s dangers of high oil dependence were experienced when the Organization of Petroleum Exporting Countries (OPEC) restricted production against pro-Israel stance of the western world. As a result of and reaction to this shortfall, International Energy Agency (IEA) was established. Since then energy independence has been used synonymously with energy security (Chester, 2010). Thus, energy security is briefly defined as uninterrupted provision of energy in adequate amount, good quality and affordable prices to sustain energy generation, consumption and transmission with an environment-friendly manner (Ediger, 2010).

Price volatility of energy sources, supply disruptions of gas and oil, and electricity blackouts due to natural disasters appeal public interest to the issue (Chester, 2010) because energy security is important to global economy as energy plays a crucial role in economic life and in progress of modern societies. Energy enables individuals to exceed their physical limitations and achieve things that would not be possible otherwise. Uneven distribution of fossil fuels makes energy a “strategic commodity”. Therefore, assuring energy security is one of the prime goals of public policy since, like environment, it is a public good, which brings invaluable benefits for both private persons and societies (Andrews, 2005; Bielecki, 2002). Energy security is important for nations against high and volatile energy prices due to supply uncertainties and rising demand. A country, on national circumstances, is said to have energy security if there are measures to prevent affordable fuel and energy resources shortages (United Nations Economic and Social Commission for Asia and the Pacific, 2007). Any country decides its energy mix to achieve a balance between domestic and foreign sources considering energy security of its own. It is also “cost-effective risk management strategy of governments”. In other words, rather than being a policy, energy security is a strategy which shapes government policies to achieve goals (Chester, 2010).

The concept is discussed under a variety of approaches. A subset of energy security, supply security is defined as “a system’s ability to provide flow of energy to meet demand in an economy in a manner and price that does not disrupt the course of the economy” (Grubb, Butler, & Twomey, 2006). It is related with micro- and macro-economic policies because supply security has direct impact on costs, inflation rate and competitiveness of a country in the international arena (Erdal, 2015). The concept has gained interest with California energy crisis in 2000 and 2001. Growing dependence on oil and natural gas from countries with less stable socio-political conditions draws attention to the issue. Also, technical problems, political restrictions and dramatic rises in demand may pose threat on supply security (Joode, Kingma, Lijesen, Mulder, & Shestalova, 2004). In other words, it is concerned about risks of system interruption. One important risk due to insufficient capacity is meeting peak demand. Other risks may be weather conditions, lack of maintenance and investment in transmission systems, and problems in fuel supply (Lieb-Dóczy, Börner, & MacKerron, 2003).

Technology, energy security and sustainability are shaping electricity generation. It was first in 2019 that global electricity generated from nuclear power and renewables was more than that of from coal. Renewables are expected to overtake coal power plants in 2025. Solar PV alone is estimated to supply 30% of global electricity by 2030 (International Energy Agency, 2020).

All forms of energy use create environmental problems. In today’s world, the most challenging problem is climate change. Climate change is a long-term alteration in the average weather events in local, regional and global climates. Changes observed since the beginning of the 20th century are specifically result of fossil fuel consumption by human (NASA, 2020) and are estimated to cause almost 1℃ of global warming compared to pre-industrial averages. If the current rate of warming continues, the expectation is 1.5℃ of increase between 2030 and 2052. Projected impacts vary according to regions but include heavy precipitations, extreme droughts, sea level rise due to melting of glaciers, loss of habitats and biodiversity (IPCC, 2018) and resulting economic, social and political impacts on human welfare. In other words, being a vital component of the Earth System, changing climates not only compel physically but also beget upheavals in anthroposphere, spreading to every component of it including energy systems and security.

Climate change and energy security are interdependent and multifaceted. Any action or measure to reduce emissions in one or another way will have impact on fuel mix and technology, and thus influence energy supply and security. On the other hand, measures aiming at energy security will again influence domestic energy mix and technology, altering emissions and contribution to climate change. For instance, increasing share of renewables to lower emissions is expected to increase energy security via use of domestic sources or increasing share of domestic fossil fuels to secure energy will have an amplifying impact on climate change (The World Bank Group, 2005).

At the crossroads of Balkans, Caucasus, Middle East and eastern Mediterranean, Turkey with her unique geographic position is both a bridge and a barrier between Asia and Europe (Dewdney & Yapp, 2020). Having a population of over 81 million with less than $10,000 per capita GDP, Turkey is an upper-middle class country with specific economic vulnerabilities. Slowing down of reforms, rising inflation and unemployment, and narrowing investments are the internal factors amplified with deteriorating relationships with key partners, never-ending geopolitical conflicts, and threats to global trade and growth (The World Bank Group, 2019). Global environmental uncertainties in connection with climate change and Turkey’s highly import dependent energy system exacerbate these risks for wealth of the country.

1973 oil crisis diverted attention to importance of domestic reserves. Turkey accepted this stance and coal had been important for the country because it is used in electricity generation, steel and cement industries. However, in 1990s, Turkey gave up reliance on domestic reserves and started importing energy sources. In the following years share of imported natural gas increased and the country has become energy dependent, which bears risks in terms of energy security (Yilmaz & Uslu, 2007).

Inefficient consumption, below global average per capita electricity consumption, high demand increase, and foreign dependency with limited suppliers define Turkey’s energy profile (Çimen, 2010). Challenges that Turkey is facing to secure energy are large share of imported fuel in the economy, risks related with suppliers, high energy consumption and need for investments in energy sector. Country’s fossil reserves are able to meet only a small amount. Turkey imports 92% of oil and 99% of natural gas needs of hers, which makes the country to depend on foreign sources and suppliers. Russia and Iran are the two biggest suppliers for Turkey and this heavy dependence on such politically, socially and economically unstable countries creates vulnerabilities for her. Additionally, with the ongoing nuclear power plant (NPP) construction by Russia, Turkey is facing an energy supply security issue (M. Balat, 2010; Özalp, 2019). Despite this high fossil dependence, Turkey intents to reduce her greenhouse gas (GHG) emissions by 21% between 2021 and 2030 in her Intended Nationally Determined Contribution (INDC), after COP 21 held in Paris[1]. Thus, Turkey challenges herself in order not to lag behind in global climate diplomacy.

As a response to the aforementioned import dependence and global climate talks, Turkey released her Supply Security Strategy in 2009. Actually, the document entered into force to overcome supply risks that might arise with liberalization of electricity sector in the country although liberalization itself aimed securing supply. In other words, the strategy document aims safeguarding liberalization of electricity sector so that investments for capacity increase, transmission and distribution development are promoted, and efficiency is increased. In the strategy climate change and other environmental issues are addressed; minimization of losses, use of new technologies and resource diversification are emphasized. It further aims grid connection of wind power plants, interconnections with neighboring countries and EU grid. Domestic sources are stressed. Especially coal is prioritized, committing to

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[1] Turkey’s INDC: https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf, access: 10.03.2020.

exploit all known reserves until 2023. Besides, renewables are emphasized with a target to reach minimum 30% share with 20 GW wind in 2023. Finally, the strategy intents lowering dependence on natural gas in electricity generation below 30% (ETKB, 2009). Similarly, Strategy Plan 2015 – 2019 of Ministry of Energy and Natural Resources focuses on energy supply security and accepts production and import, enhancing storage and distribution infrastructure, and demand management as fundamental elements of the concept. Strategy Plan emphasizes role of domestic sources in supply security and commits to increase contribution of domestic coal to electricity generation to 60 TWh until 2020. Along with coal, utilization of wind and solar power is also indicated (ETKB, 2017). Turkey has adopted an energy policy converging to pre-1990 period but with a prime difference that environmental stresses are in the agenda.

Under the light of the above discussion, the main objective of this dissertation is to assess whether domestic coal utilization is a viable solution for energy security of Turkey under climate change discussions. The fundamental motivation towards this pursuit is the sole will to contribute to wealth of the nation through investigating public benefit maximizing means of sustainable resource use. The significance of the study is that it may be the first study combining energy security and climate change mitigation by econometric techniques to assist long-term decision making rather than prioritizing short-term necessities. In order to overcome the ambiguity of security as a concept discussed by (Baldwin, 1997), the focus of this dissertation is electricity supply security to the national grid.

This dissertation employs panel data econometrics in its quest for answers to the questions it poses, which is quite a new approach in energy security literature. Econometrics is essential because it has potential to provide unrecognized insights that are result of more refined and scrutinized techniques compared with mainstream statistics. Cross-country panel data analyses are conducted to estimate parameters relating carbon dioxide emissions and energy imports as an indicator of energy security with selected explanatory variables discussed in Chapter 5. These estimated parameters are used in scenario runs to evaluate contribution of domestic coal, solar, and wind for Turkey’s energy profile in the coming decades. This two-step methodology is the novelty for energy security literature in that the dissertation not only links energy security and climate change mitigation in a quantitative manner but also makes projections for the future.

After this introduction, second chapter of the dissertation discusses energy security concept and explains its connection with climate change. Third chapter is a summary of related literature. Fourth chapter is a brief outlook of Turkey’s energy policy, electricity sector with available sources and its role in carbon emissions. Chapter 5 is exposition of this dissertation. Data and methods used for cross-country panel data analyses and scenarios are explained and the results are discussed in this chapter. Chapter 6 concludes the study.

1.1 Statement of the Problem

This study aims to evaluate role of domestic coal, solar and wind in securing electricity supply of Turkey and her efforts in climate change mitigation.

1.2 Significance of the Study

This dissertation is one that is concerned with energy security, which is getting popular and not investigated widely yet in Turkey. However, its significance lies in the contribution to the perception that energy-related political decision making may not necessarily contradict with environmental matters.

CHAPTER 2

ENERGY SECURITY, CLIMATE CHANGE AND ROLE OF DOMESTIC SOURCES

2.1 Energy Security

Energy security has different meanings according to situations, context, states and people. Nevertheless, this does not indicate different concepts. In other words, conceptually, energy security is well-defined but is expressed differently under different conditions (Ang, Choong, & Ng, 2015; Cherp & Jewell, 2014; Ciută, 2010). However, (Winzer, 2012) claims that this unclarity makes the term ambiguous.

Historically, energy security was associated with uninterrupted provision of oil, specifically for military needs after British Navy's switch from domestic coal (Cherp & Jewell, 2011; Jewell, 2011) in 1912 (Cleveland, 2008), which is clearly expressed by (Colglazier & Deese, 1983). Their definition is reduced to abrupt price changes and supply problems of crude oil, and vulnerability and damage that may be result of these states. In decades after the World War II reliance on oil increased because of its wide use in many sectors. Importing and exporting oil became a problem for many developed and developing countries. The vulnerability of this system became apparent in 1973 oil crisis, during which members of Organization of the Petroleum Exporting Countries (OPEC) stopped supplying oil to developed countries (Bielecki, 2002; Cherp & Jewell, 2011). The current energy security system is the result of this crisis. The system is designed to maintain coordination among industrialized countries during any shock or disruption in supply and to prevent use of oil as weapon (Yergin, 2006). However, contemporary energy security concerns do not only focus on oil but consider natural gas. Moreover, the world is not bipolar anymore. Today's threats are shaped by international terrorism, instability in the oil-rich Arab and other Asian, African and former Soviet countries, India and Pakistan's ability to use nuclear weapons, and new role of China. Final stages of 20th century changed thinking in energy security from ideas based on geopolitics to technical and systematic vulnerabilities in energy (Cherp & Jewell, 2011).

Today, energy security is “the uninterrupted availability of energy sources at an affordable price” and a complex problem because existing energy systems are open to wider impacts than only secure provision of oil. The concept has short-term and long-term perspectives. In the short-term energy security is related with balancing demand and supply at times of sudden changes resulting from technical problems, climatic events or political reasons. In the long-term energy security deals with planned investments for timely provision of energy in the face of economic growth and environmental issues (Bielecki, 2002; International Energy Agency, 2019). Similarly (Kisel, Hamburg, Härm, Leppiman, & Ots, 2016) define short term operational resilience and technical vulnerability. *Short term operational resilience* is the capacity of national infrastructure to react disturbances of supply and demand in seconds, minutes or days. *Technical vulnerability* is ability of an energy system to operate in the long term. In words of (Yergin, 1988), energy security aims continuous provision of energy at required level with affordable price so that major national values and targets are not under threat, and is concerned with “shocks – interruptions, disruptions and manipulations of supply” – that can cause unexpected and dramatic alterations in price, which may result in high economic and political burdens. Contemporary energy security is concerned with establishing an integrated energy system so that conditions creating vulnerability are overwhelmed (Cherp & Jewell, 2011).

For clarity of the concept (Ang et al., 2015; APERC, 2007; Cherp & Jewell, 2011; Sovacool & Brown, 2010; Sovacool, Mukherjee, Drupady, & D’Agostino, 2011) discuss dimensions of energy security. Except for (Cherp & Jewell, 2011), availability and affordability (and equal accessibility) are the common dimensions. *Availability* means supply of sufficient and uninterrupted energy with minimum reliance on foreign sources. As in example of natural gas bargain between Russia and the EU, dependence may be costly or might cause international conflict that many times experienced, for instance in the World War I or Japan’s invasion to Manchuria in 1931 and to oil rich Indonesian islands, and the invasion of the US to Iraq. In other words, it is simply related with diversification and geopolitical factors, such as wars or unstable regimes. Components of availability are supply and production security, dependency, and diversification. Diversification is benefiting a mix of energy sources and energy suppliers. Also, spatial diversification is necessary to protect infrastructure or transport route (Ang et al., 2015; Brown, Wang, Sovacool, & D’Agostino, 2014; Sovacool & Brown, 2010; Sovacool et al., 2011). *Affordability (*and *equal accessibility)* means generating energy with minimum cost and aiming equitable access because people need energy to meet their basic needs. Price stability, access and equity, decentralization, and quality of energy are the components of this dimension (Brown et al., 2014; Sovacool & Brown, 2010; Sovacool et al., 2011). *Acceptability* is discussed by (APERC, 2007) based on environmental effects and prices of any energy source or technology. For instance, coal and nuclear are resisted because of their environmental and health risks. Any mitigation measure to lower risks might bear costs that reflect themselves in consumer prices, declining accessibility.

It would not be wrong to relate the above dimensions to classical, oil-oriented perception of energy security. Current meaning of the concept needs further explanation since it has a wider context than oil. However, unlike the classical context, dimensions for this wider coverage are not agreed upon, which creates the unclarity mentioned before. One dimension is related with *technology*, discussed as energy efficiency (Ang et al., 2015; Brown et al., 2014; Sovacool & Brown, 2010), technology development (Sovacool et al., 2011) or infrastructure (Ang et al., 2015). *Technology* is enhanced performance and wide use of more efficient equipment and conservation, and is fundamental for stable and uninterrupted supply of energy (Ang et al., 2015; Brown et al., 2014; Sovacool & Brown, 2010). It is related with capacity build-up against risks and minimizing losses. Components are innovation and research, safety and reliability, resilience, efficiency and energy intensity, and investment and employment (Sovacool et al., 2011).

Another dimension is *sustainability*. Again it has different designations such as environmental stewardship (Brown et al., 2014; Sovacool & Brown, 2010) or social effects and environment (Ang et al., 2015) but is minimizing impacts on environment and society (Sovacool et al., 2011), considering future resource requirements while meeting today's demand. In order to accomplish sustainability in terms of energy security consumption should not exceed regeneration capacity of renewable resources, waste emissions should not exceed assimilation capacity of the environment and ensuring that depletion pace of non-renewables is not above the regeneration capacity of renewables. Plus, mitigation and adaptation to climate change is to be considered as a component of energy security (Brown et al., 2014; Sovacool & Brown, 2010) because climate change may alter consumption levels of fuels, use of specific technologies and energy mix of a country. In other words, energy security risks are affected by climate change (Greenleaf et al., 2009).

The last dimension elaborating energy security is *policy*, discussed as regulation and governance by (Ang et al., 2015; Sovacool et al., 2011). *Policy* is concerned with an energy policymaking that is "stable, transparent and participatory", promote competitive markets, and "enhancing social and community knowledge". Components of this dimension are governance, trade and regional interconnectivity, competition and markets, and knowledge and access to information (Ang et al., 2015) as well as planning and diplomacy (Sovacool et al., 2011).

Nevertheless, (Winzer, 2012) suggests simplifying the concept in order to overcome overlaps among energy security, economic efficiency and sustainability so that quantification of energy security would not require complex arrangements. Thus, energy security could be analyzed under these four central elements: *physical* (related with availability and accessibility), *economic* (covers affordability and technology), *sustainability* (APERC, 2007), and *policy*.

Energy security risks can be grouped into three: energy market instabilities, physical security threats and technical failures. Energy market instability may result from political or social conflicts, trade embargoes or other nations' unilateral supply contracts. Rather than physical unavailability, impact of market risks shows themselves on prices. Physical security threats, related with geopolitical situation, are attacks, sabotage or natural disasters. Effects may be similar to those of technical failures. These are related with *sovereignty* perspective of energy security that is concerned with security threats posed by external actors such as countries, companies or terrorists. Faults due to human error or accidents result in interruptions in the supply. These are called technical failures. Supply interruptions may be temporary or persistent based on the fault and complexity of the network system. Increasing dependence on energy with complex systems and limited sources created *robustness* and *resilience* perspectives. Robustness is concerned with security threats that are born by energy systems' properties or structure. Resilience is related with complexity and unpredictability of future energy systems. Resilience aims to provide generic characteristics for future energy systems and offer general solutions to avoid security risks (APERC, 2007; Cherp & Jewell, 2011; Ölz, Sims, & Kirchner, 2007).

There are three ways to maintain energy security: "managing energy demand, increasing domestic energy supply and increasing the reliability of imported or domestic supplies". Nations can reduce their energy supply vulnerability through reducing demand or increasing efficiency and restructuring, arranging stockpiles and preparing plans for emergency conditions, increasing share of alternative domestic supplies, diversification of external supplies, and taking "diplomatic, industrial and military measures" (Deese, 1979; The World Bank Group, 2005). Priority should be given to "diversification of supply" so that one can reduce the impact of disruption of depending on one supply and supplier. Resilience is another principle that aims to ensure a buffer against disruptions. It might be achieved maintaining strategic reserves, sparing production capacity or stockpiling. Third principle is "recognizing the reality of integration", which means adaptation to current global energy market. Accomplishing integration requires high quality information, as the fourth principle. Information is key for functioning of markets (Yergin, 2006).

2.1.1 Energy Supply Security and Electricity

Improving energy supply security by the three means discussed above helps minimizing and managing risks. Energy supply security is defined as “a system’s ability to provide a flow of energy to meet demand in an economy in a manner and price that does not disrupt the course of the economy”. Dramatic price increase, quality problems, sudden and long-term interruptions are indicators of insecurity for supply (Grubb et al., 2006). Supply security can be accepted as “sustainability of the energy system” (Keppler, 2007) and it is to some extent related with energy independence, relevant for households, industry, services and governments. Current economic model is dependent on electricity, oil and natural gas, and citizens demand their continuous provision. Therefore, energy supply security is a global issue (Chevalier, 2006; Kisel et al., 2016).

Energy supply security is not an easy concept because it deals with uncertain future risks that generally outstretch ability of governments’ intervention (Wright, 2005). Uncertainties regarding environment is specifically result of climate change. Further, the unclear extent of climate change impacts might require new political, fiscal and technical measures, which again creates risk on price of energy. On the other hand, restrictions on carbon dioxide emissions are expected to encourage diversity of fuel supply sources. Geopolitical uncertainties are worsened by oil and gas exporting countries, which usually struggle with political and social turmoil. Especially interruptions of global oil supply have considerable impact on world economy resulting from high prices, tight market and volatility. Uncertainties due to regulations on liberalization of energy markets play role in supply security since mechanisms have not effectively settled. On the other hand, liberalization is expected to promote supply security through competition, liquidity and fuel substitution. Besides these uncertainties there are unexpected events such as wars, terrorist attacks or natural disasters that have potential to drastically affect supply security (Chevalier, 2006).

Risks to energy supply are classified into physical, economic, social, and environmental, and these are related with reliable supply of energy, reliable transportation of supply, and reliable distribution and delivery of supply. *Physical risks* are either permanent or temporary. Permanent risks are depletion of a source or cease of production. Temporary risks result from social instability, geopolitical or environmental crisis and may bear tremendous costs to a society. Rather than permanent risks these can be under control of a government within country borders. Reliable transportation of supply is related with physical availability and maintenance, and diversity of routes. Efficient and timely delivery with equality concern are determinants of reliable distribution and delivery of supply. *Economic risks* are related with price instability and are harmful for a healthy economy. Any kind of interruption of supply has potential to create social unrest, drawing attention to *social risks*. *Environmental risks*, on the other hand, are damages that are result of leaks or accidents in and emissions from energy chain. Moreover, the concept has various dimensions. Temporal dimension is both short-, medium- and long-term. In the short-term abrupt and unexpected disruptions may happen in supply of energy due to political decisions, accidents, attacks, social unrest or weather events. In the medium- and long-term persistent political or social conflicts and resource availability based on lack of investment in capacity, transmission and storage pose threats for supply security. Space dimension of the concept is related with disruptions due to local, national or international causes (Chevalier, 2006; EU, 2000; Scheepers, Seebregts, de Jong, & Maters, 2007).

Flexibility, diversification, responsiveness, and impact reduction approaches might help to handle supply security risks. To achieve supply security, first, relations of each individual risk factor with others should be identified. Second, degree of desired or least risky level of energy independence should be determined. Ensuring a transparent and well-functioning market, which prevents price alterations based on any single factor, is the third approach. In other words, aim should be preventing abrupt price changes. Fourth, expectations, perceptions and facts should be so well managed that modern life is prepared to cope with inevitable price increases (Keppler, 2007). Nonetheless, long-term supply security and associated uncertainties preclude identification of risks. In order to overcome such uncertainties, prime feature of long-term energy security is the knowledge of primary energy source inventory (Jansen, Arkel, & Boots, 2004). Yet, there are mitigation measures for the short-term impacts. These are having emergency stocks, fuel switching, and demand and reserve capacities (Scheepers et al., 2007).

Achieving energy security through self-sufficiency could be costly and increasing diversity may not be environmentally a good option (Andrews, 2005). Energy intensity, the required energy amount during production of one unit of GDP, is a measure of energy dependence of an economy. Another measure is the weight of energy imports in the total primary energy consumption. Relative to price, energy import may be better for an economy than exploiting domestic sources because the latter usually needs incentives to sustain production. In other words, energy independence may be costly for a nation. Besides, dependence on domestic sources may pose risks for supply security during any social unrest such as strikes, civil war or natural disasters. Additionally, supply dependence has price factor. Variations in energy prices may create intolerable consequences as globally witnessed during 1970s oil crisis (Chevalier, 2006).

Basically, there are two important means to cope with risks on security of supply. Energy efficiency offers being a vital instrument for supply security against climate change, high oil and gas prices, and market tightness through reduction in energy consumption. The second means is diversification of energy supply from the perspective of technologies, primary sources and geographical diversity of imports (Chevalier, 2006).

Security of electricity supply with all its components became an issue along with supply security of energy sources (Cherp & Jewell, 2011), and prices (Bielecki, 2002). Regarding electricity, problem is related with production rather than depletion as in fossil fuels. Since electricity cannot be stored efficiently, supply at any time must meet demand, specifically peak demand. Thus, the major risk for electricity supply security is lack of investment in generation and transmission (Joode et al., 2004).

Conventional electricity supply security lies on three pillars. First is the dominant use of domestic sources. Second is importing or developing know-how or technology. Third is entering international energy market through investments and diplomatic or military means. Currently, these pillars have been challenged by climate change and nations aim to optimize their resource diversity and technological progress. Climate change forces nations for cooperation in "grid expansion, increasing interconnector capacity and harmonizing trade and other transmission related rules". Also, renewables play an important role in the face of emission reduction targets (Chalvatzis & Hooper, 2009).

Regarding energy supply security many countries give emphasis on exploiting domestic energy sources for electricity generation although even imported electricity would cost less. Unlike fossil fuels, electricity is not traded internationally in large amounts (Moriarty & Honnery, 2009). For instance, coal reserves in Spain are important for country's energy security but of course not without costs (Cansado-Bravo & Rodríguez-Monroy, 2017). Coal is six times cheaper than oil and four times cheaper than natural gas on a price-per-million-Btu basis. However, coal is a source of various air pollutants, including sulfur and nitrogen oxides, and particulates. Despite advanced emission control devices, CO_2 abatement is still not viable. Although coal is not a clean source, large domestic supplies make it an important element for secure energy (Griffin 2009). "The uneven distribution of renewable energy resources has important consequences for energy security" (Moriarty & Honnery, 2009). Renewables may play an important role in diversification and their being carbon free is an advantage. They are typically domestic sources with wide but varying availability. Improving energy efficiency by demand side management and technological progress is an important means to improve electricity supply security because energy efficiency can reduce dependence on fossil fuels (Ölz et al., 2007).

Sudden disruptions in electricity supply may be result of inefficient capacity. Blackouts, wherever on the world they happen, show strong dependence on electricity, “an essential good”. Thus, electricity supply security is a major concern for modern economies and dependence on electricity makes them vulnerable to supply shocks. Vulnerability of power systems is to weather conditions. Varying temperatures change demand and systems may have hardship to provide enough energy. Also, climatic conditions, e.g. dry or extremely wet seasons, lack of wind and overcast weather, play role in availability of electricity. Weather events may also damage systems and limit or cease electricity supply. Technology is another reason for vulnerability. Any technical problem may alter supply capacity. Furthermore, accidents, sabotage or terrorist attacks are other causes of vulnerability. Supply of primary fuels, oil, coal and natural gas, may pose threats to electricity supply and thus is a determinant of vulnerability of power systems. Liberalization and deregulation are again reasons of vulnerability because these processes create uncertainties for the investors. Therefore, critical investments on capacity increase or transmission and distribution lines may be delayed. Finally, interdependence among current generation and transmission systems also create vulnerability in case of lack of management and cooperation (Chevalier, 2006). In short, electricity supply requires capital, its storage is not yet feasible, and transmission and distribution are costly. Electricity supply security is mostly related with meeting demand, and safe and uninterrupted operation (Andrews, 2005).

2.2 Electricity Sector, Climate Change and Energy Security

> Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.

As the above quotation from Fifth Assessment Report (AR5) Synthesis Report of Intergovernmental Panel for Climate Change (IPCC) indicates that atmospheric CO_2 emissions between 1750 and 2011 were 2040±340 $GtCO_2$ and about 40% of these, 880±35 $GtCO_2$, remained in the atmosphere. Contribution of fossil fuel combustion and industrial processes to CO_2 emission rise was 78% in this period and increasing use of coal has changed the long-term trend of decreasing carbon intensity of energy supply. Since 1970 CO_2 emissions due to these sectors have tripled. In ten years from 2000, GHG emission rise was about 10 $GtCO_2$-eq and 47% of this rise was due to energy sector. In 2010, energy sector was alone responsible for 35% of GHG emissions. Electricity and heat production alone was responsible for 25% of 49 $GtCO_2$-eq in 2010 (Bruckner T., I. A. Bashmakov, Y. Mulugetta, H. Chum, A. de la Vega Navarro, J. Edmonds, A. Faaij, B. Fungtammasan & E. Hertwich, D. Honnery, D. Infield, M. Kainuma, S. Khennas, S. Kim, H. B. Nimir, K. Riahi, N. Strachan, R. Wiser, 2014). AR5 baseline scenarios predict that CO_2 emissions directly from energy supply sector will reach 24-33 $GtCO_2$-eq in 2050 (IPCC, 2018). In other words, electricity generation is the sector that emits the largest CO_2 (Bruckner T., I. A. Bashmakov, Y. Mulugetta, H. Chum, A. de la Vega Navarro, J. Edmonds, A. Faaij, B. Fungtammasan & E. Hertwich, D. Honnery, D. Infield, M. Kainuma, S. Khennas, S. Kim, H. B. Nimir, K. Riahi, N. Strachan, R. Wiser, 2014) and this trend is expected to continue. In 2030 69% of all fossil fuels will have been consumed for electric power generation (Griffin, 2009). The growth rate of global population is expected to be less than the global energy demand growth rate until 2030, which is basically due to electricity demand of developing nations. In 2010 electricity generation was 20,000 TWh. In 2030 it is expected to become 31,200 TWh. Coal and natural gas are the most exploited energy sources for electricity generation (Letcher, 2014).

Concerns on climate change have also brought attempts to link the issue with energy security but mainstream energy security discussions and policies fail to grasp it as an integral part of the issue because main focus is energy independence (Nyman, 2015). Energy security and climate change have both complementarities and tradeoffs. The link between them is tenuous and specific policies on one may result either positive or negative impacts on the other. Thus, the impact of climate change on energy security needs clarification whether it affects supply, demand, affordability or reliability of energy supply, and if so, it is a direct or an indirect impact. For instance, changing precipitation regime alters availability of water for hydropower plants, increasing temperatures reduce efficiency of solar panels, frequent extreme events damage windmills or a severe drought forces people to migrate, which may increase energy demand in the destination land. On the other hand, policies on climate change may delay depletion of fossil resources and reduce energy imports as well as demand technology transition (Cherp, Jewell, & Goldthau, 2011; Kruyt, van Vuuren, de Vries, & Groenenberg, 2009; Luft, Korin, & Gupta, 2011; Varianou Mikellidou, Shakou, Boustras, & Dimopoulos, 2018). Specifically, electricity generation and transmission efficiency might be reduced because of increasing temperatures and extreme events. Moreover, heatwaves, wildfires, extreme cold and floods may damage electricity infrastructure (Varianou Mikellidou et al., 2018).

Decision regarding climate change impacts on energy security requires weighing positive and negative outcomes. On the positive side decreasing heating needs may be listed. With less energy demand on heating, energy consumption is reduced, energy prices are lowered, and less carbon dioxide is emitted. Melting glaciers may bring positive results regarding energy security. With new and shorter trade routes for freight ships energy consumption for transportation and emissions may be reduced. Nevertheless, focusing on emission reduction might turn interest to nuclear power, which poses global security risks although electricity generated by it emits almost zero greenhouse gases. Moreover, switching from coal to natural gas increases energy dependency of a country and it is expected to pose threats on national economy if not it brings excess burden (Luft et al., 2011).

In short, there is not any policy measure that addresses both climate change and energy security although options such as efficiency, conservation and clean technology are beneficial for both. Focusing on one of them might worsen the other, thus, balance should be established (Luft et al., 2011).

CHAPTER 3

LITERATURE REVIEW

This chapter lists and briefly discusses relevant literature on energy security, electricity generation and emissions. Generally, studies using econometric methods are under focus.

3.1 Studies on Energy Security

Given the ambiguity on the term as discussed in CHAPTER 2, different approaches exist to measure energy security. Table 3-1 lists studies that quantitively deal with electricity supply security. As (Ang et al., 2015) points out, energy security is analyzed with various indicators related with the concept that the issue is addressed. Majority of the studies deal with energy security performance over time and compare the countries. Few studies aim to make predictions for the future. Main concern for the literature listed below is measuring diversity in electricity supply via Herfindahl-Hirschman or Shannon-Wiener indexes and the indicators chosen vary from dimension to dimension. (Valdés Lucas, Escribano Francés, & San Martín González, 2016) is the only study employing econometric methods on electricity supply security with a focus on renewable energy deployment across the EU.

3.1.1 Review of Recent Studies on Turkey

Energy security is a recently emerging concept in Turkish literature. Energy security analyses for Turkey have been undertaken by (Cansın, 2007), (Kardaşlar, 2016) and (Dursun, 2019), which employ index analyses to quantify energy security. Similarly, there are few studies on quantitative analysis of Turkey’s energy supply security. (Peker, 2014) and (Öznazik, 2019) aim to quantify energy supply security through security indexes. Nevertheless, the below studies use econometric methods to analyze the issue.

(Erdal, 2011) investigates determinants of supply security for Turkey. Dependency Index, Intensity Index, Local Production Index and Composite Index are the four determinants that measure energy supply security. These indices are formed by using these variables: petroleum prices, total primary energy supply, energy consumption per capita, share of renewable energy sources and carbon dioxide emissions. Econometric model is constructed with Granger Causality Test and Johansen Cointegration Analysis. Increased use of primary energy sources and renewables positively affect supply security whereas petroleum prices, per capita energy consumption and carbon emissions have a negative relationship with supply security.

(Erdal, 2015) measures energy supply security of Turkey by time series econometric methods. She develops determinants according to availability, accessibility, affordability and acceptability dimensions. Import dependency, energy intensity and domestic production rate of energy are the dependent variables for the first three dimensions. One composite indicator, as average of the other three, used as the fourth dependent variable. World oil prices, total primary energy supply, per capita energy consumption, CO_2 emission, and renewable energy ratio in total primary energy supply are the independent variables used in the analysis. As a result, it is found that renewable energy is important for supply security. Per capita energy consumption and fossil fuel use affect supply security negatively.

Based on economic vulnerability, energy intensity, carbon intensity, domestic energy production rate and energy import dependency variables, (Avar, 2018) measures Turkey’s energy supply security by principal component analysis under further investigations with Hodrick-Prescott filter in order to understand regional effects. Accordingly, short- and long-term events are found to affect energy supply security of Turkey. Besides, use of renewable and non-renewable sources, total primary energy supply, and political and social globalization have significant influence on Turkey’s supply security.

(Çoruh, 2019) tests validity of energy supply security factors for Turkey under the country’s energy policies. Augmented Dickey-Fuller, Phillips-Perron unit root and autoregressive distributed lag cointegration bound tests are applied. Finally, Toda-Yamamoto Granger causality test analysis is used. According to the analyses, oil price, per capita energy consumption and carbon dioxide emissions are negatively related with Turkey’s energy security. One-way causality relationships exist from oil price to energy supply security and from carbon dioxide emissions to energy supply security.

Table 3-1. Studies on Electricity Supply Security

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(Stirling, 1994)	United Kingdom	Diversity in electricity sector	Diversity Portfolio Optimization	• marginal utility of diversity • Shannon-Wiener diversity index	Based on costs, investment on renewables improves diversity than focusing on nuclear. The suggested technique is an analytical method for the benefit of both public and private sectors.
(Stirling, 1998)	United Kingdom	Diversity in electricity section	Shannon-Wiener Diversity index	• performance utility • proportional contribution of each option • marginal utility of diversity	Diversity is especially significant for technology choice. Reviewed indexes fail to meet desired criteria. The proposed method enables investigation of complex interactions among options in economic portfolio.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(Jansen et al., 2004)	EU	Long-term supply security	Shannon-Wiener Diversity index	*Energy supply security basic indicator* • share of primary energy source i in total primary energy supply • primary energy source index • correction factor for share of primary energy source i *Energy supply security indicator for import of energy resources* • correction factor for share of primary energy source i • share of imports of energy resource i from region j in total import source of i *Energy supply security indicator for energy imports and the extent of long-term socio-political stability in regions of origin* • extent of political stability in region j • index for import resource i, adjusted for political stability in the regions of origin *Indicator for energy imports, political stability in producing regions and for the proven regional reserves with respect to annual production in the region concerned* • depletion index for resource i in import region j • depletion index for resource i in home region k • proven reserve-production ratio for resource i in region of origin j	Indicators are quite successful in projecting long-term energy supply security development of a specific region**.**
(Joode et al., 2004)		Cost-benefit analysis	Computational general equilibrium		Security supply measures bring costs to public welfare, i.e. costs usually

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
			model (ATHENA)		outweigh benefits. Well-functioning electricity markets might secure supply.
(Doorman, Uhlen, & St, 2006)	Nordic countries	Power system vulnerability	Risk Assessment	• energy shortage • capacity shortage • power system failure	Systems are in medium risk state, requiring consideration of various measures.
(Grubb et al., 2006)	United Kingdom	Contribution of wind power to diversity	Shannon-Weiner Index Herfindahl-Hirschman Index	• proportion of generation represented by the i^{th}type of generation	Low carbon scenarios promote diversity. Intermittency does not negate wind contribution to electricity generation.
(Turton & Barreto, 2006)	Global	Supply security and climate change	Energy Research Investment Strategies (ERIS) model	• energy demand • fuel resource base	Reducing on of the risks may lower the cost of controlling the other despite complexity of interactions.
(APERC, 2007)	Asia Pacific	Energy security	Shannon Index	*Diversification of primary energy demand* • share of primary energy source i in total primary energy supply *Net energy import dependency* • share of primary energy source i in total primary energy supply • share of net import in primary energy source of source i *Efforts to switch away from carbon intensive fuel portfolio* • total demand of non-fossil primary energy sources • total primary energy demand *Net oil import dependency*	Dependence on one source or one supplier increases supply risk, thus, diversity is suggested. R&D is recommended because it substantially lowers costs while improving technology. Investment in new technologies may improve diversity. International cooperation through Clean Development Mechanism and commitment to global

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• oil primary energy demand • net oil imports • total primary energy demand	environmental measures may strengthen energy security. Public objection to nuclear and coal may be lowered with systematic public awareness activities. Efficiency and energy conservation should be enhanced.
(Awerbuch & Yang, 2007)	EU	Electricity generation, energy security and climate change mitigation	Portfolio Optimisation Analysis	• capital, fuel, operating, and CO_2 costs per kWh of generating technologies • risk or standard deviation of each risk component • correction factors among cost components	Overall risks and costs are reduced with extensive use of non-fossil sources, and improve energy security. Up to €500 billion is foreseen for the optimal mix. Optimal mix in 2020 requires more contribution from wind and nuclear.
(Chalvatzis & Hooper, 2009)	Germany, Poland, Greece, United Kingdom	Energy security vs climate change		• share of import and domestic electricity and fuels in electricity generation	A framework should be developed to assess impact of climate change policies on electricity supply security
(Greenleaf et al., 2009)	EU	Impact of climate change on energy security	PRIMES	• availability of gas and oil as primary fuel • de-rated electricity peak capacity margin • capital intensity • average load factor • required new capacity • resource concentration price indicator • resource concentration physical availability	Policies on climate change and CCS promote energy security. Energy efficiency plays a crucial role. However, in the long-term electricity supply security is negatively affected.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(J Augutis, Krikštolaitis, Matuzien, & Pe, 2009)	Lithuania	Supply security based on Ignalina NPP	Security Indicators System	*Technical* • heavy accidents as a result of radioactive material release • heavy accidents as a result of core break-down • lifespan of nuclear installations • installed capacity utilization factor *Economical* • share of electricity produced by nuclear • share of nuclear fuel in total fuel supply • share of imported electricity • per capita nuclear power consumption • price of electricity generated by Ignalina NPP • price of electricity generated by other power plants • price of electricity generated by new CCPP • price of electricity generated by new NPP • share of imported gas • share of Lithuanian electricity in West European electricity market *Socio-political* • share of nuclear fuel from dominant supplier • threat of terrorist attacks • good public opinion for nuclear • probability of political decision against nuclear • “probability that electricity network initial reserve will not be supported”	With demobilisation of Ignalina NPP, Lithuania will face the lowest level of supply security. New connections with Sweden and Poland, new CCPPs and participation in EU free electricity market may improve the situation.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• probability of decisions against nuclear installations *Environmental* • annual per capita exposition to radiation under normal operation • hazards because of natural disasters	
(Sovacool & Brown, 2010)	OECD	Supply security	Energy Security Index	*Availability* • oil import dependency • gas import dependency • dependence on petroleum transport fuels *Affordability* • retail electricity prices • retail gasoline and petrol prices *Efficiency* • energy intensity • per capita electricity use • transport fuel intensity *Environmental Stewardship* • SO_2 emissions • CO_2 emissions	Denmark, Belgium, UK and Japan have the greatest improvement in energy security whereas performances of Greece, Spain and Portugal are the worst. Scores within OECD vary highly.
(Juozas Augutis, Krikštolaitis, Pečiulytė, & Konstantinavičiūtė, 2011)	Lithuania	Energy security level based on Ignalina NPP	System of Energy Security Indicators	*Technical Block* *Electricity* • ratio of total installed generation capacity and connection lines to maximum demand • share of the largest capacity power plant in total installed capacity • share of generation technology in total generation capacity • average ratio of power plant lifetime to its technical resource time *Gas*	Decommissioning of NPP decreased energy security indicators for Lithuania because of increased gas exports and electricity prices. Free electricity market and renewable development emerged.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• ratio of total pipeline capacity to maximum demand • ratio of storage capacity to annual average consumption • ratio of the largest supplier capacity to average consumption *Oil* • ratio of oil and products supply to average consumption • ratio of the largest supplier capacity to average consumption • ratio of oil products reserve accumulation to annual average consumption *Coal* • ratio of technical supply capacity to annual demand • ratio of the largest supplier capacity to annual demand • ratio of accumulated reserves to annual consumption *Nuclear* • ratio of technical supply potential to annual demand • ratio of used repository to demand • ratio of accumulated fuel to annual average consumption *Biofuel* • ratio of production capacity to annual consumption • ratio of the largest producer capacity to annual consumption	

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• ratio of accumulated reserves to annual consumption *Heat* • ratio of total installed capacity to maximum demand • ratio of facility lifetime to technical resource time • share of the largest’s generation to total generation • percentage of heat generation maintained with fuel replacement *Economic Block* *Electricity* • ratio of electricity purchase to annual demand • share of consumers able to choose supplier • ratio of generation dependent on one fuel supplier to total generation • ratio of imported electricity to annual demand *Gas/Oil/Coal/Nuclear Fuel/Biofuel* • ratio of purchase to annual average consumption • possibility for a consumer to choose supplier • share of import from single supplier • ratio of total import to annual average consumption *Heat* • possibility for a consumer to choose supplier	

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• ratio of generation dependent on import from one supplier of a fuel to total generation • ratio of domestic fuel used for generation to total consumption of the fuel *Socio-political Block* *Geopolitics* • share of the largest foreign resource supplier in the general energy balance • import size weighted mean of foreign suppliers’ political risk factors • transit size weighted mean of foreign suppliers’ political risk factors • invested capital size weighted mean of foreign suppliers’ political risk factors • connections size weighted mean of foreign suppliers’ political risk factors • political risk factor of the country itself *Socio-politics* • average per capita energy expense to annual average income • commitment to renewable consumption • commitment to Kyoto protocol • commitment to energy saving • positive public opinion towards nuclear	
(Badea, S, Tarantola, & Bolado, 2011)	EU	Energy supply security	Ordered Weighing Averaging	• energy intensity • carbon intensity • import independency rates for oil, gas and coal	Composite indicators to assess energy security are offered.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• Shannon-Wiener index for primary energy production, electricity generation and transportation energy demand	Countries with low scores are more vulnerable in the long-run.
(Sovacool et al., 2011)	US, EU, ASEAN countries, China, India, Japan, South Korea	Energy security performance between 1990 and 2010	Empirical and Relative Scoring	*Availability* • per capita total energy supply • average reserve-to-production ratios for coal, natural gas and oil • self-sufficiency • share of renewable in total supply *Affordability* • stability of electricity prices • rate of population with quality electricity access • households dependent on traditional fuels • retail price of fuel oil *Technology Development and Efficiency* • research intensity • energy intensity • energy resources and stockpiles *Environmental Sustainability* • forest cover • water availability • per capita CO_2 emission due to energy use • per capita SO_2 emissions *Regulation and Governance* • worldwide governance rating • energy exports • per capita energy subsidies • quality of energy information	Energy security performance of all the countries under focus has decreased.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(Angelis-Dimakis, Arampatzis, & Assimacopoulos, 2012)	Greece	Sustainability of Greek energy system	Overall Sustainability Index	*Social Dimension* • share of households with electricity access • share of household income spent for fuel and electricity • share of household energy expenditure by income group *Economic Dimension* • per capita final and residential energy use • total primary energy supply per unit of GDP • energy imports per total primary energy supply *Environmental Dimension* • per capita GHG emission or emission intensity • RES contribution to final energy consumption • RES contribution to electricity generation	Greek energy system demonstrates an unbalanced development in favour of social dimension.
(Juozas Augutis, Krikstolaitis, Martisauskas, & Peciulyte, 2012)	Lithuania	Energy security level after decommissioning of Ignalina NPP	Energy Security Level	*Indicator Blocks* • technical • economical • socio-political	Energy security level decreased after Ignalina shut-down but with future planned projects, level increases again.
(Wu, Liu, Han, & Wei, 2012)	China	Energy supply security	Analytic Hierarchy Process	• energy reserve/production ratio • energy intensity • energy consumption per capita • energy self-sufficiency ratio • energy price fluctuation ratio • energy reserve ratio • energy imports diversification ratio • energy diversification index	China’s energy supply security fluctuates between 1996 and 2009. However, “energy-saving” and emission reduction targets have positive influence on the index.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• energy production security index • CO_2 emission intensity • CO_2 emission index per unit energy consumption • electricity contribution to end-use energy • contribution of clean and renewable energy	
(Francés, Marín-quemada, & González, 2013)	EU	Relationship between energy security and RES	Portfolio Theory		Generated domestically or imported, green electricity has potential to improve energy security.
(Gracceva & Zeniewski, 2014)	EU	Energy security in a low carbon energy system	Energy Technology Systems Analysis Program-TIMES Integrated Assessment Model (ETSAP-TIAM)		Energy system models are promising in revealing interactions between energy security and climate change policies.
(Kamsamrong & Sorapipatana, 2014)	Thailand	Electricity generation	Energy Supply Security Index	• primary energy supply diversification weighted by indigenous energy supply • energy intensity • electricity generation cost • monetary share value between imported electricity and total electricity consumption • CO_2 emission per unit of electricity generated	Construction of new nuclear or coal power plants may increase energy supply security however these do not lower foreign dependency and are subject to public opposition. Renewables are promising but they cause high electricity prices.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(Portugal-pereira & Esteban, 2014)	Japan	Electricity supply security	Multi-dimensional Indicator Assessment	• import dependence • diversity of resources measured by Shannon-Weiner index • period when demand reaches 85% of supply capacity • net electricity generation efficiency • CO_2 emission per unit of electricity generated • SO_2 emission per unit of electricity generated • PM_{10} emission per unit of electricity generated • amount of radioactive waste per unit of electricity generated	Phase out of nuclear and increased dependence on imported coal contradict 2030 energy security goals. However, in the long-term increasing RES share is expected to be beneficial.
(Ranjan & Hughes, 2014)	North America	Diversity in electricity supply	Shannon-Wiener Diversity Index		Diversity is related with the number of flows and their being even, and energy security is related with state of the flows rather than evenness.
(Yao & Chang, 2014)	China	Change in China's energy security after 30 years of reform	Imbalance Index	*Availability* • coal reserve to production ratio • oil import dependence ratio • natural gas reserve to consumption ratio • conventional thermal electricity availability factor • non-thermal electricity availability factor *Applicability* • energy intensity • gross generation efficiency of fossil fuel-fired power plants	Since 1980, there has been improvement in overall energy security of China. For further improvement, investment on renewables is suggested.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• crude oil distillation capacity • patents owned in energy sector • energy industry investments *Acceptibility* • share of China’s CO$_2$ emissions in global emissions • SO$_2$ emissions • PM emissions • renewable contribution to total electricity generation • nuclear contribution to total electricity generation *Affordability* • growth rate of ex-factory price indexes for coal, petroleum and electricity • coal price volatility • per capita energy consumption	
(Erahman, Purwanto, Sudibandriyo, & Hidayatno, 2016)	Indonesia	Energy security performance	Min-Max Normalization Principle Component Analysis	*Availability* • energy production per capita • self sufficiency • reserves • SWI index • production adequacy *Affordability* • petroleum product price to GDP/cap ratio • electricity price to GDP/cap *Accessibility* • electrification ratio • ratio of population depending on traditional biomass • Vehicle ownership	Indonesia’s energy security increased during 2008 – 2013 period in availability, affordability and accessibility dimensions.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				Acceptability • emissions per energy consumption • emissions intensity *Efficiency* • energy intensity • power distribution losses	
(Kisel et al., 2016)			Energy Security Matrix	(for electricity sector) *Operational Resilience to Internal and External Disturbances* • share of unreliable capacity to minimum load • share of reliable capacity to peak load • resilience to acts of terror • resilience to acts of cyber attacks • resilience to natural disasters • resilience to climate change *Technical Resilience* • reserve margin • age of reliable power capacities and networks • average return on reliable power capacities and networks *Technical Vulnerability* • diversity • ratio of potential of supply to annual consumption *Economic Dependence* • merchandise value of power exports/imports to GDP *Political Affectability* • political stability in the country	This novel matrix is to provide stronger evidence for energy policy-making.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
				• political stability in suppliers • ability of other countries to influence sectoral policies • openness to foreign influence • level of corruption	
(Valdés Lucas et al., 2016)	EU	Renewable deployment	Feasible Generalized Least Squares Partial Correlated Standard Errors	• RES contribution to total primary energy supply • energy intensity per capita • carbon intensity per capita • Kyoto protocol dummy variable • GDP per capita • oil price • contribution of coal to electricity • contribution of oil to electricity • contribution of gas to electricity • contribution of nuclear to electricity • gas economic intensity • gas physical intensity • energy import dependence • Herfindahl-Hirschman diversity index	Assessing energy security requires a wide set of indicators. Variables affecting energy security have impacts on renewable deployment. Import dependency alone is not enough to explain energy security.
(Juozas Augutis, Krikstolaitis, Martisauskas, & Peciulyte, 2017)	Lithuania	Forecasting energy security level	Bayesian Method System of Random Differential Equations		With this integrated framework, energy security level of any country can be forecast.
(Cansado-Bravo & Rodríguez-Monroy, 2017)	Spain	Domestic coal	Multi-Criteria Decision Making and Multi-Attribute Utility Theory	• coal production based on region and technology • coal mines' operating costs based on region and technology	The only commercially viable mine is in Aragon compared with import coal. Thus, coal-fuelled power plants in Spain may become dependent on import coal.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(Chalvatzis & Ioannidis, 2017)	Ireland, Spain, Portugal, Greece	Energy supply security	Shannon-Wiener Index Herfindahl-Hirschman Index	• diversity of suppliers • volume of imports from each supplier	As a result of financial crisis in 2008, import of fuels is reduced and importance of renewables increased through innovation.
(Cox, 2017)	United Kingdom	Electricity system	Transition Pathways to a Low Carbon Economy	*Availability* • approval ratings of generation mix • land requirements • participation in decisions • fuel type diversity • Fuel import dependence *Affordability* • costs of electricity generation • transmission upgrade costs • distribution upgrade costs *Sustainability* • life-cycle carbon intensity • depletion of primary fuels • depletion of secondary materials • water consumption and withdrawals *Reliability* • de-rated capacity margins • flexible supply: frequency response • flexible supply: short-term operating reserve • flexible demand	Energy policy should resolve the contradictions among security dimensions through controlling demand, electricity storage and interconnection.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(García-Gusano, Iribarren, & Garraín, 2017)	Spain and Norway	Electricity generation	Renewable Energy Security Index	• electricity demand satisfaction for each power generation technology • national renewability factor for each power generation technology	This new energy security index is feasible to fill lack of practical indicators for policy making.
(Matsumoto, Doumpos, & Andriosopoulos, 2017)	EU	Evolution of energy security performance	Shannon-Wiener Diversity Index		Denmark and Czechia have the greatest improvement.
(Filipovic, Radovanovic, & Golusin, 2018)	EU	Macroeconomic and political aspects	Principle Component Analysis	• energy intensity • reduction in CO2 intensity • share of renewables • share of imported energy in total energy consumption • per capita electricity consumption • price of electricity • per capita final energy consumption • real GDP per capita • Euromoney country risk	GDP/cap, country risk, carbon intensity, energy intensity, per capita energy consumption and electricity prices significantly influence energy security.
(García-Gusano & Iribarren, 2018)	Spain	National energy system	Life Cycle Assessment Energy Systems Modelling		Higher renewable targets in 2030 increase rate of their deployment. Aiming energy security promotes climate change mitigation.
(Veremiichuk et al., 2018)	Ukraine	Impact of RES on electricity supply security	System Formation Approach		The proposed algorithm should be used considering threats to power system.

Table 3-1. Studies on Electricity Supply Security, continued

Reference	***Country/Region***	***Focus***	***Method***	***Indicators/Indexes***	***Conclusion***
(International Energy Agency, 2020)	Global	Electricity supply	Stated Policies Scenario		In 2025 coal-based electricity generation will be less than generation by renewables. In 2030, solar PV is expected to supply 1/3 of global electricity and it will reach 8000 TWh in 2040.

3.2 Studies on Electricity Generation and Carbon Emissions

Table 3-2 lists studies investigating carbon emissions due to electricity generation by panel data analysis. As seen, benefiting from econometric methods is quite a new approach and gaining attention because econometrics enable researchers to attain insights that have not been recognized before and provide more reliable and specific information for use of decision and policy makers.

3.2.1 Review of Recent Studies on Turkey

Relationship between carbon dioxide emissions and Turkish electricity sector is analyzed by (Arı, 2010), (Kat, 2011), (Arı & Köksal, 2011), (Boran, Dizdar, Toktas, Boran, & Eldem, 2013), (Boran, Etöz, & Dizdar, 2013), (Atılgan & Azapagic, 2015), (Özcan, 2016), , (Dulkadiroğlu, 2018), (Aydın & Pınar, 2018), (Aydın, 2018), (Göçmen & Derse, 2018), (Kat, Paltsev, & Yuan, 2018), (Şahin, 2019), (Dikmen, 2019), (Önenli, 2019) and (Arı & Yıkmaz, 2019). Among these studies, (Önenli, 2019) employs econometric methods. Her study approaches the issue in two steps. First, electricity demand forecast analysis is conducted by panel data methods with random and fixed effects. Population and GDP are the two variables used to estimate electricity consumption. Second step of her dissertation is concerned with scenario analyses in order to determine emission reducing energy mix. Five scenarios are constructed and solved in General Algebraic Modeling System (GAMS). The study shows that there are options to mitigate CO_2 emissions while meeting demand on electricity.

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions

Author	***Title***	***Variables***	***Conclusion***
(Lean & Smyth, 2010)	CO_2 emissions, electricity consumption and output in ASEAN	• *CO_2 emissions* • Real GDP per capita • Electricity consumption per capita	There is significant non-linear relationship between CO_2 emission and income, and positive relationship between CO_2 emission and electricity consumption.
(Menyah & Wolde-Rufael, 2010)	CO_2 emissions, nuclear energy, renewable energy and economic growth in the US	• *CO_2 emissions* • Renewable energy consumption • Nuclear energy consumption • Real GDP	Nuclear energy consumption has potential to mitigate CO_2 emissions but renewables have not reached such a level.
(Marques, Fuinhas, & Pires Manso, 2010)	Motivations driving renewable energy in European countries: A panel data approach	• *Contribution of renewables to energy supply, % of total* • Integration in the EU and EU membership in 2001, dummies • Energy import dependency • Oil, gas and coal prices • Per capita CO_2 emission • Electricity generation from coal • Electricity generation from oil • Electricity generation from gas • Electricity generation from nuclear • Per capita energy consumption • GDP • Continuous commitment to renewable energy, dummy (1 if share of RE is greater than 10%) • Geographic area	EU membership promotes renewable deployment. Lobby pressure, being energy independent, CO_2 emissions and income are main drivers.

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions, continued

Author	***Title***	***Variables***	***Conclusion***
(Sharma, 2011)	Determinants of carbon dioxide emission: Empirical evidence from 69 countries	• *Per capita CO_2 emissions* • Trade, % of GDP • Urban population, % of total • GDP per capita, constant 2000 US$ • Electric power consumption per capita • Energy consumption per capita	GDP per capita and urbanization are the main determinants for CO_2 consumption. Other variables have insignificant effect.
(Meireles, Soares, & Afonso, 2012)	Are We Following the Right Path? Assessment of the Portuguese Electricity Generation on Atmospheric Emissions	• *Specific emissions* • Amount of energy released by domestic coal for each unit of electricity generated in 12 thermal power plants • Amount of energy released by import coal for each unit of electricity generated in 12 thermal power plants • Amount of energy released by fuel oil for each unit of electricity generated in 12 thermal power plants • Amount of energy released by gas oil for each unit of electricity generated in 12 thermal power plants • Amount of energy released by natural gas for each unit of electricity generated in 12 thermal power plants • Liberalisation • Existence of stack treatment	Coal is the largest emitter. Only SO_2 emissions show negative relationship with liberalisation.
(Gao & Zhang, 2014)	Electricity Consumption-Economic Growth-CO_2 Emissions Nexus in Sub-Saharan Africa: Evidence from Panel Cointegration	• *Per capita CO_2 emissions* • Per capita electricity consumption • Per capita GDP	There are long-run bidirectional causality among variables.

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions, continued

Author	***Title***	***Variables***	***Conclusion***
(Farhani & Shahbaz, 2014)	What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO_2 emissions in MENA region?	• *Per capita CO_2 emissions* • Per capita GDP • Renewable electricity consumption • Non-renewable electricity consumption	GDP and emission relationship supports Environmental Kuznets Curve hypothesis. The higher is the electricity consumption the higher is the CO_2 emission.
(Li & Wang, 2015)	The effects of coal switching and improvements in electricity production efficiency and consumption on CO_2 mitigation goals in China	• Fuel consumption of thermal power generation • Coal intensity of thermal power generation • Aggregate energy consumption • Population • Electricity consumption • Proportion of coal in aggregate energy consumption • Share of tertiary industry in aggregate GDP	To attain CO_2 emission goals, China should accelerate low carbon fuel switching and increase efficiency.
(Yi, 2015)	Clean-energy policies and electricity sector carbon emissions in the U.S. states	• *Total carbon emission* • *Electricity generation* • *Electricity consumption* • *Electricity sector carbon intensity* • Supply-side policy • Demand-side policy • Efficiency policy • Percentage of electricity generated from coal • Percentage of electricity generated from natural gas • Percentage of electricity generated from hydropower • Percentage of electricity generated from nuclear power • Percentage of electricity generated from renewables • Gross state production • State unemployment rate • Population	Supply-side energy policies are successful in reduction of CO_2 intensity.

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions, continued

Author	***Title***	***Variables***	***Conclusion***
		• Heating degree days • Cooling degree days • Per capita income • Electricity price • Electricity imports and exports • Energy NGOs • State citizen ideology	
(Dogan & Seker, 2016)	Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy	• *CO_2 emissions* • GDP • Electricity production from renewables • Electricity production from non-renewables • Trade openness	Renewable energy and trade mitigate CO_2 emissions.
(Chan, Fell, Lange, & Li, 2017)	Efficiency and environmental impacts of electricity restructuring on coal-fired power plants	• *Heat Rate* • *Cost of coal purchase* • Plant level coal input use • Plant-level net generation • Coal characteristics • Scrubber installed • Restructuring completed • Date of law-passed on the state-level	Restructuring promoted fuel efficiency and resulted in 15% savings in operation costs and 7.5% emission reduction.
(Zrelli, 2017)	Renewable energy, non-renewable energy, carbon dioxide emissions and economic growth in selected Mediterranean countries	• *Real GDP* • Renewable electricity consumption • Nonrenewable electricity consumption • CO_2 emissions	Renewable energy is important for economic growth and emission reduction in Mediterranean.

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions, continued

Author	***Title***	***Variables***	***Conclusion***
(Liddle & Sadorsky, 2017)	How much does increasing non-fossil fuels in electricity generation reduce carbon dioxide emissions	• *CO_2 emissions per capita* • Per capita GDP • Per capita non-fossil fuel consumption • Share of electricity generated from non-fossil sources • Coal price • Natural gas price • Share of GDP from industry	Increased non-fossil fuel consumption moderately reduces CO_2 emissions.
(Balsalobre-Lorente, Shahbaz, Roubaud, & Farhani, 2018)	How economic growth, renewable electricity and natural resources contribute to CO_2 emissions?	• *Per capita CO_2 emissions* • Per capita GDP • Renewable electricity consumption • Trade openness • Energy innovation • Natural resource abundance	N-shaped relationship between economic growth and CO_2 emissions exist. Renewable electricity consumption, natural resources and energy innovation improve environmental quality, others exert positive pressure on CO_2 emissions.
(Cai, Sam, & Chang, 2018)	Nexus between clean energy consumption, economic growth CO_2 emissions	• *Per capita real GDP* • CO_2 emissions • Nuclear energy consumption • Hydroelectricity consumption • Solar energy consumption • Wind energy consumption	Clean energy consumption increases GDP per capita in Canada, US and Germany. CO_2 emissions promote clean energy in Germany.
(Fotis & Polemis, 2018)	Sustainable development, environmental policy and	• SO_2 emissions • NO_x emissions • NMVOC • emissions	To attain energy efficiency and sustainable development, EU

Table 3-2. Studies with Panel Data Analysis of Electricity Generation and Carbon Emissions, continued

Author	***Title***	***Variables***	***Conclusion***
	renewable energy use: a dynamic panel data approach GHG	• Share of renewable energy in gross final energy consumption • Electricity generated from renewable sources as a percentage of gross electricity consumption • Energy saving • Energy intensity • Real GDP	should support new technologies and renewable use.
(Nguyen & Kakinaka, 2019)	Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis	• *Renewable energy consumption* • *Non-renewable energy consumption* • Real GDP • CO_2 emissions • Real oil price	For low income countries renewable energy contributes CO_2 emissions and lowers growth, and vice versa for high income countries.
(Lin & Li, 2020)	Is more use of electricity leading to less carbon emission growth? An analysis with panel threshold model	• *CO_2 emissions* • Primary energy use • Per capita electricity consumption • Electricity generation from clean energy • GDP • Population • Urban population • GDP from industry	Electricity consumption, especially clean energy-based electricity, level negatively affects carbon emissions whereas population, urbanization and industrialization augment.

CHAPTER 4

TURKEY'S ENERGY OUTLOOK

This chapter provides a snapshot of Turkey's energy policy, electricity generation and due carbon emissions. Information on domestic coal reserves, and capacity of solar and wind energies is given.

4.1 Turkey's Energy Policy

A country's energy policy should aim providing cheap, clean and secure energy. Cheap energy is important for a healthy economy in terms of productivity of business and living standards of citizens. Clean energy is vital in the face of air and water pollution as well as pressing climate change. Secure energy is also important for living standards of a nation since it becomes more energy dependent as it prospers. (Griffin, 2009)

Turkey's energy and resource demand has been increasing due to her economic activity. Since 2002 Turkey has the largest rise in demand to electricity among OECD countries. As of May 2021, country's electricity generation capacity is 97,689.5 MW[2], three times higher than 2002 capacity. An important characteristic of Turkish energy system is its high energy intensity. Although Turkey's per capita energy consumption is lower than OECD average, her energy intensity is 3.3 times higher than Denmark and Japan, whose per capita energy consumption ratios are 3.7 and 3.5, respectively, times higher than Turkey. This indicates that Turkey uses energy inefficiently. Besides continuous rising demand and inefficiency, foreign-

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[2] Turkish Electricity Transmission Corporation, May 2021 Installed Capacity Report, https://www.teias.gov.tr/tr-TR/kurulu-guc-raporlari, last accessed: 30.06.2021

source dependency is another fundamental characteristic of Turkish energy system. Therefore, aim is to lower this dependency through energy strategy. Prioritizing energy security without neglecting sustainability concerns is one of the principles of energy strategy. To achieve this, share of domestic sources and renewables, and energy efficiency will be increased. Source diversification is also important in this respect. Besides, Turkish energy policy aims to support R&D activities, and continue establishing an open and competent energy market (M. Balat, 2010; Dış İşleri Bakanlığı, 2011).

Turkish energy policy needs to consider the relationship between economy and energy prices, demand-supply balance since the country experiences high demand rise, and dependency on foreign sources. Turkey's geopolitics as a transit country is also important for her energy security because the country is poor of fossil sources but surrounded with neighbors having huge sources. One new challenge for Turkey is climate change because it is defined by and defines energy consumption (Çimen, 2010; Ediger, 2010).

4.2 Turkey's Electricity Sector and Assessment of Coal, Wind and Solar Potentials

Turkey's first electricity generation plant was established in 1902 in Tarsus by a 2kW capacity water mill. In 1913 first anthracite-fired power plant, Silahtarağa Electric Plant, started operation in İstanbul. Generation capacity reached 45 MW with 38 plants in 1923 and was 500 MW in 1950 (Karagöl & Tür, 2017). As stated above, current installed capacity is 97.69 GW (see Figure 4-1). Below Figure 4-2 shows contribution of each primary source with total capacity of plants. The largest capacity belongs to hydropower plants with 32.9%, 23.8% (23.2 GW) dams and 8.29% (8.1 GW) river. Among fossil fuels, natural gas-fired power plants make the biggest contribution with 25.7 GW (26.33%). Total installed capacity of coal-fired power plants is 20.3 GW. Lignite with 10.1 GW (10.36%), import coal 8.9 GW (9.2%), anthracite with 0.8 GW (0.83%) and asphaltite with 0.4 GW (0.41%) constitute this sum. Renewables, wind 9.89% (9.66 GW), solar with 7.32% (7.1 GW), geothermal 1.69% (1.65 GW) and biomass 1.23% (1.2 GW), make 20.13% of total installed capacity. Thus, total fossil-based capacity is 46.68 GW (47.78%) and non-fossil is 51.01 GW (52.22%). In terms of primary sources, domestic share in installed capacity is 64.21%.

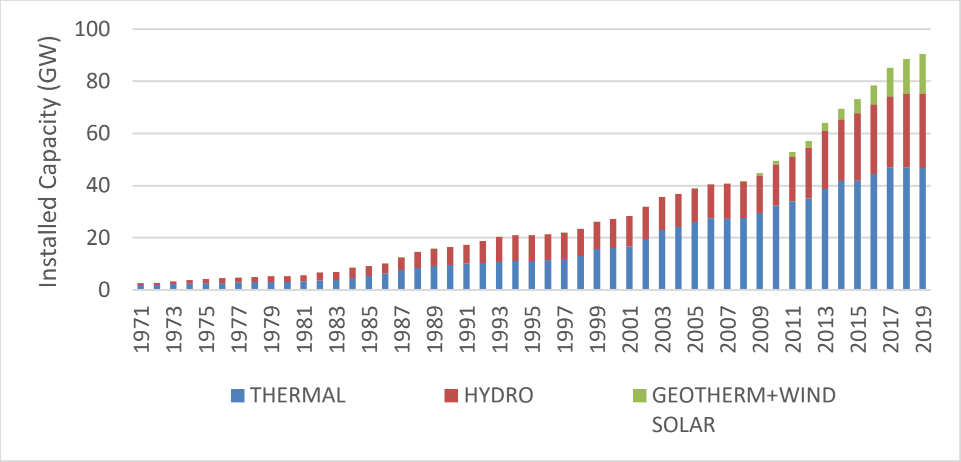

Figure 4-1. Change in Turkey's Installed Capacity from 1971 (Source: TEİAŞ)

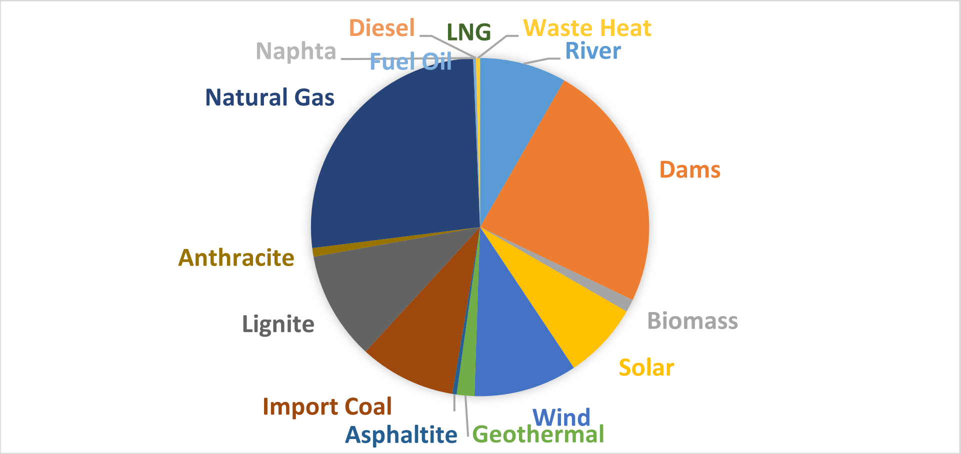

Figure 4-2. Turkey’s Installed Capacity Distribution based on Primary Energy Sources (Source: TEİAŞ)

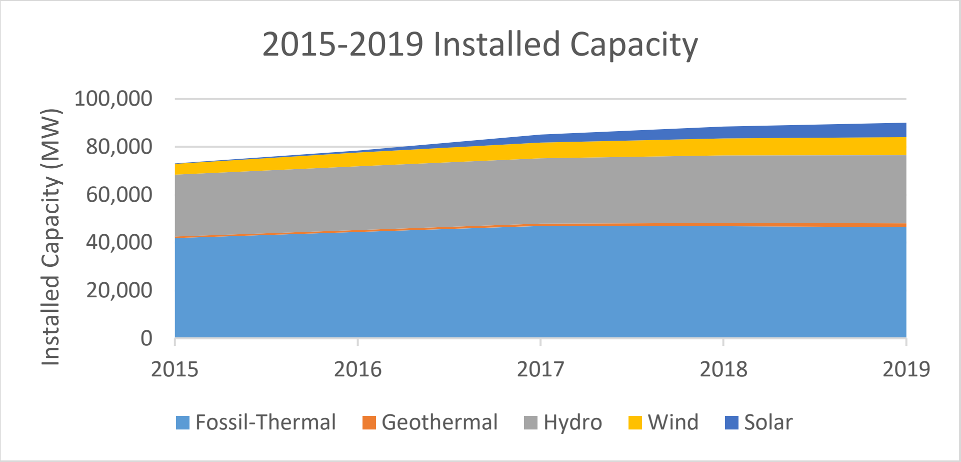

Figure 4-3. Change in Installed Capacity between 2015 and 2019 (Source: TEİAŞ)

In 2018 with 1,642.2 MW solar had the largest increased capacity. Following solar, dams with 760.10 MW and wind with 460.10 MW capacities have the second and third rank, respectively. Increase in installed capacity of river-type hydropower plants was 258.20 MW and that of geothermal was 218.80 MW. In short, in 2018 capacity was increased by 4,025 MW and 93% of this was sourced by renewable power (Dikmen, 2019). Comparing the current installed capacity with the 2009 Supply Security Strategy, only the target lowering share of natural gas to below 30% has been attained. It is possible to extend this analysis for the period, 2015 – 2019, covered by the last Strategy Report of Ministry of Energy and Natural Resources, which commits decreasing energy import dependency via domestic sources, and increasing share of renewables (ETKB, 2017). According to sector reports of Turkish Electricity Transmission Corporation (TEİAŞ)[3], installed capacities based on primary source types and annual change in each source type are shown by Figure 4-3 and Figure 4-4, respectively. Installed capacity of the country has increased every year and as narrated above, share of fossil is always the largest and considerably rose in 2016 and 2017 as other non-fossil sources. Unfortunately, it is not possible to

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[3] Sector Reports of Turkish Electricity Transmission Corporation: https://www.teias.gov.tr/tr-TR/sektor-raporlari, last access: 22.03.2020

observe share of coal and natural gas separately. Regarding non-fossil sources, their share has significantly increased, solar with the largest rise, even larger than the rise in fossil fueled-power plants. Specifically, during 2015 – 2019, rise in installed capacity of solar is 5,350.4 MW whereas that of fossil is 4,909 MW, and total of non-fossil is 11,877.7 MW, almost three times higher than fossil-based sources. In brief, Turkey was in progress, although slight, towards accomplishing her security and sustainability goals in energy for the last five years.

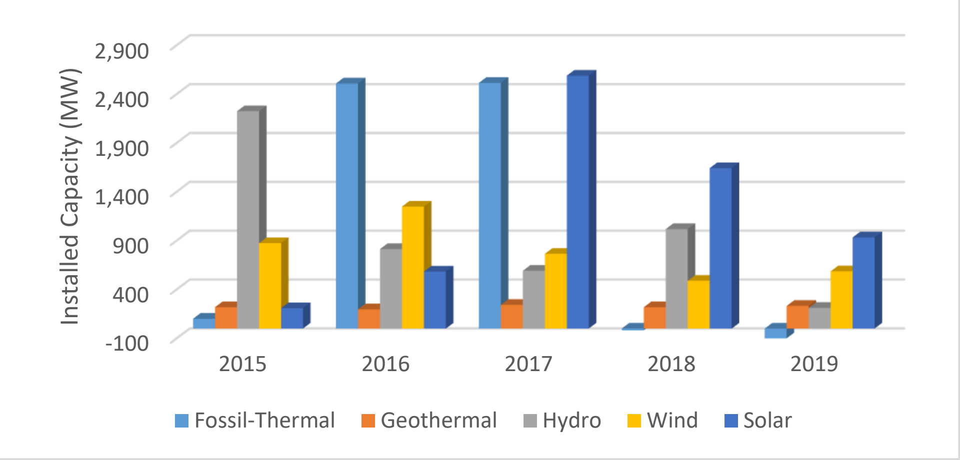

Figure 4-4. Change in Installed Capacity of Each Primary Energy Source between 2015 and 2019 (Source: TEİAŞ)

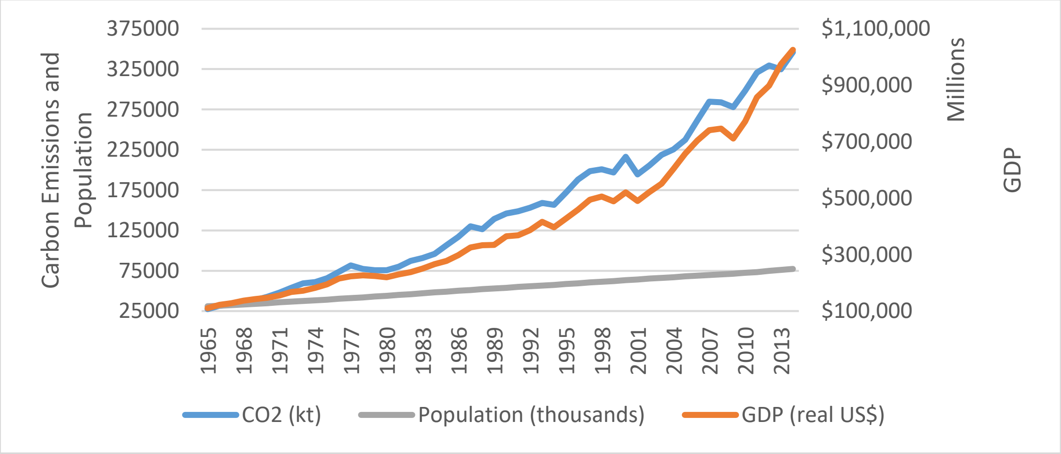

Figure 4-5. Turkey’s Carbon Emission Profile (Source: WDI)

Referring to the discussion in Section 2.2 on the contribution of electricity generation to climate change, Turkey’s emission profile is presented above. As shown by Figure

4-5, Turkey's total carbon emission has an increasing trend in accordance with her GDP rise. However, Turkey's population growth does not exhibit a sharp inclination as carbon and GDP trends. According to the data obtained from World Development Indicators database (WDI), Turkey's carbon dioxide emission was 27,388.82 kt in 1965 and reached 345,981.45 kt in 2014. In almost 50 years, country's emission increased more than 10 times, GDP less than 10 times and population 2.5 times.

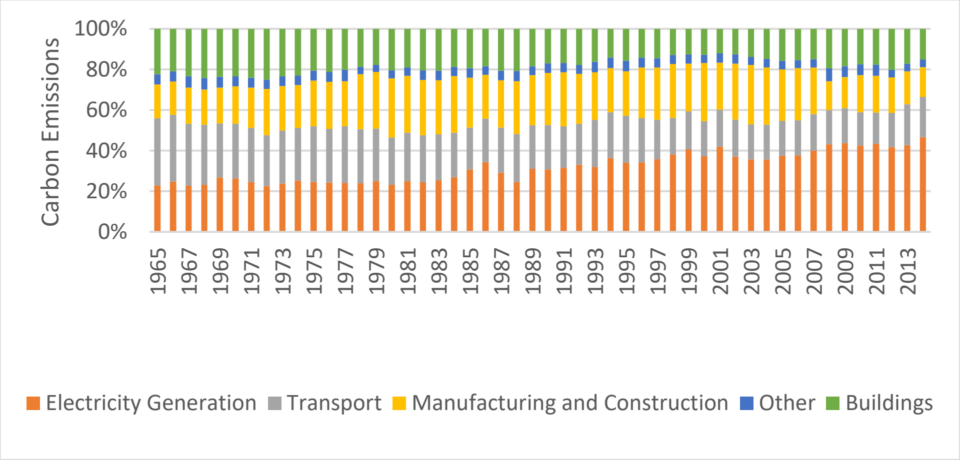

Figure 4-6. Turkey's Sectoral Carbon Emission Profile in kt (Source: WDI)

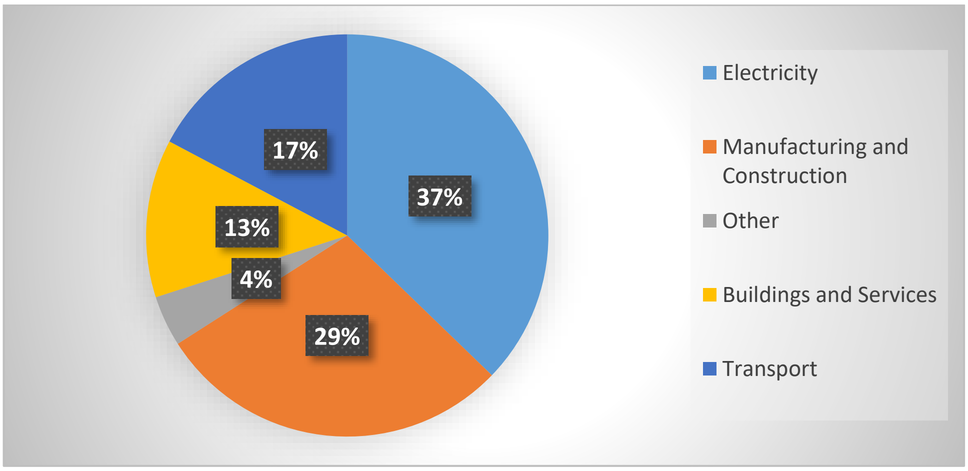

Figure 4-7. Turkey's Sectoral Carbon Emission Profile in 2000 in kt (Source: WDI)

Figure 4-6 is a depiction of change in sectoral emissions causing this increase. Before 1980s, largest share of emission belonged to transport, ranging between 33% and 25%. Starting with 1980, electricity generation outweighs all other sectors in carbon emission and reaches 46% in 2014. Figure 4-7 and Figure 4-8 are comparison of this change in 2000 and 2014. In fifteen years, share of electricity sector has risen from 37% to 43%.

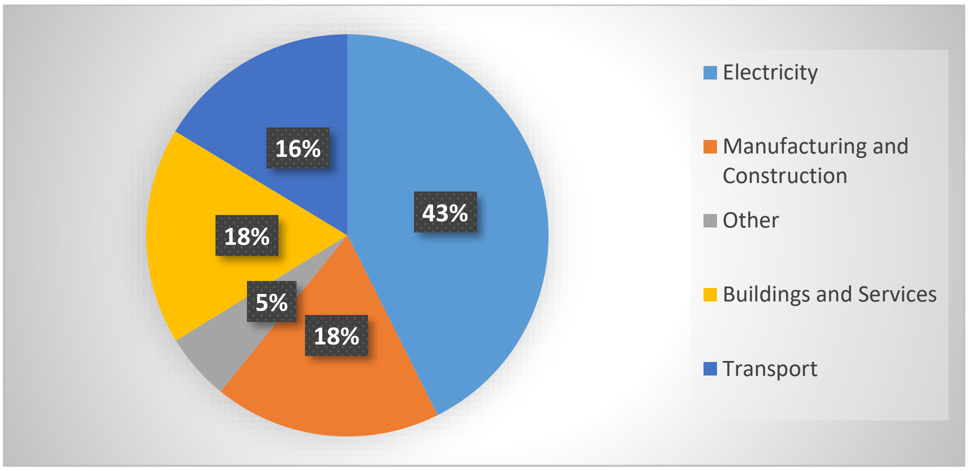

Figure 4-8. Turkey’s Sectoral Carbon Emission Profile in 2010 in kt (Source: WDI)

4.2.1 Turkey’s Domestic Energy Sources

This section focuses on Turkey’s coal reserves and potential of solar and wind powers since this dissertation is questioning faith of these three primary energy sources in Turkey’s future energy mix in connection with electricity supply security and climate change mitigation issues.

Coal Reserves

Compared with the world reserve and production values, Turkey’s capacity is assessed as medium for lignite and low for anthracite. 3.2% of world lignite/sub-bituminous coal reserves is found in Turkey but used only for thermal power generation due to low heat capacity.

Zonguldak and surroundings have the most valuable anthracite reserves in the country. Although total amount is estimated as 1.3 billion tons, productive amount is about 506 million tons (ETKB, n.d.-b). The earliest records of anthracite production in Turkey date back to 1865. Total production between 1865 and 2018 was more than 400 million tons. In 1974 maximum production capacity, 5 million tons/year, was attained but after 1982 production rate started decreasing as anthracite imports increased. In the early 1980s, domestic anthracite production was able to meet 80% of the country's need. This value decreased to 45% to the end of the same decade and was only 3.29% in 2017. Share of thermal anthracite in imports is large and more than half of it is used in thermal power generation (Türkiye Taşkömürü Kurumu, 2018).

Total lignite reserves of Turkey is 17.9 billion tons and 46% of these reserves are in Afşin-Elbistan basin (ETKB, n.d.-b). Nevertheless, calorific value of domestic lignite is quite low, ranging between 1,000 and 4,200 kcal/kg, 90% of the reserves have a value less than 3,000 kcal/kg. Unlike anthracite, domestic lignite production has fluctuated. In 1970s lignite production gained importance and the capacity reached to almost 65 million tons in 1998 from 5.8 million tons in 1970. Due to increasing natural gas imports, domestic lignite production dwindled after 1998. However, since 2014 there has been an increasing production trend again and 2017 production was 71.46 million tons (Türkiye Kömür İşletmeleri Kurumu, 2017).

Turkey also has asphaltite reserves. These are in South-east Anatolia Region and make up a total of 82 million tons. Calorific value of the asphaltite in Turkey ranges between 2,876 and 5,536 kcal/kg. Unlike lignite and anthracite, asphaltite production is low in the country. In 1980 production was 558,000 tons and it only reached to 668,000 tons in 2005 (Demir, 2009). Asphaltite has been generally used by industry and construction but since 2015 it has been being exploited for electricity generation (Demirci, Sivrikaya, & Vapur, 2019).

Solar Potential

Based on measurements of insolation and flux, Turkey's annual average insolation has been calculated as 2,741 hours (7.5 h/d) and total average flux as annually 1,527 kWh/m^2 (4.18 kWh/(m^{2}day)) (ETKB, n.d.-a). Mainly Mediterranean and South-East regions of Turkey have the highest potentials according to Solar Power Potential Map (EİGM, n.d.) as shown by Figure 4-9. Conversion of this potential to electricity is a function of photovoltaic (PV) area installed along with efficiency of the technology (Önenli, 2019). For instance,(H. Balat, 2005) calculates PV-based electricity generation as 56 TWh/year. (Ertekin, Kulcu, & Evrendilek, 2008) estimate solar potential of Turkey as 88 million tonnes of oil equivalent (mtoe) per year without any technical, economic or environmental restriction. They claim that 40% of this potential, equal to 409.4 TWh[4], is economically feasible. Comparing with 2019 electricity generation, 304.3 TWh[5], Turkey's solar potential looks promising for the country's future electricity demand.

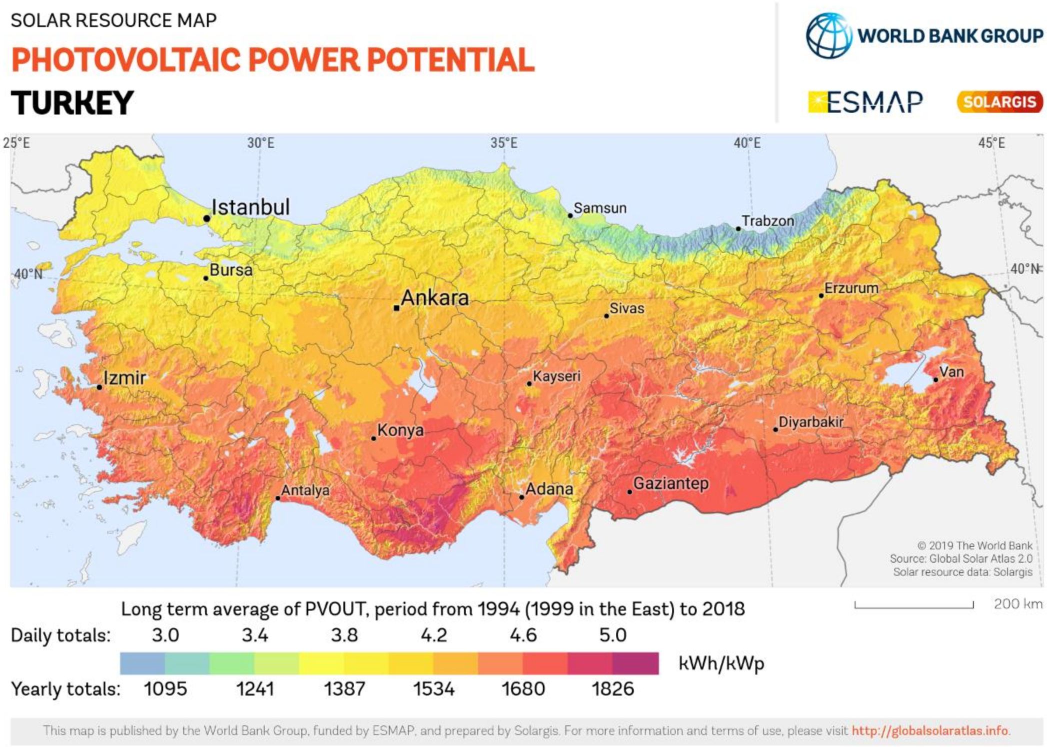

Figure 4-9. Turkey's PV Power Potential (Source: SolarGIS[6])

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[4] IEA Unit Converter and Glossary, https://www.iea.org/reports/unit-converter-and-glossary, last access: 24.03.2020

[5] Turkish Electricity Transmission Corporation, https://www.teias.gov.tr/tr-TR/rakamlarla-elektrik-iletimi, last access: 24.03.2020

[6] SolarGIS, 2021, Solar resources maps of Turkey, https://solargis.com/maps-and-gis-data/download/turkey, last access: 22.03.2021

Wind Potential

Turkey has a potential of 5 MW/m^2 at 50 m height with 7.5 m/s wind speed, which makes up 48 GW (ETKB, n.d.-c). This potential constitutes more than half of the current total installed capacity. According to the Wind Potential Map of Turkey, highest potentials exist in Çanakkale, Balıkesir, İzmir and Hatay (YEGM, n.d.).

CHAPTER 5

METHODOLOGY, DATA, RESULTS, AND DISCUSSION

This chapter explains the methodology and data employed, and is concluded with discussion of the results.

5.1 Methodology

One aim of this dissertation is to prove that econometrics is very helpful for Earth System Science also. Although econometrics is primary for economic measurement, it is used as a set of research techniques by other fields of study such as accounting, finance, marketing, management, social sciences, e.g. history, sociology and political science, and forestry and agricultural economics (Hill, Griffiths, & Lim, 2012). This list is expected to be updated with Earth System Science. Econometrics is related with providing the best estimate of parameters, mainly economic, given the data as a basis for statistical inference. In other words, with the help of econometric models and a sample of data, inferences about the real world are made through estimating, predicting and testing (Hill et al., 2012).

Panel data analysis is used for statistical inference in this dissertation. A panel of data is formed by combination of cross-sectional units, e.g. people, households, firms, countries, who are observed over time. In other words, panel data is obtained by “pooling time-series of cross-sections”. Generally, these cross-sectional units are referred as individuals even they contain information on firms or countries. The number of cross-sectional units are denoted by N, and the number of time periods in which these units are observed are indicated by T. Pooling data results in a diverse source of variation which enables more efficient parameter estimates (Baltagi, 2011; Hill et al., 2012). (Hsiao, 2014) lists advantages of panel data as follows:

1. Panel data enables researchers to obtain more reliable inference of parameters because there are large numbers of observations, and larger degrees of freedom. Panel data also reduces collinearity among independent variables.
2. Researchers are able to analyze important questions by panel data because panel data merges “interindividual differences with intraindividual dynamics, which is not possible with cross-sectional or time series data.

The following formula is an example of panel data regression equation, in which cross-sections and time series are pooled. i denotes cross-sectional units and t denotes time. Initially, regressors are assumed as nonstochastic, and the error term behaves accordingly with the classical assumptions, $E(u_{it}) \sim N(0, \sigma^2)$ (Gujarati, 2004).

$$Y_{it} = \beta_1 + \beta_2 X_{2it} + \beta_3 X_{3it} + u_{it} \tag{5-1}$$

Estimation of (5-1) requires the following assumptions about the intercept, the slope coefficient, and the error term. Each assumption increases complexity for estimation of panel data regression model. Because of collinearity, further complexity might be added with introduction of more independent variables (Gujarati, 2004):

1. Constant intercept and slope coefficients across time and space. The differences over time and units are explained by the error term.
2. Constant slope coefficients, varying intercept over units.
3. Constant slope coefficients, varying intercept over both units and time.
4. All parameters vary over units.
5. All parameters vary over units and time.

Based on the above assumptions, there are four structures for panel data models (Greene, 2018):

Pooled Regression: If the model only has a constant term, i.e. no group-specific variables, ordinary least squares are able to provide consistent and efficient estimates of the common intercepts and slope coefficients.

Fixed Effects: If there are unobserved effects correlated with regressors, then least square estimator of slope coefficients are biased and inconsistent due to omitted variable. Fixed effects assumes intercept as group-specific constant term having nonstochastic correlation with independent variables.

Random Effects: Unobserved individual heterogeneity is assumed to be uncorrelated with regressors. In such a case, a linear regression with compound errors are estimated efficiently but not consistently by least squares. Random effects approach accepts error term as a group-specific random element that enters the regression in each period.

Random Parameters: A modification of random effects approach that is all coefficients vary randomly for individuals as well as the constant term. This approach allows more heterogeneity across individuals but retains some commonalities among parameters.

In this study fixed effects model is used. The estimation technique in comparison with random effects model is explained below.

5.1.1 Fixed Effects Model

Taking individuality of each unit is possible with a varying intercept with constant slope coefficients. The formula (5-2) represents such a relationship. Subscript i on the intercept term indicate that each cross-sectional unit has different intercept due to unobserved effects (Gujarati, 2004).

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + u_{it} \tag{5-2}$$

The model represented by (5-2) is known as fixed effects regression, where the intercept differs across cross-sectional units but constant over time (Gujarati, 2004).

5.1.2 Random Effects Model

If there is uncertainty regarding individual effects, random error term is introduced to reflect individuality of units. ε_i term of the formula (5-3) is inserted to capture unobservable individual effects and is called error components model or random effects model (Gujarati, 2004).

$$Y_{it} = \beta_{1i} + \beta_2 X_{2it} + \beta_3 X_{3it} + u_{it} + \varepsilon_i$$

(5-3)

ε_i is the cross-section, or individual-specific, error component and is called unobservable, or latent, variable; u_{it} is the combined error component of time series and cross-sections. Both error terms are assumed to be not correlated with each other and not auto-correlated across cross-sections and time series (Gujarati, 2004).

Taking

$$\nu_{it} = u_{it} + \varepsilon_i$$

(5-4)

Error term assumptions for the random effects model is summarized below (Hill et al., 2012):

Zero mean: $E(\nu_{it}) = 0$

(5-5)

Homoskedasticity: $var(\nu_{it}) = \sigma_u^2 + \sigma_\varepsilon^2$

(5-6)

Errors for individual cross-sections are correlated: $cov(\nu_{it}, \nu_{js}) = \sigma_\varepsilon^2 \; for \; t \neq s$

(5-7)

Errors for different individuals are uncorrelated: $cov(\nu_{it}, \nu_{js}) = 0 \; for \; i \neq j$

(5-8)

Errors u_{it} are not correlated with independent variables:

$$cov(u_{it}, X_{2it}) = 0, cov(u_{it}, X_{3it}) = 0 \tag{5-9}$$

Random effects are uncorrelated with dependent variables:

$$cov(\varepsilon_i, X_{2it}) = 0, cov(\varepsilon_i, X_{3it}) = 0 \tag{5-10}$$

5.1.3 Specification Tests

This section explains panel specification tests used for this study.

Breusch-Pagan Lagrange Multiplier Test

(Breusch & Pagan, 1980) define Lagrange Multiplier (LM) as one of the asymptotic test techniques that econometric models are susceptible to. “LM test is based on estimation with the hypothesis imposed as parametric restrictions” and is generally more useful with restricted models. However, there are situations in which maximum likelihood estimation under the null hypothesis is not easy. For such situations they propose a pseudo-LM method based on heteroscedastic regression. It has the same asymptotic properties as the true one but requires only root-*N* consistent estimators of the unknow parameters.

Breusch-Pagan LM Test is used to decide between Pooled Ordinary Least Square (OLS) and Random Effects Model. If the null hypothesis, $H_0: \sigma_u^2 = 0$ that is homoskedasticity, is rejected, it is to conclude that random individual differences exist and random effects model is more appropriate than a pooled regression model (Hill et al., 2012).

Chow Test

Chow Test reveals whether parameters of one group are equal to parameters of other groups. In other words, it is used to choose between Pooled OLS and Fixed Effects

Model. Fixed effects model is chosen if only the intercepts differ among groups. If the null hypothesis

$$H_0 : \forall \alpha_i = \alpha \; and \; \forall \beta_i = \beta \tag{5-11}$$

is rejected, groups have different slopes and intercepts, therefore, data is not suitable for pooling[7].

Hausman Test

Hausman test is used to check whether the error component ε_i is correlated with regressors in a random effects model. Unless there is correlation between ε_i and independent variables, estimators of both the random effects and fixed effects are consistent, and they should converge to true parameter values in large samples. If ε_i is correlated with any of the regressors, only fixed effects estimator is consistent. In such a case, for large samples the fixed effects estimator converges to true parameter value while the random effects estimator converges to some other value. Hausman test can be carried out using *t*-test, jointly with *F*-test or χ^2-test, for testing that there is no difference between the estimators (Hill et al., 2012):

$$t = \frac{b_{FE,k} - b_{RE,k}}{\left[\widehat{var}(b_{FE,k}) - \widehat{var}(b_{RE,k})\right]^{1/2}} \tag{5-12}$$

,where $b_{FE,k}$ is the fixed effects estimate and $b_{RE,k}$ is the random effects estimate of the parameter β_k.

Modified Wald Test

This test is used as a statistic for groupwise heteroskedasticity in the residuals after

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[7] Gould, W., n. d., Can you explain Chow Tests?, Stata, https://www.stata.com/support/faqs/statistics/chow-tests/, Last access: 24.04.2021

a fixed effect model with assuming homoskedasticity. A likely deviation from homoskedasticity in a panel data model is related with error variances due to characteristics of cross-sections. Modified Wald statistic tests $H_0: \sigma_i^2 = \sigma$ for all cross-sectional units distributed over χ^2[8].

Testing for Weak Cross-sectional Dependence

In case a time-invariant ordering reveals itself among cross-sectional units, dependence of cross-sections (i.e. spatial autocorrelation) is tested referring to a pre-specified connection matrix (Pesaran, 2004) that provides characteristics of the spatial dependence pattern according to pre-specified rules (Pesaran, 2015).

(Pesaran, 2004) proposes the below test to overcome shortcoming of the Breusch-Pagan LM test. The alternative is "based on pair-wise correlation coefficients":

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{p_{ij}}\right)$$

(5-13)

,where $\widehat{p_{ij}}$ is "the sample estimate of the pair-wise correlation of the residuals and expressed as

$$\widehat{p_{ij}} = \widehat{p_{ji}} = \frac{\sum_{t=1}^{T} e_{it}e_{jt}}{(\sum_{t=1}^{T} e_{it}^2)^{1/2}\left(\sum_{t=1}^{T} e_{jt}^2\right)^{1/2}}$$

(5-14)

and e_{it} is the OLS estimate of u_{it}.

For fixed values of N and T the above statistic (5-13) has exactly zero mean regarding a variety of panel data models, including unbalanced panels.

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[8] Baum, C. F., 2000, Modified Wald statistics for groupwise heteroskedasticity in fixed effect model, xttest3, Statalist Distribution

5.2 Data

Data for all countries and geographic divisions are downloaded from WDI database. Countries not members of EU, OECD, BRICS or ASEAN are eliminated and remaining are cleaned off missing observations. After cleaning 47 countries are left (see Table 5-1). In order to obtain the most up-to-date data available, IEA and BP databases are also used. The final dataset contains data from three databases: WDI, BP and IEA. WDI provides energy-related data for 1960 – 2015 with gaps in cross-sections and time series. BP provides data for years after 2015 but there are less cross-sections than WDI. Moreover, fossil-based electricity generation data of BP is far shorter than its nonfossil-based power generation data. To overcome these problems, energy-related data for 47 countries have been compiled from IEA webpage, which covers the period between 1990 and 2017. Missing observations on electricity generation from non-fossil sources by BP are replaced with those of EIA.

Table 5-1 List of Countries

Name	**Code**	**EU**	**OECD**	**ASEAN**	**BRICS**	**n**
Australia	AUS	0	1	0	0	28
Austria	AUT	1	1	0	0	28
Belgium	BEL	1	1	0	0	28
Brazil	BRA	0	0	0	1	28
Canada	CAN	0	1	0	0	28
Switzerland	CHE	0	1	0	0	26
Chile	CHL	0	1	0	0	28
China	CHN	0	0	0	1	28
Colombia	COL	0	1	0	0	28
Czech Republic	CZE	1	1	0	0	28
Germany	DEU	1	1	0	0	28
Denmark	DNK	1	1	0	0	28
Spain	ESP	1	1	0	0	28
Estonia	EST	1	1	0	0	25
Finland	FIN	1	1	0	0	28
France	FRA	1	1	0	0	28

Table 5 1 List of Countries, continued

Name	Code	EU	OECD	ASEAN	BRICS	n
United Kingdom	GBR	0	1	0	0	28
Greece	GRC	1	1	0	0	28
Hungary	HUN	1	1	0	0	27
Indonesia	IDN	0	0	1	0	28
India	IND	0	0	0	1	28
Ireland	IRL	1	1	0	0	28
Iceland	ISL	0	1	0	0	28
Israel	ISR	0	1	0	0	28
Italy	ITA	1	1	0	0	28
Japan	JPN	0	1	0	0	28
Korea, Rep.	KOR	0	1	0	0	28
Luxembourg	LUX	1	1	0	0	28
Latvia	LVA	1	1	0	0	22
Mexico	MEX	0	1	0	0	28
Myanmar	MMR	0	0	1	0	18
Malaysia	MYS	0	0	1	0	28
Netherlands	NLD	1	1	0	0	28
Norway	NOR	0	1	0	0	28
New Zealand	NZL	0	1	0	0	28
Philippines	PHL	0	0	1	0	28
Poland	POL	1	1	0	0	28
Portugal	PRT	1	1	0	0	28
Russian Federation	RUS	0	0	0	1	28
Singapore	SGP	0	0	1	0	26
Slovak Republic	SVK	1	1	0	0	28
Slovenia	SVN	1	1	0	0	28
Sweden	SWE	1	1	0	0	28
Thailand	THA	0	0	1	0	28
Turkey	TUR	0	1	0	0	28
United States	USA	0	1	0	0	28

Table 5 1 List of Countries, continued

Name	Code	EU	OECD	ASEAN	BRICS	n
South Africa	ZAF	0	0	0	1	28

Table 5-2 Description of Variables

Variable	Label
AFC	Dummy for 1997 Asian Financial Crisis
SEPT11	Dummy for 9/11
GFC	Dummy for 2007 - 2009 Global Financial Crisis
EC	Dummy for global energy crisis due to high crude oil prices between 2008 and 2012
COP21	Dummy for Paris Agreement
FUKUSHIMA	Dummy for the Fukushima Daiichi NPP explosion in 2011
H	Countries with higher than 12375$ per capita income based on WB 2019 classificat
UM	Countries with less than 12376$ and higher than 3995$ per capita income based on
LM	Countries with less than 3996$ and higher than 1025$ per capita income based on
L	Countries with less than 1026$ per capita income based on WB 2019 classification
lnCO2	Natural logarithm of carbon dioxide emissions, million tonnes,
lnEI	Natural logarithm of net energy imports, million tonnes of oil equivalent
lnCTP	Natural logarithm of electricity generation by coal, TWh
lnGTP	Natural logarithm of electricity generation from natural gas sources, TWh
lnSP	Natural logarithm of electricity generation by solar pv, gross output, TWh
lnWP	Natural logarithm of electricity generation from wind power, gross output, TWh
lnNP	Natural logarithm of electricity generation from nuclear power, TWh
lnINDUSTRY	Natural logarithm of total final energy consumption by industry sector, ktoe
lnRESIDENT	Natural logarithm of total final energy consumption by residential sector, ktoe
lnTRANSPORT	Natural logarithm of total final energy consumption by transport sector, ktoe
lnSERVICE	Natural logarithm of total final energy consumption by service sector, ktoe
lnENERGYINTENSITY	Natural logarithm of total primary energy supply by GDP, toe per 2010 constant US$
lnCARBONINTENSITY	Natural logarithm of carbon dioxide emissions by GDP, kg CO_2 per 2010 constant US$
lnGDP	Natural logarithm of current billion US$
lnPOP	Natural logarithm of total population, million

Table 5-3 Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
lnCO2	1292	4.81	1.618	.693	9.133
lnEI	989	3.2	1.522	0	6.601
lnCTP	1188	3.117	2.242	-6.908	8.409
lnGTP	1232	2.248	2.33	-6.804	7.257
lnSP	785	-3.213	3.121	-11.513	4.769
lnWP	959	-1.226	3.108	-11.744	5.687
lnNP	637	3.635	1.454	-2.9	6.745
lnINDUSTRY	1292	9.316	1.568	5.864	13.837
lnTRANSPORT	1292	9.233	1.508	5.293	13.351
lnRESIDENTIAL	1292	9.079	1.558	5.609	12.718
lnSERVICE	1292	8.165	1.521	3.85	12.262
lnENERGYINTENSITY	1292	-1.846	.615	-3.219	.049
lnCARBONINTENSITY	1292	-1.12	.695	-2.813	.924
lnGDP	1292	5.631	1.587	1.388	9.877
lnPOP	1292	3.054	1.763	-1.367	7.234

Variables summarized by Table 5-2 and described by Table 5-3 are included in the analyses. lnCO2 and lnEI are the dependent variables estimated. lnCO2 is estimated because it is the prime concern in climate change as it is a by-product of energy generation. lnEI is accepted as a proxy of energy security, meaning that the larger is the net energy import of a nation, the greater is its dependency to foreign energy sources. Despite of air pollution and carbon emissions, coal will be used in electricity generation in the coming decades because it already exists in the energy mix, is able to supply continuous power, and there are many countries with coal reserves.Therefore, lnCTP is included in the analyses. lnGTP is taken due to the same reasons of lnCTP. Additionally, gas-fired power plants are seen as the best available alternatives to nuclear power, which has been seriously objected due to inherent risks although it is climate friendly. lnNP is included because there are still a quite number of countries generating their electricity from nuclear power. lnSP and lnWP are included because they are the key variables of this dissertation, with lnCTP, since these technologies are the hope for climate change mitigation. Moreover, their role in energy security is of interest. Sectoral energy consumption data are included since sectors substantially contribute to climate change, play critical roles in energy security, and are function of development of nations. Energy intensity and carbon in-

Table 5-4 Matrix of Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) lnCO2	1.000														
(2) lnEI	0.793	1.000													
(3) lnCTP	0.948	0.727	1.000												
(4) lnGTP	0.755	0.759	0.722	1.000											
(5) lnSP	0.428	0.464	0.403	0.499	1.000										
(6) lnWP	0.459	0.379	0.393	0.498	0.634	1.000									
(7) lnNP	0.535	0.703	0.415	0.371	0.291	0.184	1.000								
(8) lnINDUSTRY	0.967	0.746	0.890	0.667	0.359	0.452	0.508	1.000							
(9) lnTRANSPORT	0.954	0.823	0.849	0.763	0.461	0.513	0.671	0.918	1.000						
(10) lnRESIDENTIAL	0.957	0.725	0.883	0.669	0.366	0.513	0.522	0.943	0.916	1.000					
(11) lnSERVICE	0.922	0.853	0.815	0.771	0.465	0.470	0.710	0.882	0.957	0.887	1.000				
(12) lnENERGYINTEN~Y	0.332	-0.001	0.419	-0.045	-0.154	-0.113	-0.120	0.380	0.129	0.366	0.073	1.000			
(13) lnCARBONINTEN~Y	0.522	0.168	0.652	0.204	0.009	-0.035	-0.095	0.504	0.295	0.484	0.231	0.916	1.000		
(14) lnGDP	0.879	0.838	0.751	0.789	0.557	0.594	0.679	0.846	0.947	0.844	0.950	-0.107	0.071	1.000	
(15) lnPOP	0.919	0.661	0.855	0.609	0.358	0.462	0.364	0.920	0.847	0.942	0.777	0.485	0.589	0.744	1.000

tensity deemed important in different respects. Energy intensity is a measure of energy efficiency, the “fifth fuel”, and an indicator of nations’ commitment to climate change mitigation. Carbon intensity on the other hand is expected to provide basis for the ‘domestic fuel discourse’ as almost all the countries disproportionately have fossil reserves. Finally, lnGDP and lnPOP are present in the regressions because they are the primary drivers of energy and power consumption as well as carbon emissions.

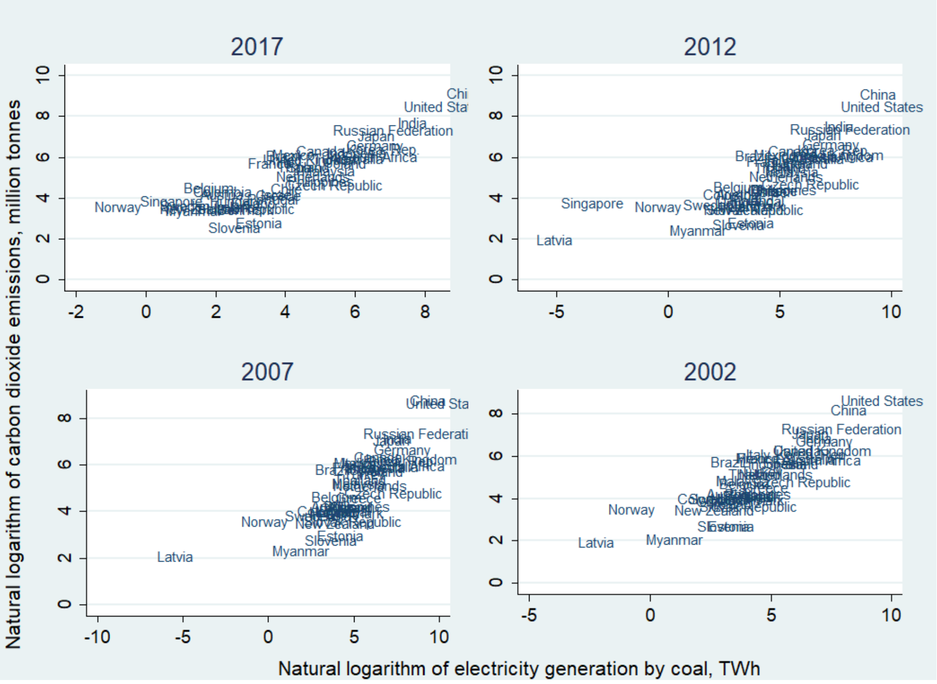

Figure 5-1. Scatterplot of lnCO2 and Natural Logarithm of Electricity Generation by Coal

Figure 5-1 – Figure 6-10 (In Appendix B), and Figure 5-4 – Figure 6-20 (in Appendix B) scatter plots of the regressands lnCO2 and lnEI with regressors, respectively. All the regressors have positive trends although lnSP and lnWP are expected to scatter with negative trends but direction of correlation with efficiency and income variables is not clear.

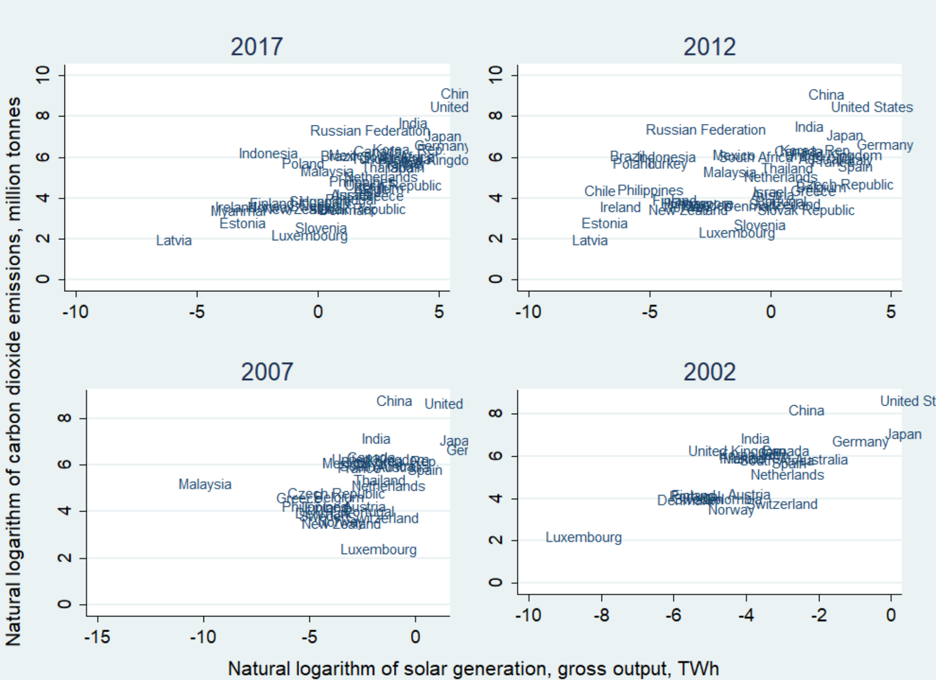

Figure 5-2. Scatterplot of lnCO2 and Natural Logarithm of Solar Generation

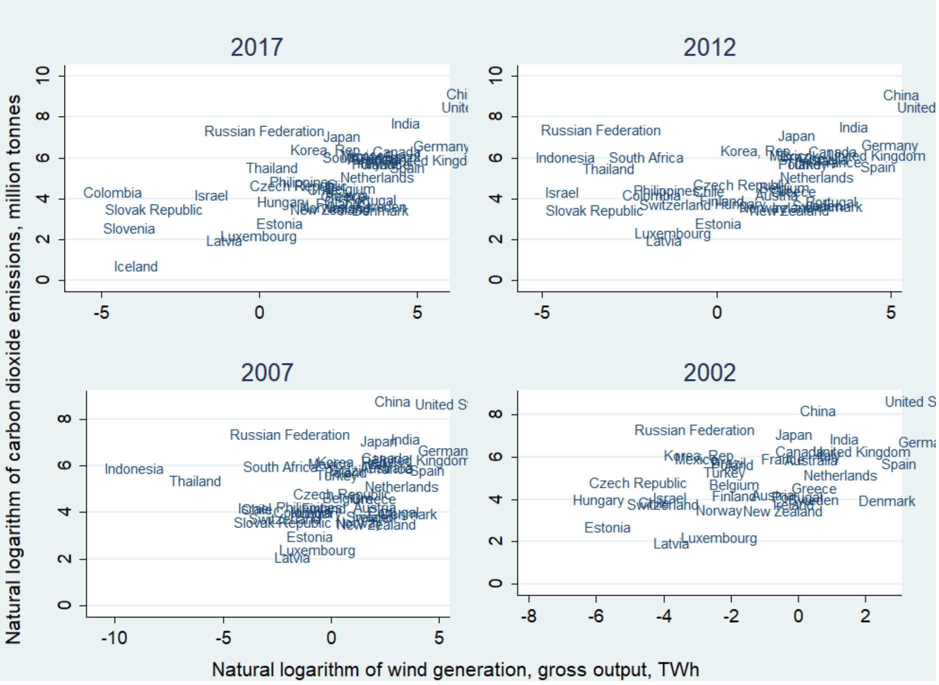

Figure 5-3. Scatterplot of lnCO2 and Natural Logarithm of Wind Generation

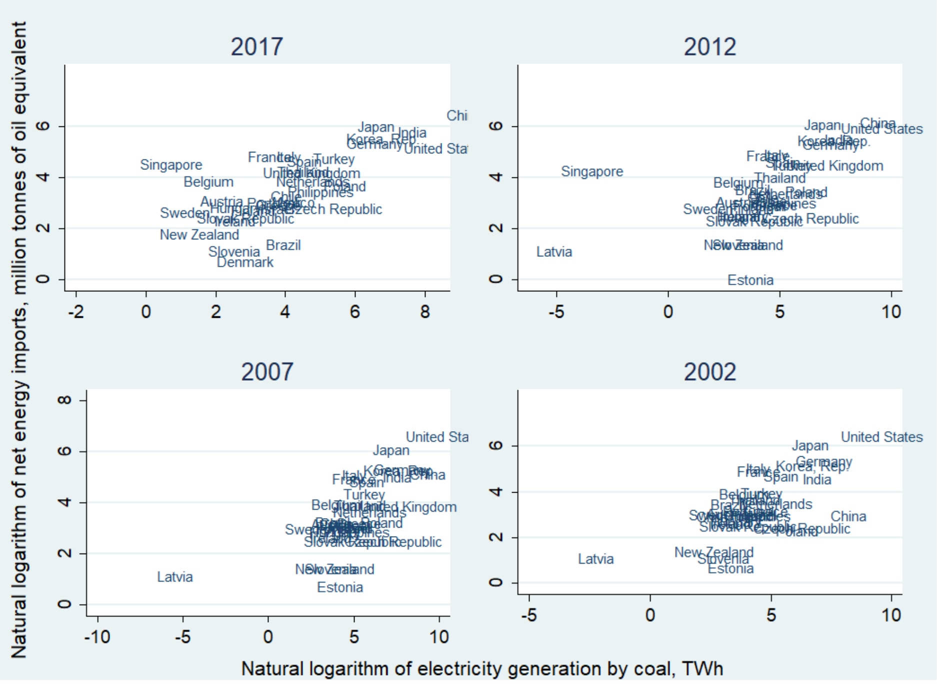

Figure 5-4. Scatterplot of lnEI and Natural Logarithm of Electricity Generation by Coal

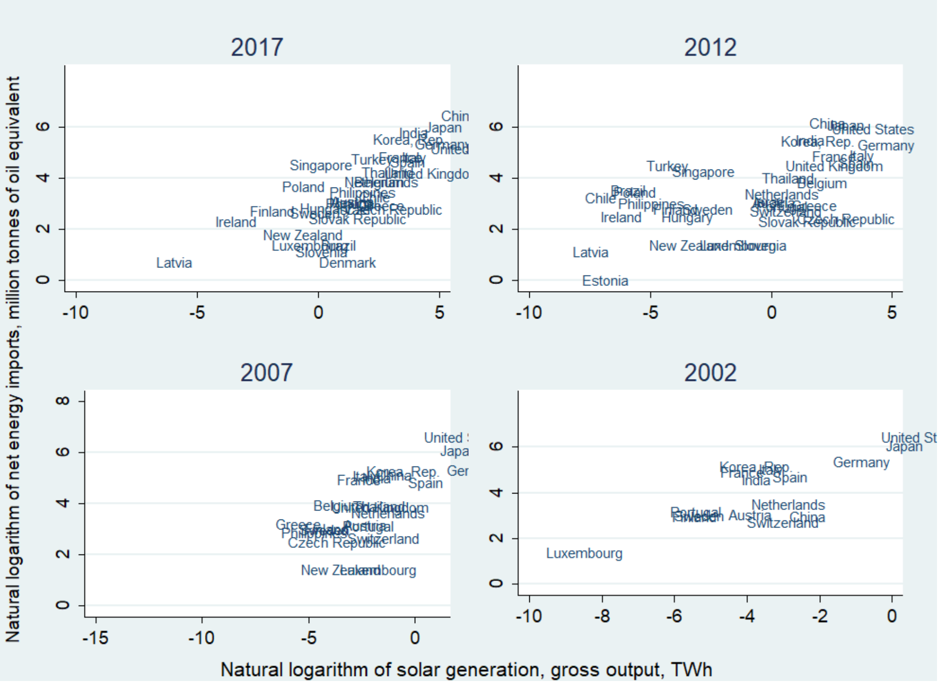

Figure 5-5. Scatterplot of lnEI and Natural Logarithm of Solar Electricity Generation

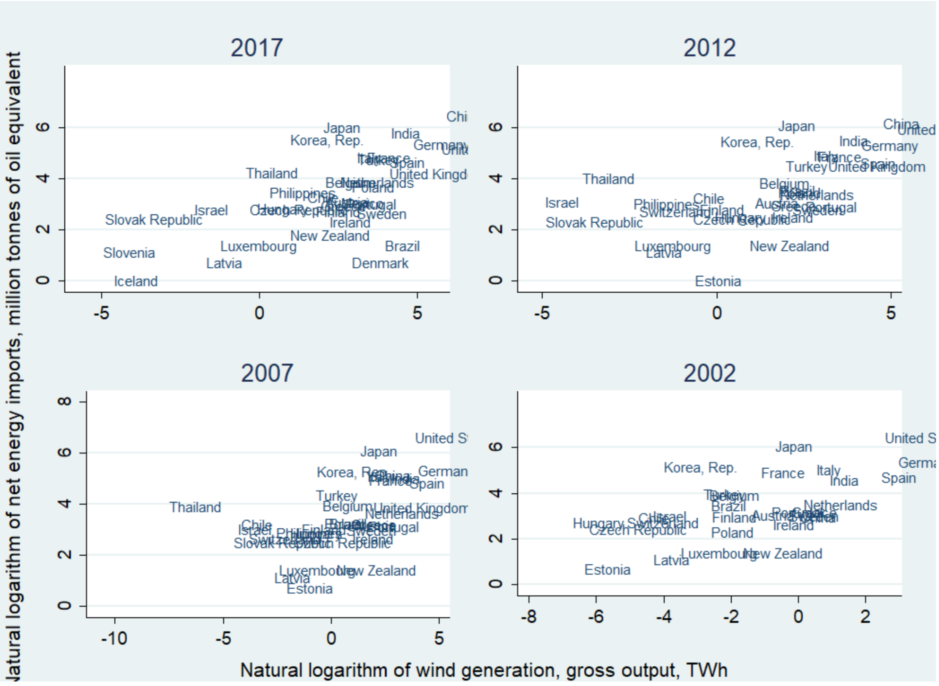

Figure 5-6. Scatterplot of lnEI and Natural Logarithm of Electricity Generation by Wind

Comparing the behavior of the countries, China becomes leader in all variables after 2007. Figure 5-1 shows the correlation between carbon emissions and coal utilization in electricity generation. Latvia’s generation from coal is less than 1 TWh/a and starting in 2014, the country does not use coal. Therefore, it is not seen on 2017 scatter. On the other hand, in 2012 it is the first time that Singapore utilizes coal in electricity generation, less than 1 TWh, and that is the reason why it is distinctively seen on 2012 graph. Figure 6-1 is another demonstration of increasing use of gas in electricity generation. In 2007 South Africa is distinct because gas was introduced to energy mix first in 2003 and in 2007 its contribution was still less than 1 TWh/a. Figure 6-2 shows countries having nuclear in their energy mix. As seen, the graph is almost static, i.e., there is not a clear change in nuclear use in electricity generation. Only Japan becomes distinct starting in 2012, which might be attributed to Fukushima Daiichi accident in 2011. Figure 5-2 indicates increasing number of countries utilizing solar power in power generation. After 2012, it is possible to infer that in terms of capacity, countries converge to each other. Similarly, Figure 5-3 shows that in every 5-years more countries include wind in their energy mix. Nevertheless, it is not possible to mention any convergence among countries as in solar power. Countries like China, United States, Germany, United Kingdom and Denmark keep their leading role through 2002 – 2017. Figure 6-3 – Figure 6-6 (in Appendix B) show sectoral energy consumption without considerable changes in country profiles. Figure 6-7 and Figure 6-8 (in Appendix B) depict the relationship between energy intensity and carbon intensity with carbon emissions. Actually, they are the same and it is possible to state that increasing carbon intensity increases energy intensity and carbon emissions. On both figures Denmark is distinct in 2017 because the country has accomplished reducing carbon emissions, uses comparatively less fossil in electricity generation after 2012. Figure 6-9 and Figure 6-10 (in Appendix B) are repetition of the relationship between GDP and population with carbon release. The higher are the former the higher is the latter. Figure 5-4 – Figure 6-20, however, do not help for remarkable inference. Except for few countries like China, net energy import of a country does not change considerably. Therefore, it is not possible to comment on the impact of increases in regressor variables to net energy imports.

Figure 5-7 depicts relationship between carbon emissions and GDP rise for selected countries. As seen only Germany has decoupled growth and emissions. Others including Turkey emit more accordingly with income rise but Spain, Greece, Italy and Portugal release less CO_2 because their income has decreased. Figure 5-8 shows the same trends with real values.

Figure 5-9 shows change of energy import for selected countries. There is not any distinct trend for Germany, Spain, Greece, Italy and Portugal. The remaining countries have continued increasing their energy imports.

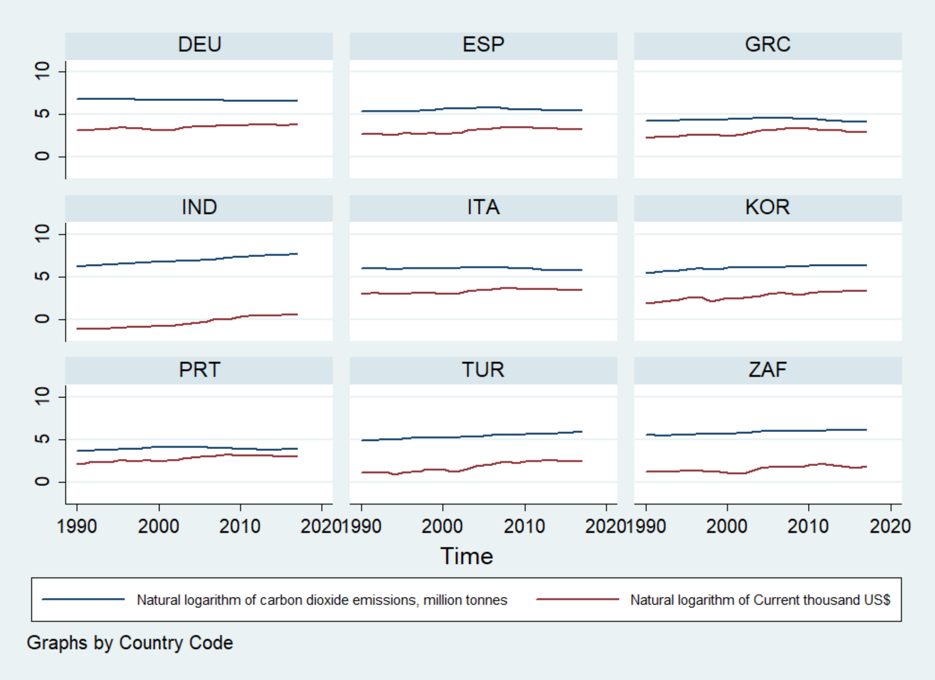

Figure 5-7. Change of CO_2 and GDPCAP for Selected Countries in Linear Form

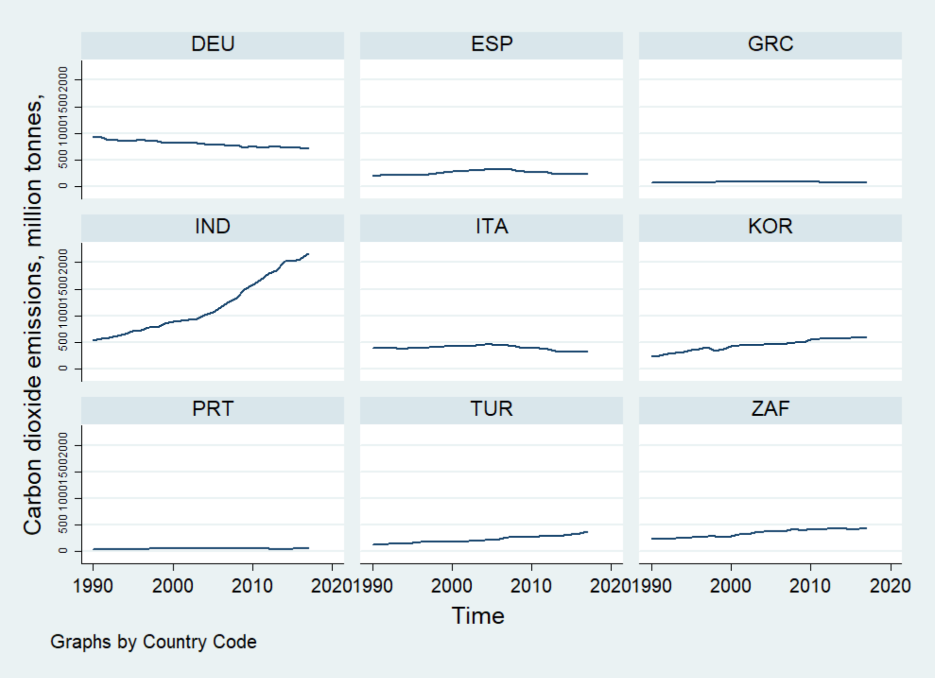

Figure 5-8. Change of CO_2 for Selected Countries

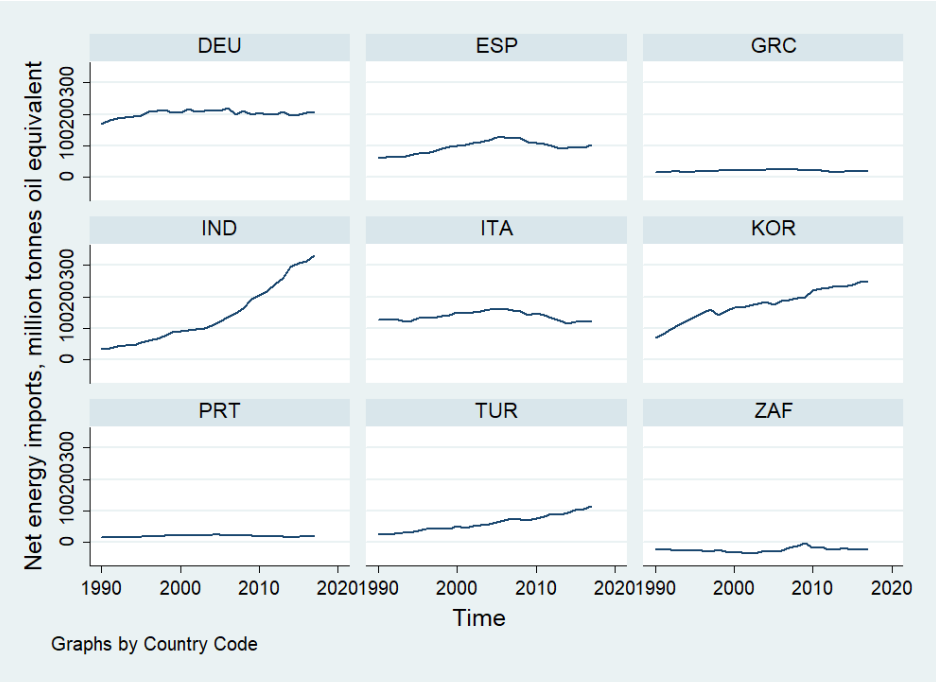

Figure 5-9. Change of Energy Import for Selected Countries

5.3 Econometric Analyses and Results

The aim of this study is to lay the link between climate change mitigation and energy security and assess the role of coal in securing energy. To accomplish this, two panel data models are generated. Table 5-5 give panel descriptive statistics.

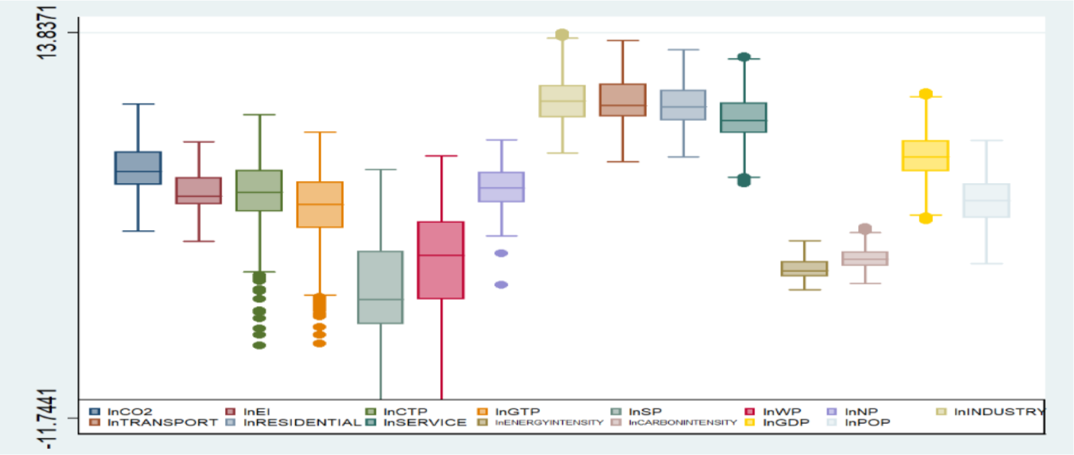

Figure 5-10 Boxplot of Variables

Table 5-5 Panel Descriptive Statistics

Variable		Mean	Std.Dev.	Min	Max	Observations		
lnCO2	overall	4.810	1.618	0.693	9.133	N	=	1292
	between		1.636	0.693	8.565	n	=	47
	within		0.207	3.866	5.809	T-bar	=	27.489
lnEI	overall	3.200	1.522	0	6.601	N	=	989
	between		1.468	0	6.127	n	=	38
	within		0.437	-1.329	5.120	T-bar	=	26.026
lnCTP	overall	3.117	2.242	-6.908	8.409	N	=	1188
	between		2.616	-5.561	7.526	n	=	45
	within		0.536	-0.721	5.459	T-bar	=	26.400
lnGTP	overall	2.248	2.330	-6.804	7.257	N	=	1232
	between		2.047	-2.309	6.606	n	=	46

Table 5-5 Panel Descriptive Statistics, continued

	Variable	Mean	Std.Dev.	Min	Max	Observations	Variable	
	within		1.185	-2.969	5.858	T-bar	=	26.783
lnSP	overall	-3.213	3.121	-11.513	4.769	N	=	785
	between		1.864	-8.261	0.502	n	=	46
	within		2.588	-10.950	3.612	T-bar	=	17.065
lnWP	overall	-1.226	3.108	-11.744	5.687	N	=	959
	between		2.186	-6.763	2.921	n	=	44
	within		2.401	-8.362	3.776	T-bar	=	21.796
lnNP	overall	3.635	1.454	-2.900	6.745	N	=	637
	between		1.395	1.334	6.648	n	=	23
	within		0.484	-1.058	5.447	T-bar	=	27.696

Table 5-5 Panel Descriptive Statistics, continued

Variable	Mean	Std.Dev.	Min	Max	Observations	Variable	
lnINDU~Y overall	9.316	1.568	5.864	13.837	N	=	1292
between		1.580	6.502	13.127	n	=	47
within		0.246	7.946	10.362	T-bar	=	27.489
lnTRAN~T overall	9.233	1.508	5.293	13.351	N	=	1292
between		1.518	5.511	13.258	n	=	47
within		0.249	7.995	10.324	T-bar	=	27.489
lnRESI~L overall	9.079	1.558	5.609	12.718	N	=	1292
between		1.566	5.813	12.577	n	=	47
within		0.130	8.384	9.594	T-bar	=	27.489

Table 5-5 Panel Descriptive Statistics, continued

Variable	Mean	Std.Dev.	Min	Max	Observations	Variable	
lnSERV~E overall	8.165	1.521	3.850	12.262	N	=	1292
between		1.525	4.622	12.158	n	=	47
within		0.346	6.703	10.156	T-bar	=	27.489
lnENER~Y overall	-1.846	0.615	-3.219	0.049	N	=	1292
between		0.596	-2.991	-0.599	n	=	47
within		0.182	-2.449	-1.123	T-bar	=	27.489
lnCARB~Y overall	-1.120	0.695	-2.813	0.924	N	=	1292
between		0.665	-2.500	0.383	n	=	47
within		0.219	-1.870	-0.396	T-bar	=	27.489
lnGDP overall	5.631	1.587	1.388	9.877	N	=	1292
between		1.526	2.440	9.340	n	=	47

Table 5-5 Panel Descriptive Statistics, continued

Variable	Mean	Std.Dev.	Min	Max	Observations	Variable	
within		0.548	3.840	7.356	T-bar	=	27.489
lnPOP overall	2.678	1.664	-1.464	6.689	N	=	1292
between		1.674	-1.301	6.237	n	=	47
within		0.131	2.126	3.130	T-bar	=	27.489

Both Table 5-5 and Figure 5-10 show statistical properties of the variables. ‘within variation’ is variation over time or given individual (time-variant) whereas ‘between variation’ is the variation across individuals (time-invariant). In general, electricity generation, GDP and GDP generating sectors, industry and service, exhibit huge variance both within and between variation. Others like population, residential and transport sectors do not vary much in time but differences among cross-sections are significant. These facts support Fixed Effects model choice.

The first is estimation of carbon emissions as given by the below regression function for an unbalanced panel of 47 countries that is number of observations varies for cross-sections:

$$\begin{aligned} lnCO2_{it} = \beta_0 + \beta_1 lnCTP_{it} + \beta_2 lnGTP_{it} + \beta_3 lnSP_{it} + \beta_4 lnWP_{it} + \beta_5 lnINDUSTRY_{it} \\ + \beta_6 lnTRANSPORT_{it} + \beta_7 lnENERGYINTENSITY_{it} \\ + \beta_8 lnCARBONINTENSITY_{it} + \beta_9 lnGDP_{it} + \beta_{10} lnPOP_{it} + u_{it} \end{aligned} \tag{5-15}$$

Fixed Effects model is able to provide consistent and efficient estimates and estimation results are presented below. Appendix A gives Random Effects model results.

lnCO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.210	0.009	23.33	0.000	0.192	0.228	***
lnGTP	0.030	0.004	7.35	0.000	0.022	0.038	***
lnSP	-0.003	0.002	-2.00	0.046	-0.006	0.000	**
lnWP	-0.012	0.002	-5.82	0.000	-0.017	-0.008	***
lnINDUSTRY	0.456	0.019	24.42	0.000	0.419	0.492	***
lnENERGYINTENSITY	0.159	0.032	4.90	0.000	0.095	0.222	***
lnGDP	0.080	0.013	5.98	0.000	0.054	0.107	***
lnPOP	0.648	0.077	8.37	0.000	0.496	0.800	***
Constant	-2.474	0.293	-8.46	0.000	-3.048	-1.899	***

Mean dependent var	5.462	SD dependent var	1.469
R-squared	0.889	Number of obs	687.000
F-test	638.409	Prob > F	0.000
Akaike crit. (AIC)	-2004.346	Bayesian crit. (BIC)	-1963.555

**** p<0.01, ** p<0.05, * p<0.1*

Above results show estimations for 41 cross-sections. As expected electricity generation by solar and wind power reduces carbon emissions (95% and 99%

confidence, respectively) and coal-based electricity generation contributes to carbon partial pressure in the atmosphere (99% confidence). According to the results, ceteris paribus 1% increase in solar generation releases 0.003% less and wind-based electricity generation releases 0.012% less CO_2, while coal-based electricity generation emits 0.210% more CO_2. Similarly, 1% electricity generation from gas-fired power plants releases 0.030% (99% confidence), industrial activities 0.456% (99% confidence), 1% increase in energyintensity 0.159% (99% confidence), 1% income rise 0.080% (99% confidence) and population increase 0.648% (99% confidence) more carbon. It is necessary to note that high R^2 (0.899) is the result of atmospheric carbon mass balance. In other words, each of the independent variables contribute to carbon emissions and especially coal-based electricity generation, industrial energy consumption and industrial energy consumption variables boost the coefficient of determination.

Below results show the estimates with some of the dummy variables listed by Table 5-2. As seen 2008 – 2012 global energy crisis (EC) caused 0.024% less CO_2 emissions. Being an upper-mid income or lower-mid income country increases carbon emissions by 0.072% and 0.0112%, respectively.

lnCO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.208	0.009	24.13	0.000	0.191	0.225	***
lnGTP	0.034	0.004	8.65	0.000	0.026	0.042	***
lnSP	-0.004	0.002	-2.56	0.011	-0.007	-0.001	**
lnWP	-0.009	0.002	-4.48	0.000	-0.013	-0.005	***
lnINDUSTRY	0.385	0.020	19.08	0.000	0.345	0.424	***
lnENERGYINTENSITY	0.229	0.033	7.01	0.000	0.165	0.293	***
lnGDP	0.116	0.015	7.62	0.000	0.086	0.146	***
lnPOP	0.536	0.076	7.08	0.000	0.387	0.685	***
EC	-0.024	0.006	-4.11	0.000	-0.036	-0.013	***
UM	0.072	0.014	5.21	0.000	0.045	0.099	***
LM	0.112	0.016	6.82	0.000	0.080	0.144	***
Constant	-1.475	0.307	-4.80	0.000	-2.078	-0.872	***

Mean dependent var	5.462	SD dependent var	1.469
R-squared	0.899	Number of obs	687.000
F-test	514.820	Prob > F	0.000
Akaike crit. (AIC)	-2064.692	Bayesian crit. (BIC)	-2010.303

*** *p<0.01, *** *p<0.05, ** *p<0.1*

The second is estimation of energy imports as given by the below regression function for an unbalanced panel of 47 countries:

$$\begin{aligned} lnEI_{it} = \beta_0 + \beta_1 lnCTP_{it} + \beta_2 lnGTP_{it} + \beta_3 lnSP_{it} + \beta_4 lnWP_{it} + \beta_5 lnINDUSTRY_{it} \\ + \beta_6 lnTRANSPORT_{it} + \beta_7 lnENERGYINTENSITY_{it} \\ + \beta_8 lnCARBONINTENSITY_{it} + \beta_9 lnGDP_{it} + \beta_{10} lnPOP_{it} + u_{it} \end{aligned}$$

(5-16)

Fixed Effects model is able to provide consistent and efficient estimates and estimation results are presented below. **Error! Reference source not found.**Random Effects model results are presented in Appendix A. Because of collinearity, there are two estimation results, one with lnWP and the other with lnSP.

Below results show estimations with lnWP for 34 cross-sections (net energy importers). As expected electricity generation by wind power reduces energy imports (95% confidence) but coal-based electricity generation also contributes to foreign energy dependence (99% confidence). According to the results, ceteris paribus 1% increase in wind-based electricity generation results in 0.024%, energy intensity 0.999% (99% confidence) and population 2.484% (99% confidence) less imports. Increase in coal-based electricity generation by 1% results in 0.283%, gas-fired electricity generation 0.064% (99% confidence), industrial activities 0.829% (99% confidence) and income rise 0.347% (99% confidence) more energy imports.

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.283	0.037	7.69	0.000	0.210	0.355	***
lnGTP	0.064	0.019	3.44	0.001	0.027	0.101	***
lnWP	-0.024	0.010	-2.35	0.019	-0.044	-0.004	**
lnINDUSTRY	0.829	0.103	8.04	0.000	0.626	1.031	***
lnENERGYINTENSITY	-0.999	0.168	-5.94	0.000	-1.329	-0.669	***
lnGDP	0.347	0.073	4.77	0.000	0.204	0.489	***
lnPOP	-2.484	0.387	-6.41	0.000	-3.244	-1.723	***
Constant	-1.418	1.267	-1.12	0.263	-3.905	1.070	

Mean dependent var	3.572	SD dependent var	1.441
R-squared	0.421	Number of obs	711.000
F-test	69.474	Prob > F	0.000
Akaike crit. (AIC)	501.651	Bayesian crit. (BIC)	538.184

*** *p<0.01, *** *p<0.05, ** *p<0.1*

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.223	0.038	5.82	0.000	0.148	0.299	***
lnGTP	0.117	0.032	3.66	0.000	0.054	0.181	***
lnSP	-0.026	0.008	-3.41	0.001	-0.042	-0.011	***
lnRESIDENTIAL	-0.349	0.161	-2.17	0.030	-0.665	-0.033	**
lnGDP	0.912	0.081	11.24	0.000	0.752	1.071	***
lnPOP	-2.171	0.635	-3.42	0.001	-3.419	-0.924	***
Constant	7.637	2.062	3.70	0.000	3.586	11.688	***
Mean dependent var		3.860	SD dependent var			1.438	
R-squared		0.449	Number of obs			561.000	
F-test		70.585	Prob > F			0.000	
Akaike crit. (AIC)		331.746	Bayesian crit. (BIC)			362.054	

**** p<0.01, ** p<0.05, * p<0.1*

Above results show estimations with lnSP for 36 cross-sections. As expected electricity generation by solar power reduces energy imports (99% confidence) but coal-based electricity generation contributes to foreign energy dependency (99% confidence). In this estimation, industrial energy consumption and energy intensity variables' estimations are insignificant but residential energy consumption is in the regression function. According to the results, ceteris paribus 1% increase in solar-based electricity generation results in 0.026%, residential energy use 0.349% (95% confidence) and increase in population 2.171% (99% confidence) less energy imports, and coal-based electricity generation results in 0.223%, gas-fired electricity generation 0.117% (99% confidence) and income rise %0.912 (99% confidence), more energy imports. Energy imports models generate significant estimates with some of the dummy variables listed by Table 5-2.

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.227	0.036	6.24	0.000	0.155	0.298	***
lnGTP	0.051	0.019	2.69	0.007	0.014	0.088	***
lnWP	-0.029	0.010	-2.80	0.005	-0.050	-0.009	***
lnINDUSTRY	0.690	0.107	6.47	0.000	0.481	0.900	***
lnENERGYINTENSITY	-0.735	0.166	-4.43	0.000	-1.061	-0.409	***
lnGDP	0.256	0.073	3.51	0.000	0.113	0.399	***
UM	0.144	0.052	2.76	0.006	0.042	0.246	***
Constant	-7.049	0.881	-8.00	0.000	-8.778	-5.320	***
Mean dependent var		3.572	SD dependent var			1.441	
R-squared		0.392	Number of obs			711.000	
F-test		61.687	Prob > F			0.000	
Akaike crit. (AIC)		535.982	Bayesian crit. (BIC)			572.516	

**** p<0.01, ** p<0.05, * p<0.1*

According to the above results, being an upper-mid income country increases energy imports by 0.144% (99% confidence) if wind is in electricity portfolio. This might be attributed to intermitant character of wind and need for investment in energy infrastructure in these countries.

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.155	0.034	4.55	0.000	0.088	0.222	***
lnGTP	0.114	0.028	4.06	0.000	0.059	0.169	***
lnSP	-0.016	0.007	-2.28	0.023	-0.029	-0.002	**
lnGDP	0.719	0.094	7.65	0.000	0.534	0.903	***
lnPOP	-2.200	0.609	-3.61	0.000	-3.396	-1.003	***
EC	-0.122	0.033	-3.76	0.000	-0.186	-0.058	***
UM	0.219	0.098	2.23	0.026	0.026	0.412	**
LM	-0.632	0.190	-3.33	0.001	-1.005	-0.259	***
L	-1.419	0.233	-6.09	0.000	-1.877	-0.961	***
Y2000	0.207	0.084	2.45	0.014	0.041	0.372	**
Constant	6.027	1.804	3.34	0.001	2.484	9.571	***

Mean dependent var	3.860	SD dependent var	1.438
R-squared	0.560	Number of obs	561.000
F-test	65.499	Prob > F	0.000
Akaike crit. (AIC)	214.112	Bayesian crit. (BIC)	261.739

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Above are the results of estimation with lnSP, which reveal different results. In this model, residential energy use variable, lnRESIDENTIAL, became insignificant. As seen, 2008 – 2012 global energy crisis caused 0.122% less energy imports. Being an upper-mid income country causes more energy imports by 0.219% while lower-mid or lower income countries depend 0.632% and 1.419% less on foreign energy, respectively. Finally, in year 2000, nations having solar power in their energy mix imported significantly more energy, 0.207%, than in other years (1990 – 2017).

To summarize, the results indicate that electricity generation by solar and wind helps both securing energy and climate change mitigation as anticipated. However, the dataset reveals that coal-based power generation does not contribute to energy security unlike mainstream energy policy advocates, which may be attributed to higher hard coal (anthracite) demand than brown coal, i.e. low-rank coal underlined by (Kessels Stefan Bakker, and Bas Wetzelaer, 2008). In case dependence on fossil sources is inevitable for the coming decades, relying on natural gas is estimated to be less risky for climate change mitigation and electricity supply security since it releases less carbon than coal, and there are more countries with natural gas reserves than those with coal reserves. The dataset does not cast any distinct role for energy efficiency in terms of energy intensity. Increasing energy intensity, i.e. decreasing energy efficiency releases more carbon as anticipated. However, increasing energy intensity, i.e. decreasing energy efficiency, contributes to energy security of the countries with wind power in the energy mix.

To illustrate better, lnENERGYINTENSITY is replaced with lnCARBONINTENSITY due to high correlation ($r = 0.8647$) between these variables and the below estimations are generated. As seen, relying on fossil fuels promotes energy security since almost all the countries have at least one kind of fossil reserve. In that case, **emphasizing domestic coal may prove justifiable in the future provided that nations invest in exploiting their coal reserves.**

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.276	0.044	6.35	0.000	0.191	0.362	***
lnGTP	0.062	0.019	3.23	0.001	0.024	0.099	***
lnWP	-0.025	0.011	-2.26	0.024	-0.046	-0.003	**
lnINDUSTRY	0.817	0.108	7.54	0.000	0.605	1.030	***
lnCARBONINTENSITY	-0.428	0.149	-2.87	0.004	-0.722	-0.135	***
lnGDP	0.463	0.072	6.45	0.000	0.322	0.605	***
lnPOP	-2.247	0.404	-5.56	0.000	-3.040	-1.454	***
Constant	-1.336	1.293	-1.03	0.302	-3.874	1.203	

Mean dependent var	3.572	SD dependent var	1.441
R-squared	0.397	Number of obs	711.000
F-test	63.127	Prob > F	0.000
Akaike crit. (AIC)	529.510	Bayesian crit. (BIC)	566.043

*** *p<0.01*, ** *p<0.05*, * *p<0.1*

Finally, it is necessary to explain the dilemma with energy efficiency in this dissertation. Increasing carbon intensity might be interpreted as relying more on traditional technologies with low capacity factors. In other words, countries with high energy intensity are those relying on existing fossil infrastructure in electricity generation and/or with heavy industries, which consume large amounts of fuel. These countries exploit their fossil sources with less efficient technologies. On the other hand, energy efficiency is frequently related with technological progress. Despite there are efficiency improvements in old technologies, these are not widely applied since the world is in a transition to green technologies but the dataset is not able to interpret effect of green transition on power generation. That is why energy efficiency is estimated as a risk for energy security.

5.4 Scenario Analyses

Upon estimation of parameters, this section explains the data, scenarios, methodology and assumptions used for the scenarios, and provides the results.

There are three business-as-usual (BAU) cases, which differ in GDP rise, and four energy mix scenarios. Each scenario is repeated with two different population estimations: TUIK and OECD.

These scenarios are based on the estimations given in the previous section. The panel equations (PE) forming the base of the analyses are given below.

$$\begin{aligned} PE1{:}\, lnCO2 = {} & -2.474 + 0.21 lnCTP + 0.03 lnGTP - 0.003 lnSP - 0.012 lnWP \\ & + 0.456 lnINDUSTRY + 0.159 lnENERGYINTENSITY + 0.08 lnGDP \\ & + 0.648 lnPOP \end{aligned} \tag{5-17}$$

$$\begin{aligned} PE2{:}\, lnEI = {} & -1.418 + 0.283 lnCTP + 0.064 lnGTP - 0.024 lnWP + 0.829 lnINDUSTRY \\ & - 0.999 lnENERGYINTENSITY + 0.347 lnGDP - 2.484 lnPOP \end{aligned} \tag{5-18}$$

$$\begin{aligned} PE3{:}\, lnEI = {} & 7.637 + 0.223 lnCTP - 0.026 lnSP - 0.349 lnRESIDENTIAL + 0.912 lnGDP \\ & - 2.171 lnPOP \end{aligned} \tag{5-19}$$

Equation (5-17), EP1, is the result of panel data analysis, equation (5-15), to estimate carbon emissions. This equation explains the impact of the independent variables on the left on carbon emissions, lnCO2. Equations (5-18) and (5-19) are result of the equation (5-16) which estimates energy imports, lnEI. Due to the collinearity between lnWP and lnSP, impacts of wind power and solar power on net energy imports are separately estimated by PE2 and PE3, respectively.

5.4.1 Data and Forecast

Scenarios are run for Turkey based on the three equations, PE1, PE2 and PE3, listed above. Therefore, the existing data except population is used for the forecast until 2050. Figure 5-11 – Figure 5-13 show the trend equations to forecast lnCTP, lnGTP, lnSP, lnWP, lnINDUSTRY, lnRESIDENTIAL, and lnENERGYINTENSITY. Excel TREND function is used to extend data beyond 2017 till 2050.

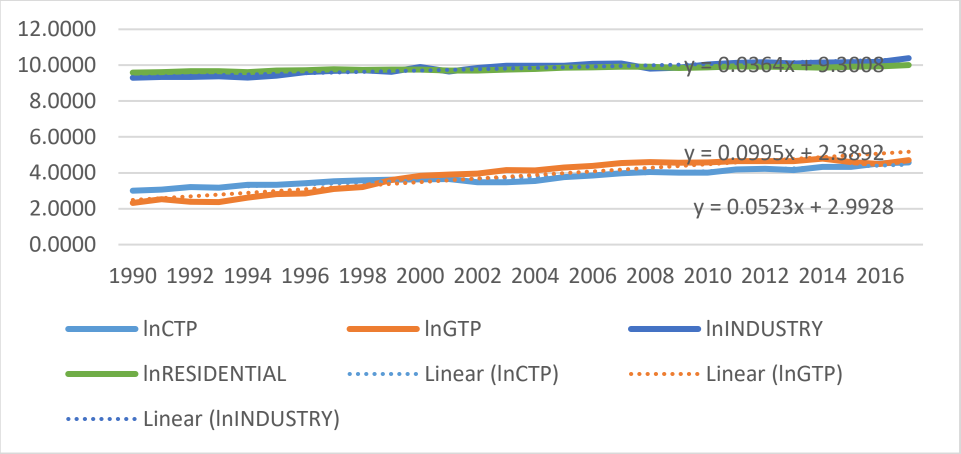

Figure 5-11. Trend Equations used in Forecast

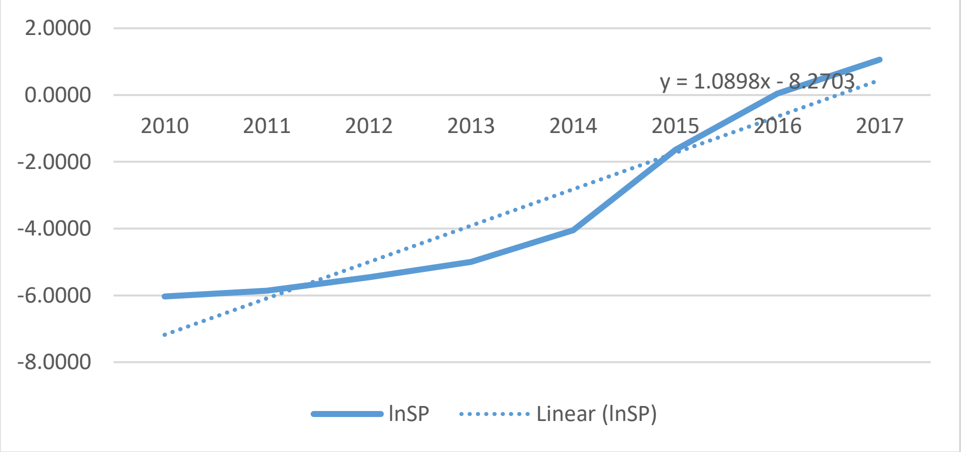

Figure 5-12 Trend Equation for Natural Logarithm of Solar Power used in Forecast

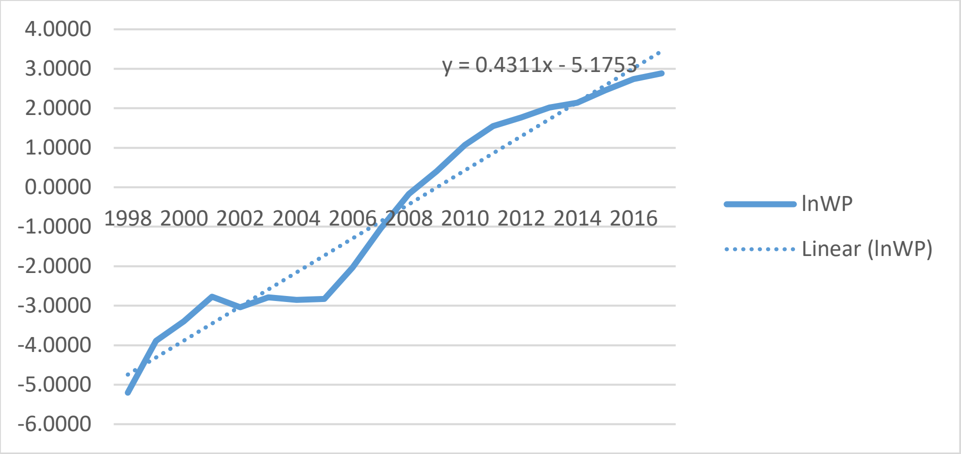

Figure 5-13 Trend Equation for Natural Logarithm of Wind Power used in Forecast

Future GDP is calculated with 4%, 4.5%, and 5% annual increase estimation based on 2017 real value.

Population estimations are gathered from TUIK and OECD forecasts until 2050.

Below table is the summary of scenarios detailed by the proceeding sections.

Table 5-6 Summary of Scenarios

Scenario	*Assumptions*	*Determinant Variable*
Business-as-Usual1 (BAU1)	All variables except GDP and POP increase according to historical trends. Annual GDP rise is 4%.	GDP
Business-as-Usual2 (BAU2)	All variables except GDP and POP increase according to historical trends. Annual GDP rise is 4.5%.	GDP
Business-as-Usual3 (BAU3)	All variables except GDP and POP increase according to historical trends. Annual GDP rise is 5%.	GDP
60 TWh Domestic Coal (60TWhDC)	Electricity generation and GDP variables are real values. Domestic coal-based generation is 60 TWh by the end of 2019.	CTP

Table 5-6 Summary of Scenarios, continued

Scenario	*Assumptions*	*Determinant Variable*
Full Domestic Coal (FullDC)	All domestic coal potential is used until 2033. Additional capacity is 13,670 MW. Annual increase of installed domestic coal capacity is 1000 MW. CF is taken constant at 2019 value for all years. WP, SP, GTP and imported-coal are kept constant at 2019 values.	CTP
45 GW Installed Wind (45GWWind)	All wind potential is used until 2050. Annual increase of installed wind capacity is 1,200 MW. CF is taken constant at 2019 TEİAŞ for all years, 38%. Average daily generation is 20 hours. CTP, GTP, SP are kept constant at their 2019 values.	WP
Maximum Solar Power (MaxSP)	Total solar potential is 46.8 GW and utilized until 2050. Annual increase of installed solar capacity is 1,300 MW. Average net daily solar generation is 4 hours. CTP, GTP and WP are kept at their 2019 values.	SP

5.4.2 Scenarios and Results

Business-As-Usual (BAU)

The BAU scenarios are run with the forecasted data described above for three GDP rise alternatives, 4%, 4.5% and 5%. Future carbon emissions and energy import data are calculated by the parameters estimated with panel econometrics presented under heading 5.3.

Figure 5-14 and Figure 5-15 depict lnCO2 (EP1) increase in BAU scenarios. As seen TUIK and OECD population forecasts are almost equal, thus, there is not any significant difference between the two figures. Also, different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, $\ln CO2_{2018}$ is 6.367 and $\ln CO2_{2050}$ is 7.305. With 5% GDP rise and TUIK population forecast, $\ln CO2_{2018}$ is 6.368 and $\ln CO2_{2050}$ is 7.330. Therefore, for brevity further results are shared only with TUIK data.

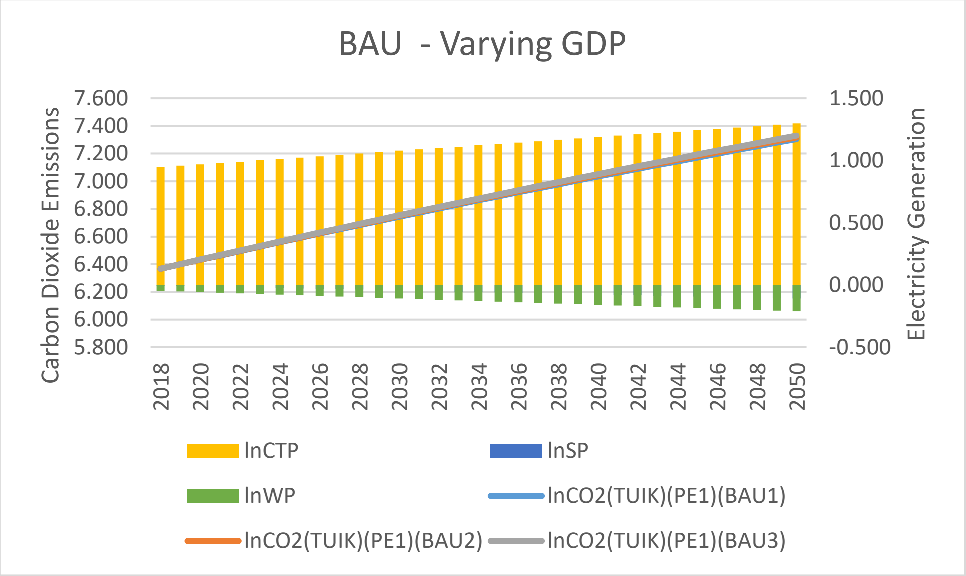

Figure 5-14 Carbon Emissions in Business-as-Usual Scenarios

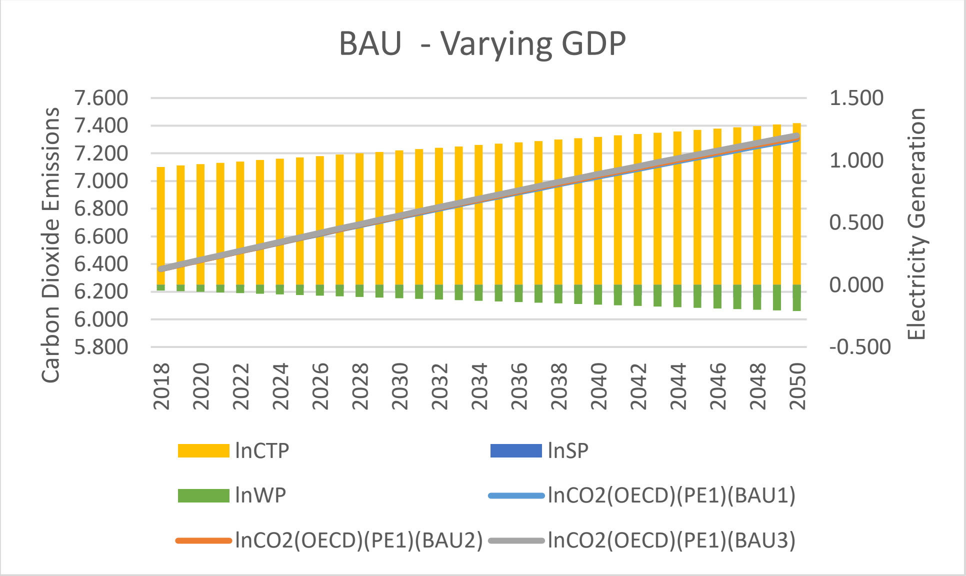

Figure 5-15 Carbon Emissions in Business-as-Usual Scenarios

Figure 5-16 shows lnEI with wind power in the energy mix (EP2). With 4% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 2.191, and $\ln EI_{2050}$ is 3.512. With 5% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 2.194, and $\ln CO2_{2050}$ is 3.622.

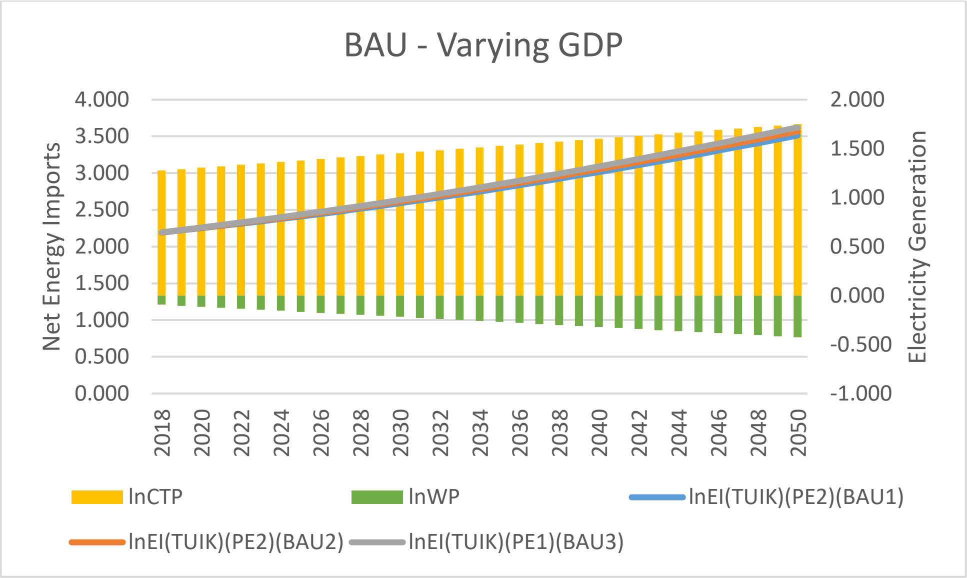

Figure 5-16 Energy Security in Business-as-Usual Scenarios

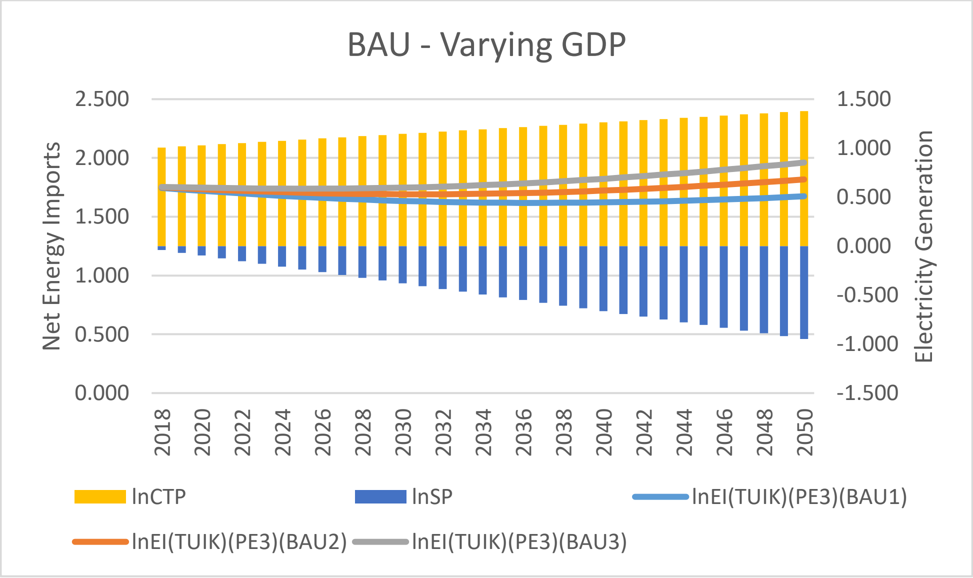

Figure 5-17 Energy Security in Business-as-Usual Scenarios

Figure 5-17 shows lnEI with solar power in the energy mix (EP3). With 4% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 1.745, and $\ln EI_{2050}$ is 1.673. With 5% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 1.754, and $\ln EI_{2050}$ is 1.961.

As expected, both carbon emissions and energy imports, thus energy dependency, increase under BAU scenarios.

60 TWh Domestic Coal-Based Generation

This scenario is actually a target designated in 2015 – 2019 Strategic Plan (ETKB, 2017), which aims 60 TWh electricity generation from domestic coal by the end of 2019. The purpose here is to assess whether the target is attained and to evaluate its impact on emissions and energy security in 2018 and 2019. Unlike BAU scenarios, real data is used except for lnINDUSTRY, lnENERGYINTENSITY, and lnPOP variables. Electricity generation data are obtained from TEİAŞ electricity statistics webpage[9], and GDP are taken from World Bank database[10]. 2018 and 2019 carbon emissions and energy import data are calculated by the parameters estimated with panel econometrics presented under heading 5.3.

Electricity generation information from TEİAŞ does not provide data distinctly for all domestic coal types. Therefore, from the installed capacities given by TEİAŞ electricity generation from domestic coal is estimated. Calculation results are tabulated by Table 5-7 and state that 60 TWh by the end of 2019 was not attained.

Besides, based on the real values and TUIK population forecast, $\ln CO2_{2018}$ is 6.390, and $\ln CO2_{2019}$ is 6.395. $\ln EI_{2018}$ is 2.181, and $\ln EI_{2019}$ is 2.145 with wind power. With solar power in the energy mix $\ln EI_{2018}$ is 1.661, and $\ln EI_{2019}$ is 1.604.

Comparing with BAU, lnCO2 results are slightly higher and lnEI results are slightly

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[9] TEİAŞ, 2020, Elektrik İstatistikleri Türkiye Elektrik Üretim – İletim İstatistikleri, https://www.teias.gov.tr/tr-TR/turkiye-elektrik-uretim-iletim-istatistikleri, last access: 27.05.2021

[10] The World Bank Group, 2021, GDP (current US$) – Turkey, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=TR, last access: 27.05.2021

smaller. The difference in lnEI is higher with the econometric model having lnSP.

Table 5-7 Approximation of Electricity Generation from Domestic Coal

Year	**ETKB Domestic Coal Generation Target (TWh)**	**TEİAŞ Hard Coal+ Imported Coal+ Asphaltite (TWh)**	**TEİAŞ Lignite (TWh)**	**hours/day Lignite used for electricity generation**	**Hard Coal + Asphaltite (TWh)**	**Total Domestic Coal (TWh)**	**CF by TEİAŞ for Fossil Fuel**
2013	32.9						
2015	40	44.83	31.34	15.93	4.39	35.73	0.622
2016		53.70	38.57	18.41	5.07	43.64	0.629
2017	50	56.78	40.69	19.02	5.43	46.13	0.642
2018		68.16	45.09	19.94	5.70	50.78	0.655
2019	60	66.02	46.87	19.26	5.50	52.37	0.669

realized
estimate

Full Domestic Coal (Full DC)

This scenario assumes utilization of all domestic coal potential in electricity generation, which is calculated as additional 13,670 MW by (Önenli, 2019). The scenario is run with 1000 MW/a increase in installed domestic coal capacity until 2033 while keeping all other electricity generation variables constant in 2019 real values. Capacity factor is also taken constant at 2019 (see Table 5-7).

Figure 5-18 shows the results for carbon emissions with varying GDP values. Different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, lnCO2_{2018} is 6.435 and lnCO2_{2033} is 6.920. With 5% GDP rise and TUIK population forecast, lnCO2_{2018} is 6.436 and lnCO2_{2033} is 6.933.

Figure 5-19 shows the results for energy security with wind power in energy mix. Different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, lnEI_{2018} is 2.274 and lnEI_{2033} is 2.756. With 5% GDP rise and TUIK population forecast, lnEI_{2018} is 2.277 and lnEI_{2033} is 2.809.

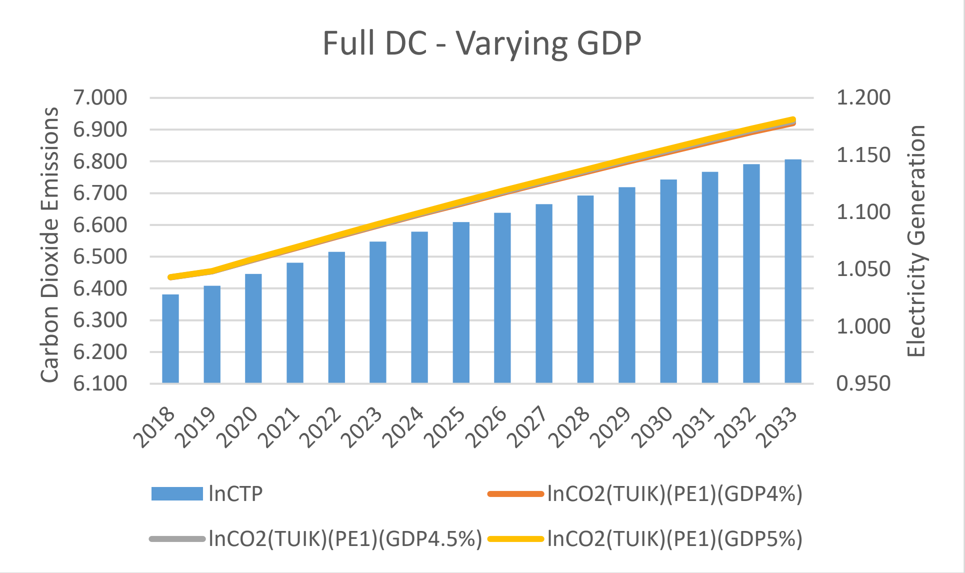

Figure 5-18 Carbon Emissions in Full DC Scenario

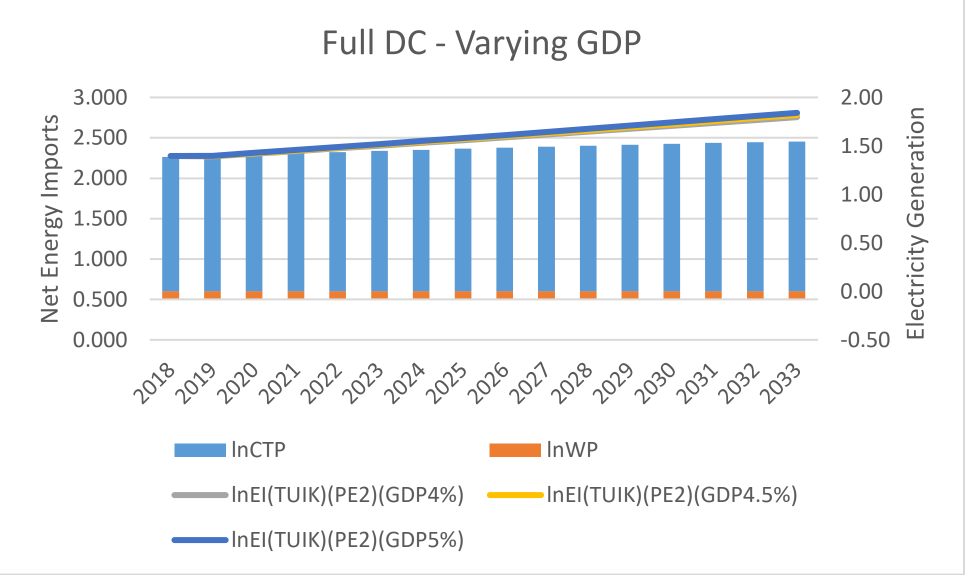

Figure 5-19 Energy Security in Full DC Scenario

Figure 5-20 shows the results for energy security with solar power in energy mix. Different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, $lnEI_{2018}$ is 1.818 and $lnEI_{2033}$ is 2.066. With 5% GDP rise and TUIK population forecast, $lnEI_{2018}$ is 1.827 and $lnEI_{2033}$ is 2.206.

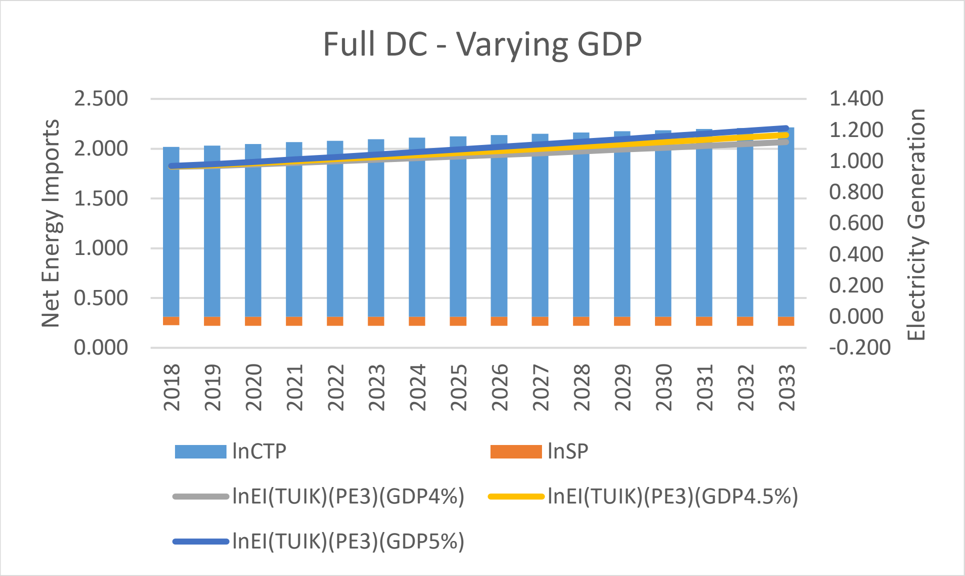

Figure 5-20 Energy Security in Full DC Scenario

Comparing with BAU results, all the outcomes of this scenario are higher. Although panel data analysis estimates a positive parameter for lnCTP (see heading 5.3), impact of utilization of domestic coal in energy imports is expected to be negative. Therefore, calculation is done as in 60 TWh scenario and it is found that domestic coal in electricity generation reduces the total energy imports by 91.25% in 2033. However, CO_2 emission rises almost 7 folds in comparison to 1990 value (136.442 million tonnes).

45 GW Wind

This scenario aims full utilization of wind potential in electricity generation until 2050. The assumption is that annual installed wind capacity increases by 1200 MW. All other electricity generation data are kept constant at 2019 real values. Also, capacity factor for wind is taken constant in 2019 TEİAŞ value, 38%.

Figure 5-21 shows the results for carbon emissions. Different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, $lnCO2_{2018}$ is 6.400, and $lnCO2_{2050}$ is 7.124. With 5% GDP rise and TUIK population forecast, $lnCO2_{2018}$ is 6.401 and $lnCO2_{2050}$ is 7.149.

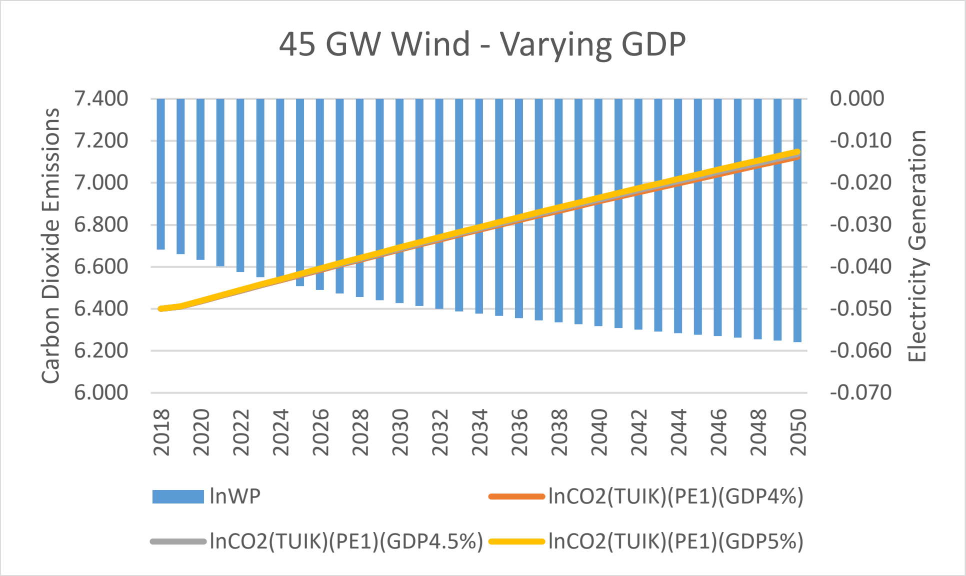

Figure 5-21 Carbon Emissions in 45 GW Wind Scenario

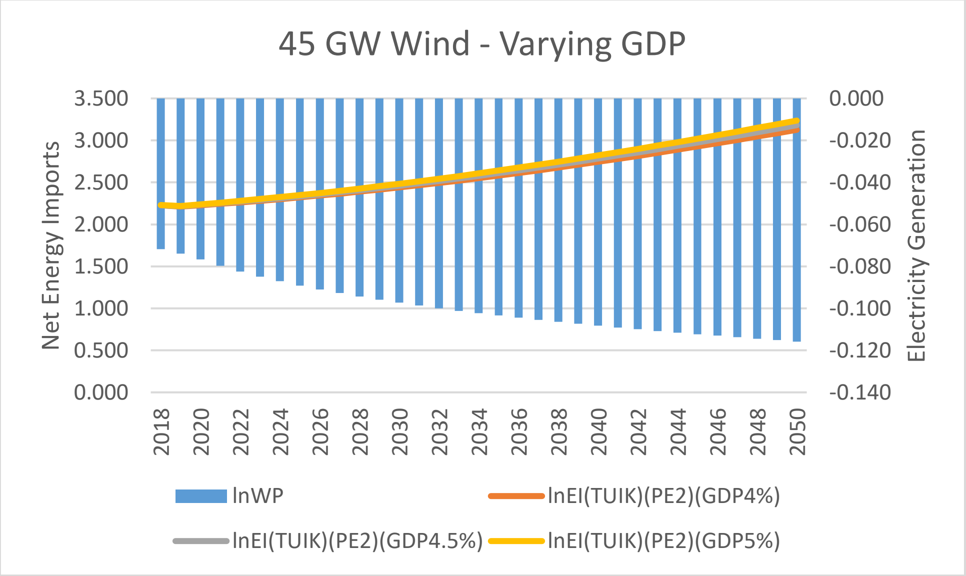

Figure 5-22 Energy Security in 45 GW Wind Scenario

Figure 5-22 visualizes the results for energy security. Different GDP increase does not result in significant distinction. With 4% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 2.226 and $\ln EI_{2050}$ is 3.126. With 5% GDP rise and TUIK population forecast, $\ln EI_{2018}$ is 2.230 and $\ln EI_{2050}$ is 3.236.

Comparing with BAU and Full DC results, all the outcomes of this scenario are lower.

Maximum Solar Power (Max SP)

This scenario aims maximum utilization of solar potential in electricity generation, which is estimated as 46.8 GW installed capacity by (Önenli, 2019). The assumption is that annual installed solar capacity increases by 1300 MW until 2050. All other electricity generation data are kept constant at 2019 real values. Average daily net electricity generation duration is taken as 4 hours.

Figure 5-23 shows the results for carbon emissions. GDP increase does not reveal remarkable difference. With 4% GDP rise and TUIK population forecast, $lnCO2_{2018}$ is 6.400 and $lnCO2_{2050}$ is 7.139. With 5% GDP rise and TUIK population forecast, $lnCO2_{2018}$ is 6.401 and $lnCO2_{2050}$ is 7.164.

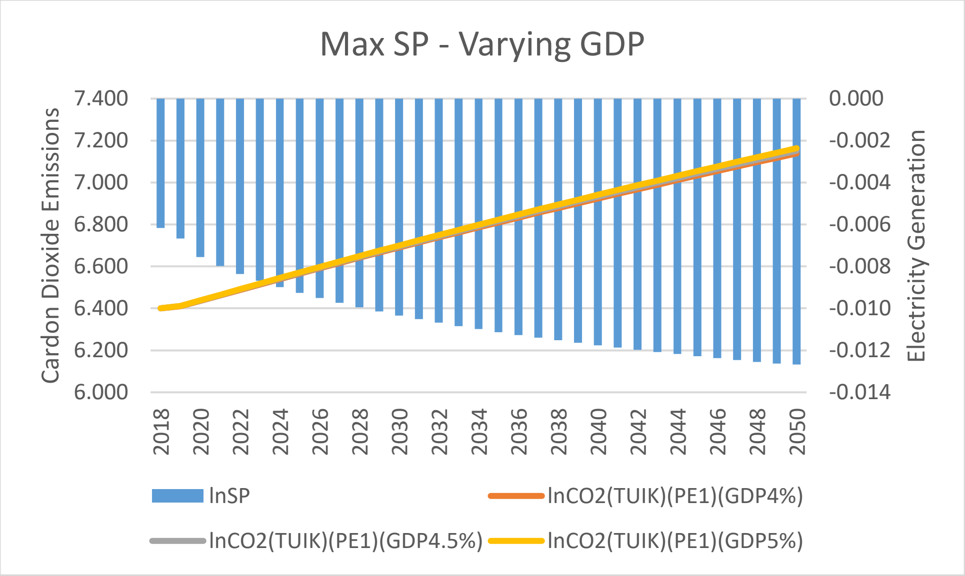

Figure 5-23 Carbon Emissions in Max SP Scenario

Figure 5-24 shows the results for energy security. Unlike other scenarios, GDP increase matters in Max SP. With 4% GDP rise and TUIK population forecast, $lnEI_{2018}$ is 1.781 and $lnEI_{2050}$ is 2.185. With 5% GDP rise and TUIK population forecast, $lnEI_{2018}$ is 1.789 and $lnEI_{2050}$ is 2.473.

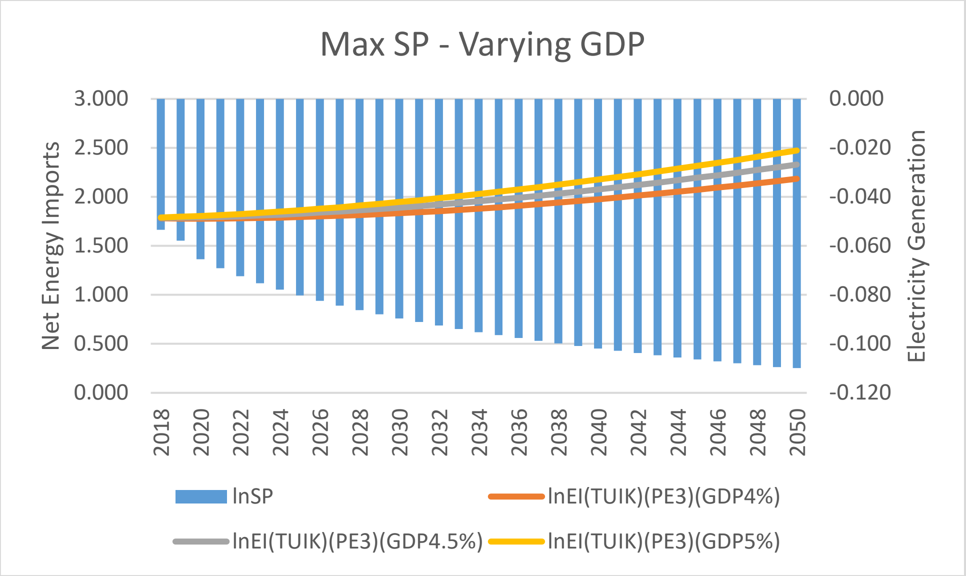

Figure 5-24 Energy Security in Max SP Scenario

Comparing with all other scenarios, results of Max SP are lower than BAUs and Full DC. However, 45 GW Wind emission forecast is less than Max SP while Max SP reveals better outcomes in energy security.

In brief, **relying on domestic coal exacerbates CO_2 emissions** but wind power and solar power may be beneficial for Turkey to reach her emission reduction targets (see Figure 5-25). According to Figure 5-26, among the technologies analysed in this dissertation, **wind power is more promising in lowering carbon emissions**, i.e. climate change mitigation while Figure 5-27 **highlights solar power to secure energy more than wind**. The former outcome is attributed to intermitent character and smaller capacity factor of solar power since wind is able to generate more power than solar. The latter outcome is attributed to off-grid use potential of solar power. Although the panel econometrics narrated under 5.3 estimate the role of coal contrary to main energy policy discourse, **manual calculation of Turkey's domestic coal-based power generation proves grave for the country's energy security** but at the expense of climate change mitigation efforts.

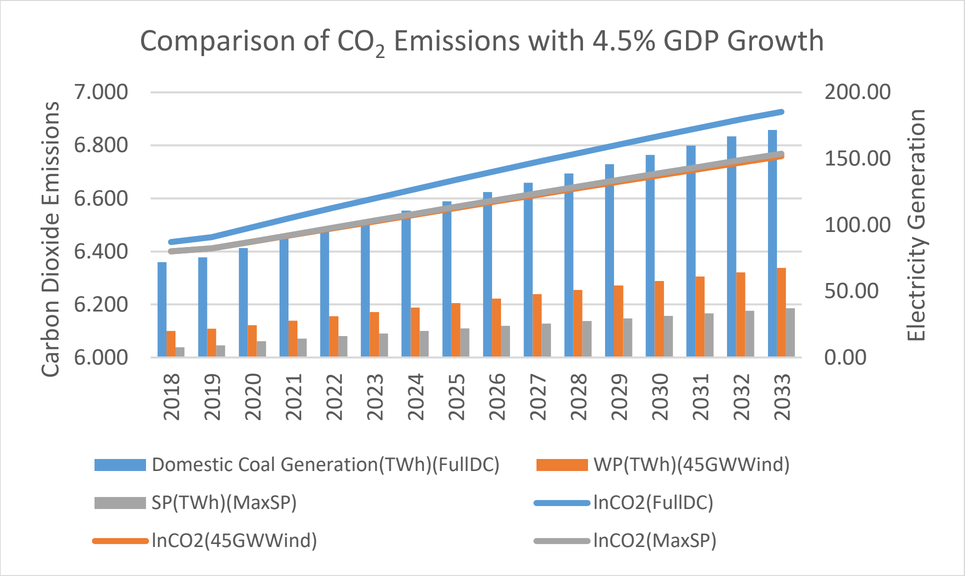

Figure 5-25 Comparison of Carbon Emissions with Domestic Sources

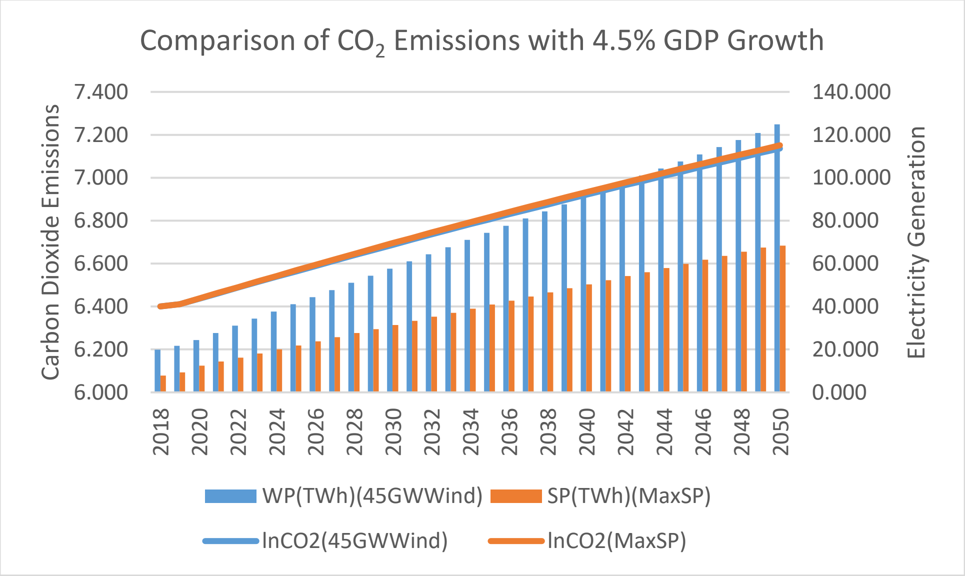

Figure 5-26 Comparison of Carbon Emissions between WP and SP

In linear values the above results are repeated (see Figure 5-28 – Figure 5-30). With Full DC in 2033 CO_2 emission rises to 1,018.943 million tonnes that is 747% higher than 1990 value. With 45 GW Wind and Max SP scenarios CO_2 emissions in 2033 are forecasted as 861.949 million tonnes (632% rise) and 870.146 million tonnes (638% rise), respectively. These values are 1,256.726 million tonnes and 1,275.693 million tonnes in 2050, respectively. Comparing energy import results, 45 GW Wind scenario reaches 24.077 mtoe in 2050 while Max SP scenario results in 10.273 mtoe that is more than half a lower value than wind power. (Erdal, 2015) gives similar results in terms of renewables' contribution to energy security.

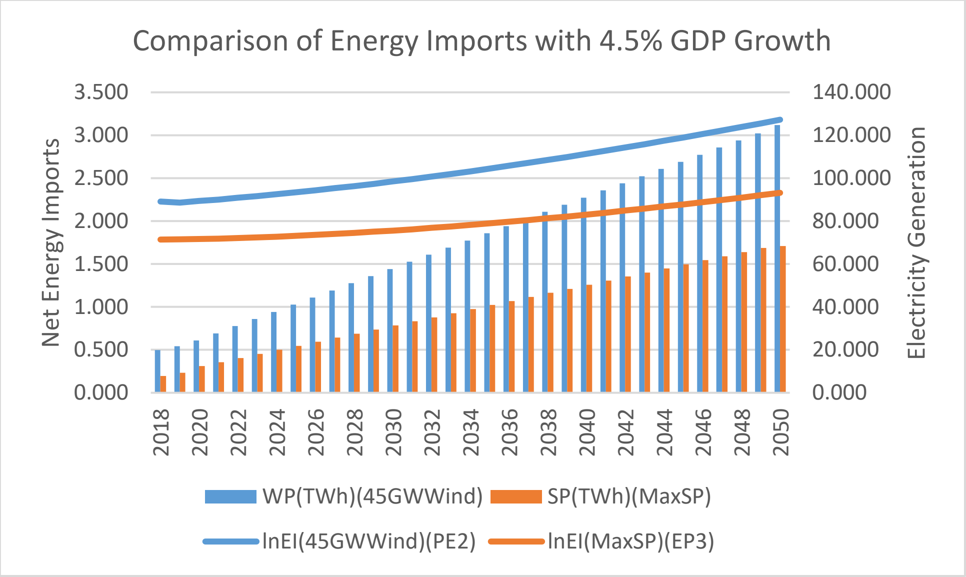

Figure 5-27 Comparison of Energy Security between WP and SP

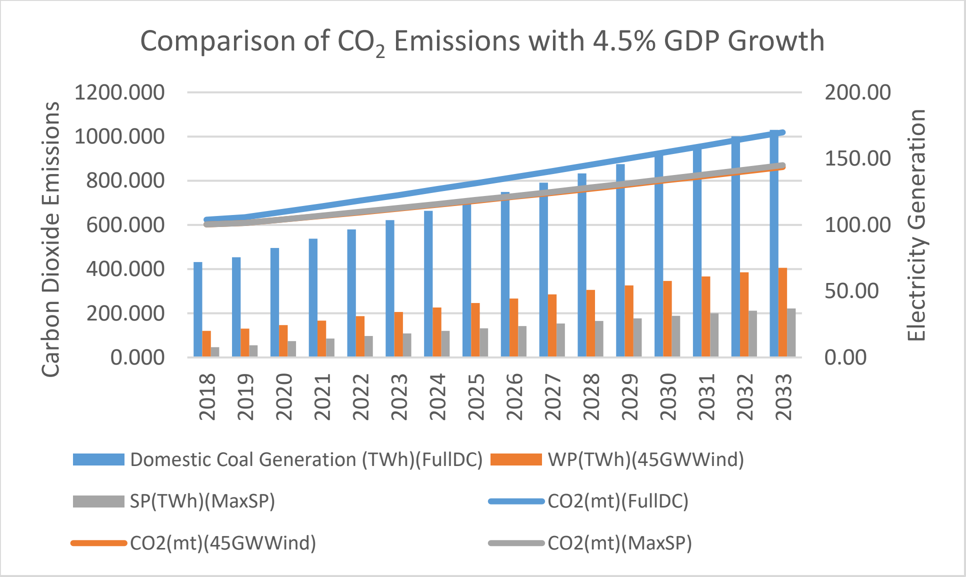

Figure 5-28 Comparison of Carbon Emissions with Domestic Sources

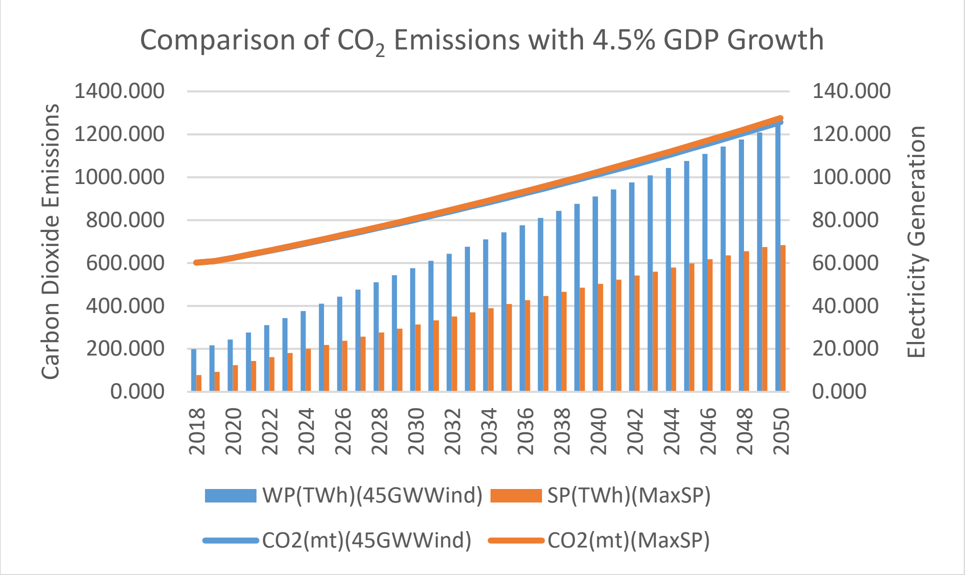

Figure 5-29 Comparison of Carbon Emissions between WP and SP

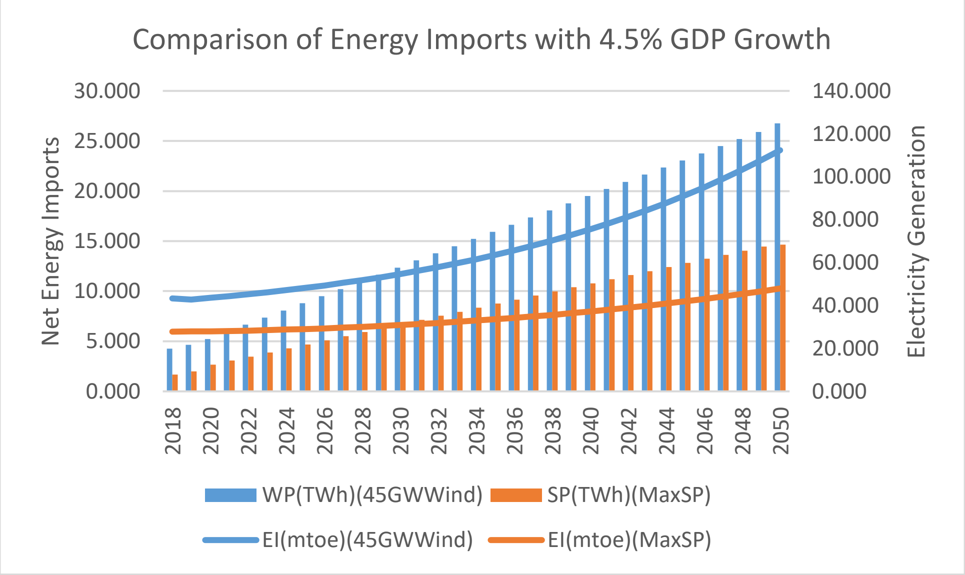

Figure 5-30 Comparison of Energy Security between WP and SP

Despite Figure 4-7 and Figure 4-8, INDC of Turkey claims that in 2012 70% of total emissions were from energy sector and sets the target "up to 21% reduction in GHG emissions by 2030." BAU scenarios forecast a rise of 213% while Full DC scenario forecasts 232%. 45 GW Wind and Max SP reveal doubling of emissions in 2030 compared with 2012 values. (Arı, 2010; Arı & Köksal, 2011; Arı & Yıkmaz, 2019) give similar results, emphasizing the role of renewables in emission reduction. It is to state that investing on renewal energy-based power generation may contribute to attainment of emission reduction targets of Turkey however only change in electricity generation technology or fuel is not adequate for climate change mitigation.

CHAPTER 6

DISCUSSION AND CONCLUSION

This dissertation is concerned with the role of domestic coal utilization in energy security, specifically electricity supply security, of Turkey under climate change discussions.

Climate change is basically driven by energy sector and share of electricity generation is as important as the share of transportation sector. Therefore, long-term planning of energy policies is vital for the mitigation of climate change. Climate change and energy security issues are interrelated. Main assumption is that climate change threatens energy security but since the link between them is complex, positives and negatives should be carefully assessed before policy-making (Luft et al., 2011).

Although environmental pressures, along with others, dominate the daily life and perception of public in Turkey, policies in the country fail to answer these realities and expectation of public. Energy policies are shaped by economic and/or political priorities. For instance, Strategy Plan of MENR (ETKB, 2017) emphasizes electricity generation security more than environmental problems related with power sector. The Ministry’s main objective for securing electricity supply is exploitation of domestic coal rather than prioritizing investment on solar and wind power. This study is developed from this approach.

Energy security is the sole aim of energy policy of a country. When the concept first emerged, it was only referring to oil security because dependence on foreign oil has direct and indirect impacts on economy as a whole through price fluctuations due to supply interruption (Bohi & Toman, 1993). Through decades, energy security has evolved and today it has a far wider scope that is concerned with sustainability along with affordability and continuity.

Inefficient, below global average per capita electricity consumption, high demand increase, and foreign dependency with limited suppliers define Turkey’s energy profile (Çimen, 2010). Challenges that Turkey is facing to secure energy are large share of imported fuel in the economy, risks related with suppliers, increasing energy consumption and need for investments in energy sector. Country's fossil reserves are able to meet only a small amount. Turkey imports 92% of oil and 99% of natural gas needs of hers, which makes the country to depend on foreign sources and suppliers. Russia and Iran are the two biggest suppliers for Turkey and this heavy dependence on such politically, socially and economically unstable countries creates vulnerabilities for her. Additionally, with the ongoing nuclear power plant (NPP) construction by Russia, Turkey is facing an energy supply security issue (M. Balat, 2010; Özalp, 2019). Despite this high fossil dependence, Turkey intents to reduce her greenhouse gas (GHG) emissions by 21% between 2021 and 2030 in her Intended Nationally Determined Contribution (INDC), after COP 21 held in Paris[11]. Thus, Turkey challenges herself in order not to lag behind in global climate diplomacy.

There are three ways to maintain energy security: "managing energy demand, increasing domestic energy supply and increasing the reliability of imported or domestic supplies". Nations can reduce their energy supply vulnerability through reducing demand or increasing efficiency and restructuring, arranging stockpiles and preparing plans for emergency conditions, increasing share of alternative domestic supplies, diversification of external supplies, and taking "diplomatic, industrial and military measures" (Deese, 1979; The World Bank Group, 2005). Similarly, Strategy Plan 2015 – 2019 of Ministry of Energy and Natural Resources (ETKB, 2017) focuses on energy supply security and accepts production and import, enhancing storage and distribution infrastructure, and demand management as fundamental elements of the concept. Strategy Plan emphasizes role of domestic sources in supply security and commits to increase contribution of domestic coal to electricity generation to 60 TWh until 2020. Along with coal, utilization of wind and solar power is also indicated.

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[11] Turkey's INDC: https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Turkey/1/The_INDC_of_TURKEY_v.15.19.30.pdf, access: 10.03.2020.

According to the sector reports of Turkish Electricity Transmission Corporation (TEİAŞ)[12], installed capacity of the country increased every year during 2015 – 2019, share of fossil was always the largest and considerably rose in 2016 and 2017 as other non-fossil sources. Regarding the latter, their share significantly increased, solar with the largest rise, even larger than the rise in fossil fueled-power plants. Specifically, during 2015 – 2019, rise in installed capacity of solar was 5,350.4 MW whereas that of fossil was 4,909 MW, and total of non-fossil was 11,877.7 MW, almost 2.5 times higher than fossil-based sources. In brief, Turkey was in progress, although slight, towards accomplishing her security and sustainability goals in energy for the last five years.

Based on the progress, this study aims to evaluate role of domestic coal, solar and wind in securing electricity supply of Turkey and her efforts in climate change mitigation, and is important because it is one that is concerned with energy security, an issue getting popular and not investigated widely yet in Turkey. However, its significance lies in the contribution to the perception that energy-related political decision making might not necessarily contradict with environmental matters through combining the two themes, which are generally handled distinctively. Another significance of the dissertation is that econometric methods, specifically panel data econometrics, are used since they are able to offer better insights and enable researchers to grasp more.

Chapter 5 of the dissertation presents data, methodology and results. Data for 47 countries of OECD, EU, ASEAN, and BRICS (see Table 5-1) have been compiled from WDI and BP databases, and through IEA webpage for the period between 1990 and 2017. Variables summarized by Table 5-2 and described by Table 5-3 are included in the analyses. lnCO2 and lnEI are the dependent variables estimated by panel econometrics. lnCO2 is estimated because it is the prime concern in climate change as it is a by-product of energy generation. lnEI is accepted as a proxy of energy security, meaning that the larger is the net energy import of a nation, the greater is its dependency to foreign energy sources. Regressors to explain those regressands are variables of coal- and gas-based electricity generation, wind

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[12] Sector Reports of Turkish Electricity Transmission Corporation: https://www.teias.gov.tr/tr-TR/sektor-raporlari, last access: 22.03.2020

and solar power, industrial and residential energy consumption, energy intensity, GDP, and population.

Two panel data models are generated. The first is estimation of carbon emissions as given by (5-15) for an unbalanced panel of 47 countries that is number of observations varies among cross-sections. The second is estimation of energy imports as given by (5-16) function for an unbalanced panel of 47 countries.

The results indicate that electricity generation by solar and wind helps both securing energy and climate change mitigation as anticipated. However, the dataset reveals that coal-based power generation does not contribute to energy security unlike mainstream energy policy advocates. The dataset does not cast any distinct role for energy efficiency in terms of energy intensity. Increasing energy intensity, i.e. decreasing energy efficiency releases more carbon as anticipated. However, increasing energy intensity, i.e. decreasing energy efficiency, contributes to energy security of the countries with wind power in the energy mix. In that case, **emphasizing domestic coal may prove justifiable in the future provided that nations invest in exploiting their coal reserves. Additionally, highlighting domestic fossil sources might be a better outcome considering the behavior of energy intensity as an independent variable.**

Upon estimation of parameters, scenario analyses are conducted to forecast contribution of domestic coal, solar and wind power to Turkey's securing energy and climate change mitigation efforts. There are three business-as-usual (BAU) cases, which differ in GDP rise, and four energy mix scenarios, 60 TWh Domestic Coal, Full Domestic Coal (Full DC), 45 GW Wind, and Maximize Solar (Max SP).

Scenario results indicate that **relying on domestic coal exacerbates CO_2 emissions** but wind power and solar power may be beneficial for Turkey to reach her emission reduction targets. Among the technologies analysed in this dissertation, **wind power is more promising in lowering carbon emissions**, i.e. climate change mitigation while **solar power for securing energy**. Despite the global role of coal revealed by panel estimation, **Turkey's use of domestic coal is also important in securing electricity supply**.

In linear terms, BAU scenarios forecast a rise of 213% while Full DC scenario forecasts 232% in carbon emissions. 45 GW Wind and Max SP reveal doubling of emissions in 2030 compared with 2012 values. Considering INDC of Turkey, it is to state that investing on renewal energy-based power generation may contribute to attainment of emission reduction targets of Turkey however only change in electricity generation technology and/or fuel is not adequate for climate change mitigation.

6.1 Further Studies

This dissertation focuses on electricity supply security and evalutes only coal, solar and wind power potential considering climate change mitigation. Impact of nuclear, improved energy efficiency, and decreasing losses through the grid system might be included in further studies. The dissertation also does not consider financial or economic impacts of securing electricity supply in Turkey. Global and local energy prices might be included to forecast cost to public. True cost of energy security might be calculated with consideration of externalities emerging because of electricity generation. Finally, impact of electric vehicles’ introduction to system on electricity demand and supply security needs contemplation.

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APPENDICES

A. Random Effect Model Estimations

Random-effects GLS regression Number of obs = 687
Group variable: code Number of groups = 41

R-sq: within = 0.8822 Obs per group: min = 2
between = 0.9689 avg = 16.8
overall = 0.9714 max = 28

Wald chi2(8) = 6290.65
corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000

lnCO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.200	0.009	23.11	0.000	0.183	0.217	***
lnGTP	0.033	0.004	8.07	0.000	0.025	0.041	***
lnSP	-0.004	0.002	-2.29	0.022	-0.007	-0.001	**
lnWP	-0.009	0.002	-4.25	0.000	-0.013	-0.005	***
lnINDUSTRY	0.444	0.018	24.12	0.000	0.408	0.480	***
lnENERGYINTENSITY	0.127	0.031	4.04	0.000	0.066	0.189	***
lnGDP	0.114	0.013	8.78	0.000	0.089	0.140	***
lnPOP	0.172	0.026	6.65	0.000	0.121	0.223	***
Constant	-0.930	0.150	-6.21	0.000	-1.224	-0.637	***

Mean dependent var	5.462	SD dependent var	1.469
Overall r-squared	0.971	Number of obs	687.000
Chi-square	6290.645	Prob > chi2	0.000
R-squared within	0.882	R-squared between	0.969

*** *p<0.01*, ** *p<0.05*, * *p<0.1*

Random-effects GLS regression Number of obs = 687
Group variable: code Number of groups = 41

R-sq: within = 0.8953 Obs per group: min = 2
between = 0.9642 avg = 16.8
overall = 0.9668 max = 28

Wald chi2(11) = 6829.99
corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0000

lnCO2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.199	0.008	24.02	0.000	0.183	0.216	***
lnGTP	0.036	0.004	9.21	0.000	0.029	0.044	***
lnSP	-0.005	0.002	-2.89	0.004	-0.008	-0.001	***
lnWP	-0.007	0.002	-3.32	0.001	-0.011	-0.003	***
lnINDUSTRY	0.375	0.019	19.25	0.000	0.337	0.414	***
lnENERGYINTENSITY	0.209	0.032	6.53	0.000	0.146	0.272	***
lnGDP	0.148	0.014	10.28	0.000	0.120	0.177	***
lnPOP	0.174	0.026	6.72	0.000	0.123	0.224	***
EC	-0.030	0.006	-4.96	0.000	-0.042	-0.018	***

UM	0.069	0.014	4.92	0.000	0.042	0.097	***
LM	0.111	0.017	6.71	0.000	0.078	0.143	***
Constant	-0.348	0.162	-2.15	0.031	-0.664	-0.031	**

Mean dependent var	5.462	SD dependent var	1.469
Overall r-squared	0.967	Number of obs	687.000
Chi-square	6829.991	Prob > chi2	0.000
R-squared within	0.895	R-squared between	0.964

*** *p<0.01, ** p<0.05, * p<0.1*

```
Random-effects GLS regression                Number of obs      =      711
Group variable: code                         Number of groups   =       34

R-sq:  within  = 0.3947                      Obs per group: min =        2
       between = 0.7424                                     avg =     20.9
       overall = 0.7297                                     max =       28

                                          Wald chi2(7)      =    544.47
corr(u_i, X)   = 0 (assumed)              Prob > chi2       =    0.0000
```

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.194	0.033	5.93	0.000	0.130	0.258	***
lnGTP	0.060	0.019	3.20	0.001	0.023	0.096	***
lnWP	-0.028	0.010	-2.85	0.004	-0.048	-0.009	***
lnINDUSTRY	0.726	0.097	7.47	0.000	0.535	0.916	***
lnENERGYINTENSITY	-0.541	0.147	-3.68	0.000	-0.830	-0.253	***
lnGDP	0.307	0.072	4.26	0.000	0.166	0.449	***
lnPOP	-0.417	0.098	-4.26	0.000	-0.609	-0.225	***
Constant	-5.860	0.682	-8.59	0.000	-7.197	-4.523	***

Mean dependent var	3.572	SD dependent var	1.441
Overall r-squared	0.730	Number of obs	711.000
Chi-square	544.474	Prob > chi2	0.000
R-squared within	0.395	R-squared between	0.742

*** *p<0.01, ** p<0.05, * p<0.1*

```
Random-effects GLS regression                 Number of obs      =      561
Group variable: code                          Number of groups   =       36

R-sq:  within  = 0.4332                       Obs per group: min =        2
       between = 0.6589                                      avg =     15.6
       overall = 0.7416                                      max =       28

                                         Wald chi2(6)       =    467.68
corr(u_i, X)   = 0 (assumed)             Prob > chi2        =    0.0000
```

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.193	0.033	5.75	0.000	0.127	0.258	***
lnGTP	0.117	0.030	3.87	0.000	0.058	0.177	***
lnSP	-0.037	0.007	-5.07	0.000	-0.051	-0.023	***
lnRESIDENTIAL	-0.298	0.133	-2.24	0.025	-0.558	-0.038	**
lnGDP	0.760	0.065	11.72	0.000	0.633	0.887	***
lnPOP	0.022	0.130	0.17	0.867	-0.232	0.276	
Constant	0.395	0.932	0.42	0.672	-1.432	2.221	

Mean dependent var	3.860	SD dependent var	1.438
Overall r-squared	0.742	Number of obs	561.000
Chi-square	467.677	Prob > chi2	0.000
R-squared within	0.433	R-squared between	0.659

**** p<0.01, ** p<0.05, * p<0.1*

```
Random-effects GLS regression                Number of obs      =      711
Group variable: code                          Number of groups   =       34

R-sq:  within  = 0.3879              Obs per group: min =        2
       between = 0.7774                             avg =     20.9
       overall = 0.7720                             max =       28

                                       Wald chi2(7)      =    544.37
corr(u_i, X)   = 0 (assumed)           Prob > chi2       =    0.0000
```

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.195	0.033	5.95	0.000	0.131	0.259	***
lnGTP	0.062	0.019	3.31	0.001	0.025	0.099	***
lnWP	-0.028	0.010	-2.76	0.006	-0.047	-0.008	***
lnINDUSTRY	0.473	0.085	5.58	0.000	0.307	0.640	***
lnENERGYINTENSITY	-0.653	0.144	-4.53	0.000	-0.935	-0.370	***
lnGDP	0.263	0.072	3.67	0.000	0.122	0.403	***
UM	0.151	0.052	2.90	0.004	0.049	0.253	***
Constant	-4.806	0.654	-7.35	0.000	-6.089	-3.524	***

Mean dependent var	3.572	SD dependent var	1.441
Overall r-squared	0.772	Number of obs	711.000
Chi-square	544.373	Prob > chi2	0.000
R-squared within	0.388	R-squared between	0.777

*** *p<0.01*, ** *p<0.05*, * *p<0.1*

```
Random-effects GLS regression                 Number of obs      =       561
Group variable: code                          Number of groups   =        36

R-sq:  within  = 0.5464                  Obs per group: min =         2
       between = 0.6612                                 avg =      15.6
       overall = 0.7533                                 max =        28

                                               Wald chi2(10)      =    698.24
corr(u_i, X)   = 0 (assumed)                   Prob > chi2        =    0.0000
```

lnEI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
lnCTP	0.133	0.030	4.40	0.000	0.074	0.192	***
lnGTP	0.113	0.028	4.09	0.000	0.059	0.167	***
lnSP	-0.025	0.007	-3.83	0.000	-0.038	-0.012	***
lnGDP	0.507	0.074	6.81	0.000	0.361	0.653	***
lnPOP	0.102	0.103	0.99	0.322	-0.099	0.303	
EC	-0.100	0.032	-3.10	0.002	-0.164	-0.037	***
UM	0.143	0.099	1.44	0.149	-0.051	0.336	
LM	-0.870	0.183	-4.75	0.000	-1.229	-0.510	***
L	-1.636	0.232	-7.04	0.000	-2.091	-1.181	***
Y2000	0.184	0.086	2.14	0.033	0.015	0.352	**
Constant	-0.711	0.377	-1.89	0.059	-1.449	0.028	*

Mean dependent var	3.860	SD dependent var	1.438
Overall r-squared	0.753	Number of obs	561.000
Chi-square	698.237	Prob > chi2	0.000
R-squared within	0.546	R-squared between	0.661

**** p<0.01, ** p<0.05, * p<0.1*

B. Scatter Graphs

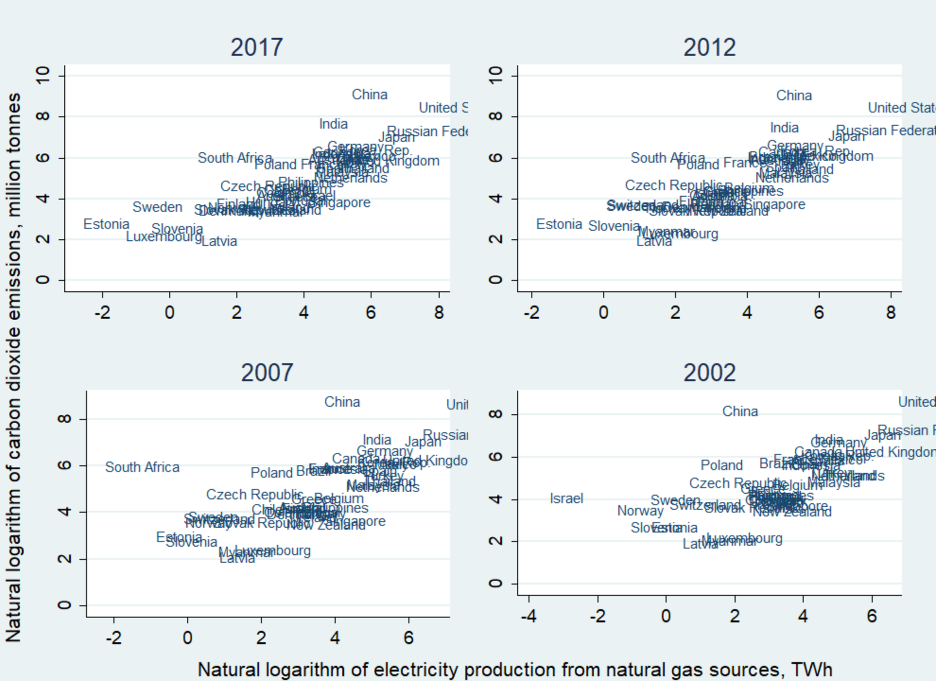

Figure 6-1. Scatterplot of lnCO2 and Natural Logarithm of Electricity Generation from Gas

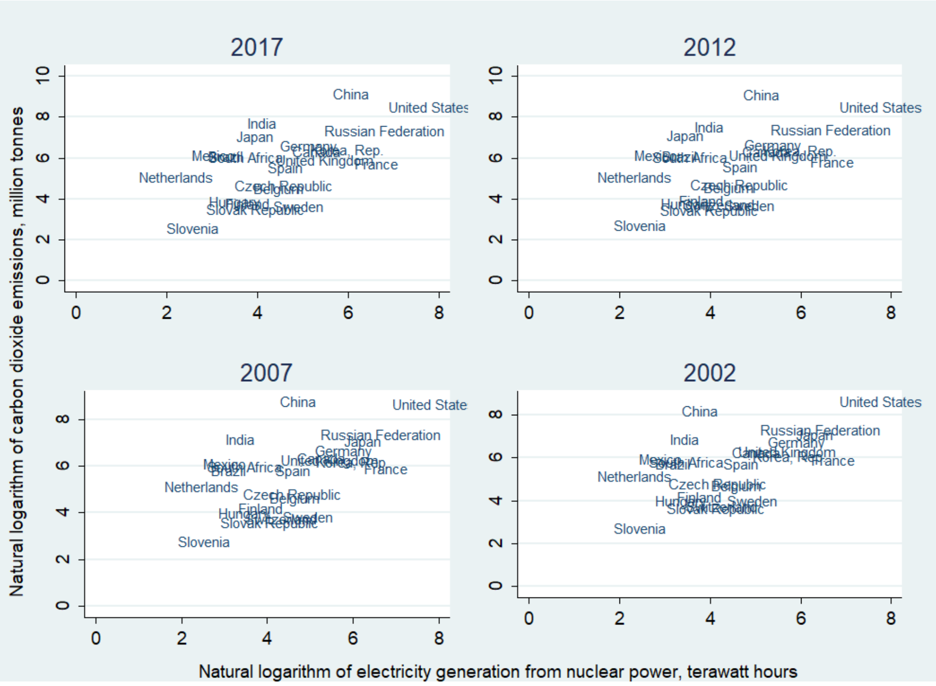

Figure 6-2. Scatterplot of lnCO2 and Natural Logarithm of Nuclear Power

Figure 6-3. Scatterplot of lnCO2 and Natural Logarithm of Energy Consumption by Industry Sector

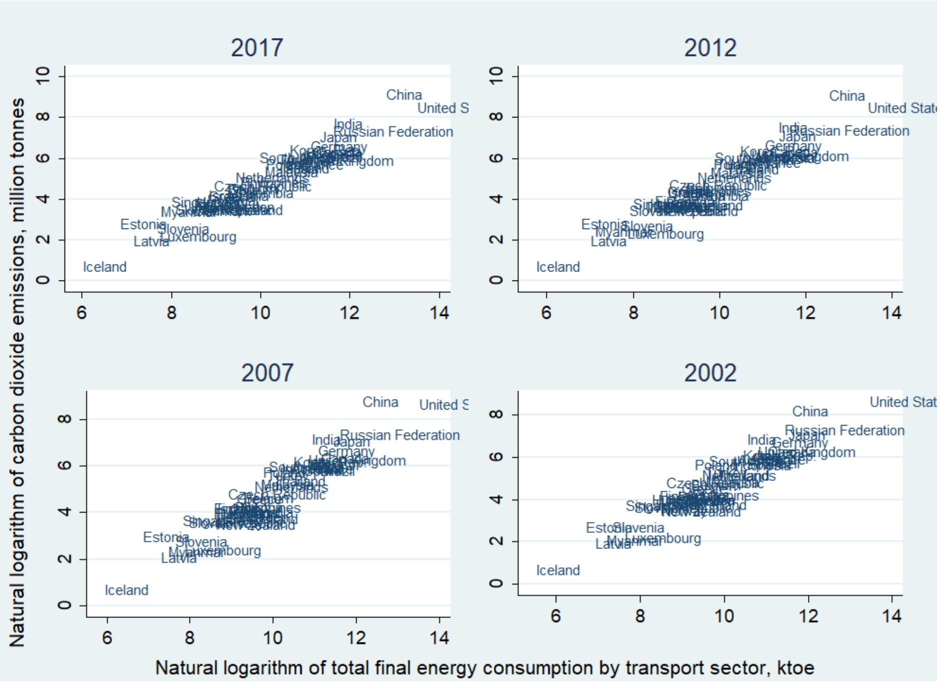

Figure 6-4. Scatterplot of lnCO2 and Natural Logarithm of Energy Consumption by Transport Sector

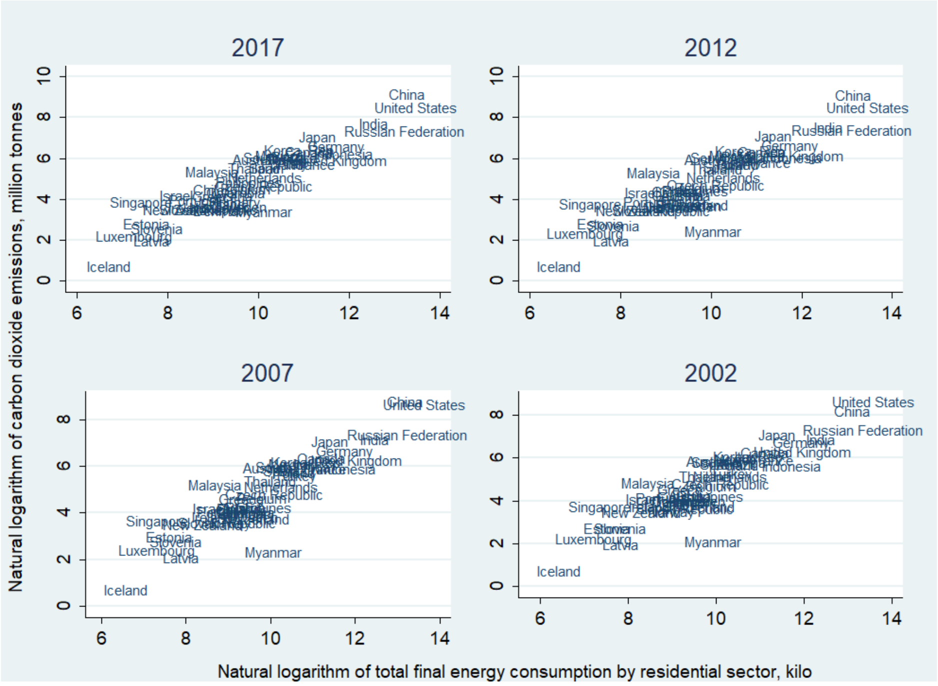

Figure 6-5. Scatterplot of lnCO2 and Natural Logarithm of Energy Consumption by Residential Sector

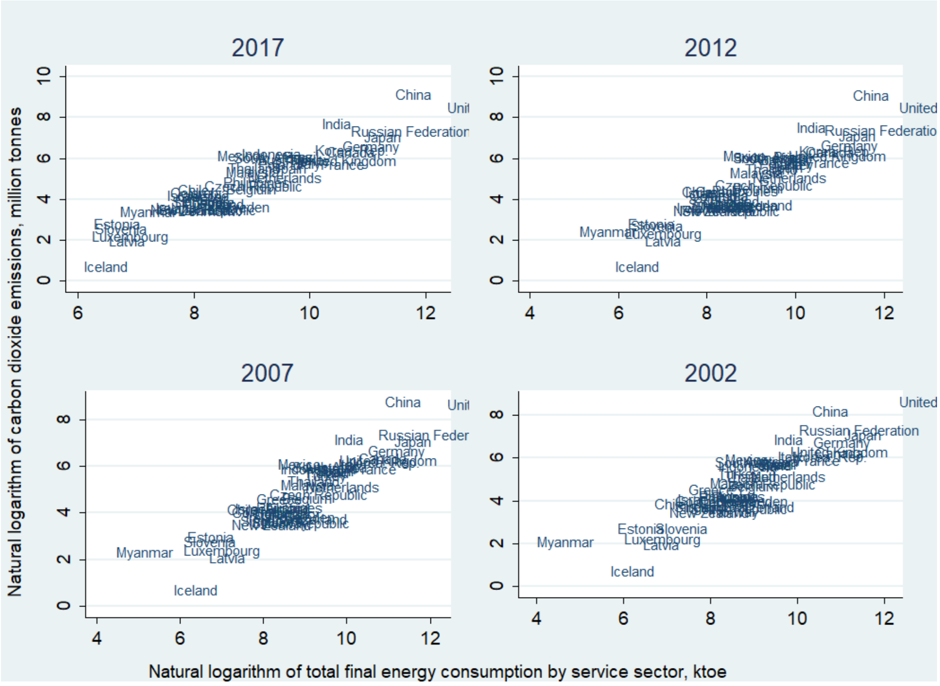

Figure 6-6. Scatterplot of lnCO2 and Natural Logarithm of Energy Consumption by Service Sector

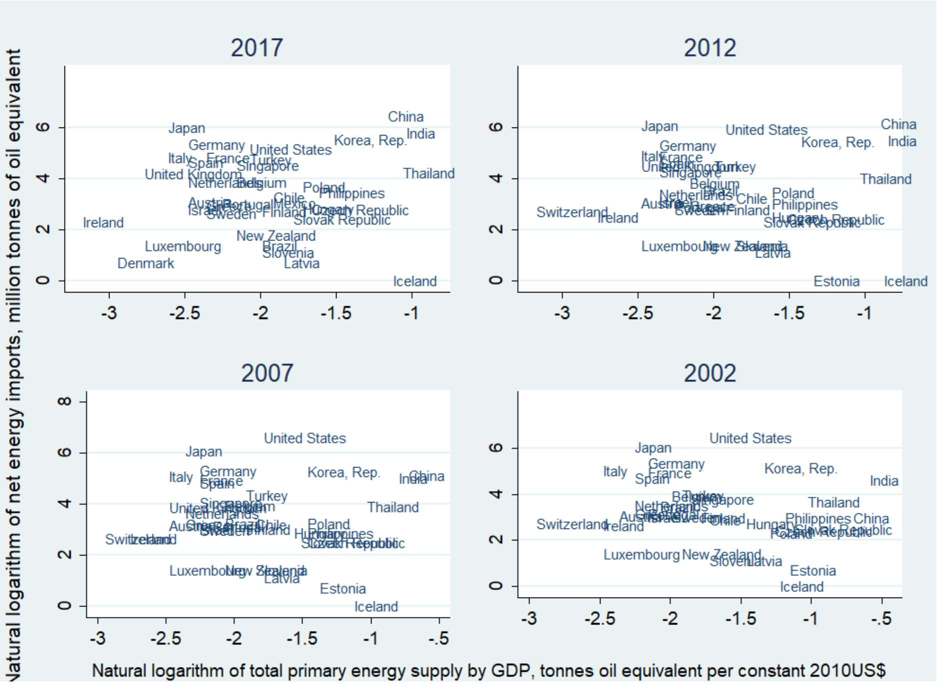

Figure 6-7. Scatterplot of lnCO2 and Natural Logarithm of Energy Intensity

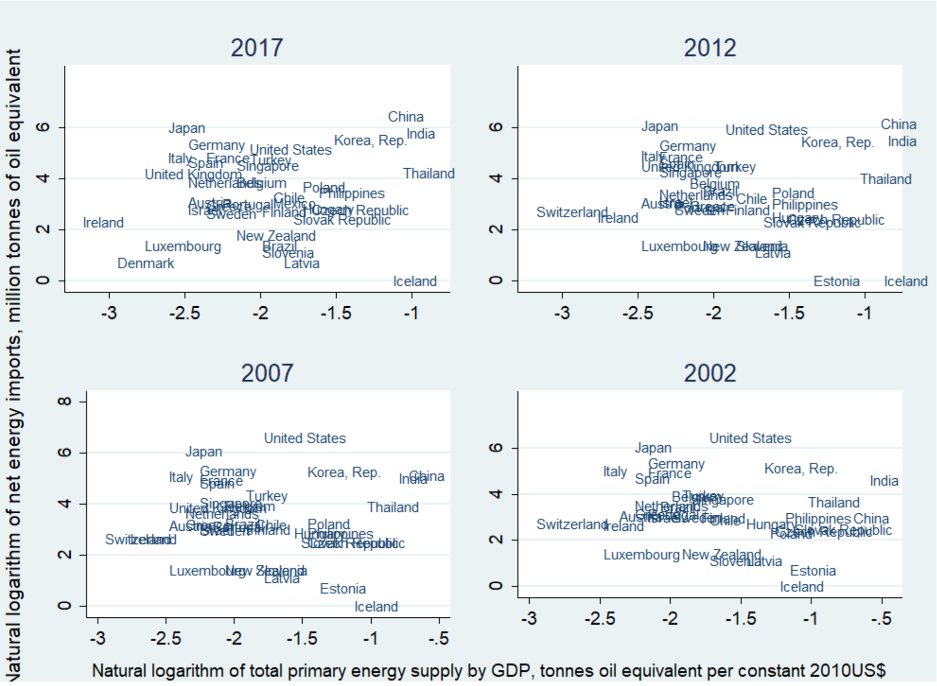

Figure 6-8. Scatterplot of lnCO2 and Natural Logarithm of Carbon Intensity

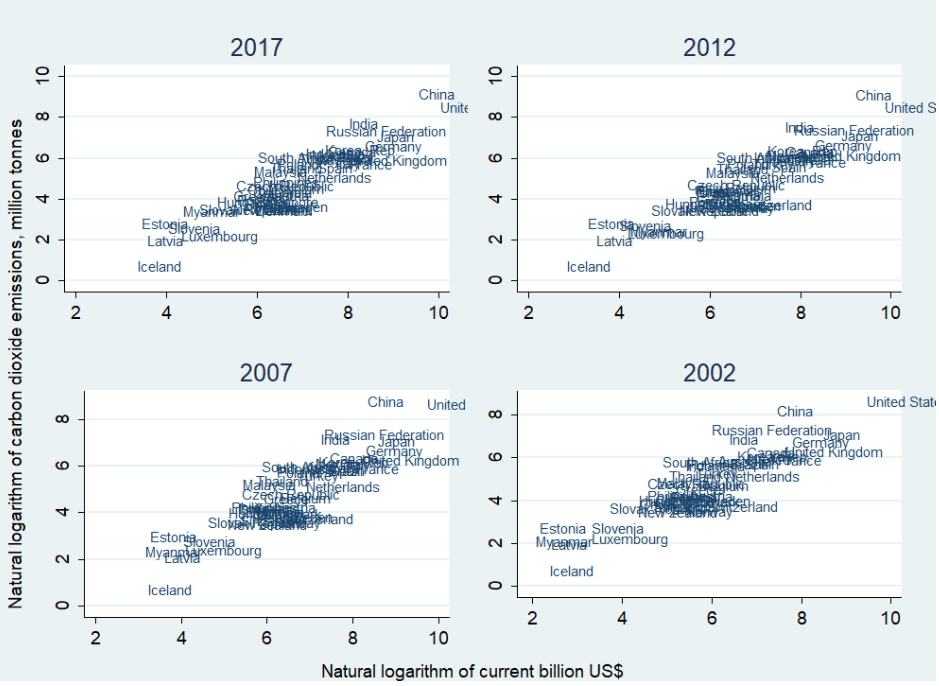

Figure 6-9. Scatterplot of lnCO2 and Natural Logarithm of Gross Domestic Product

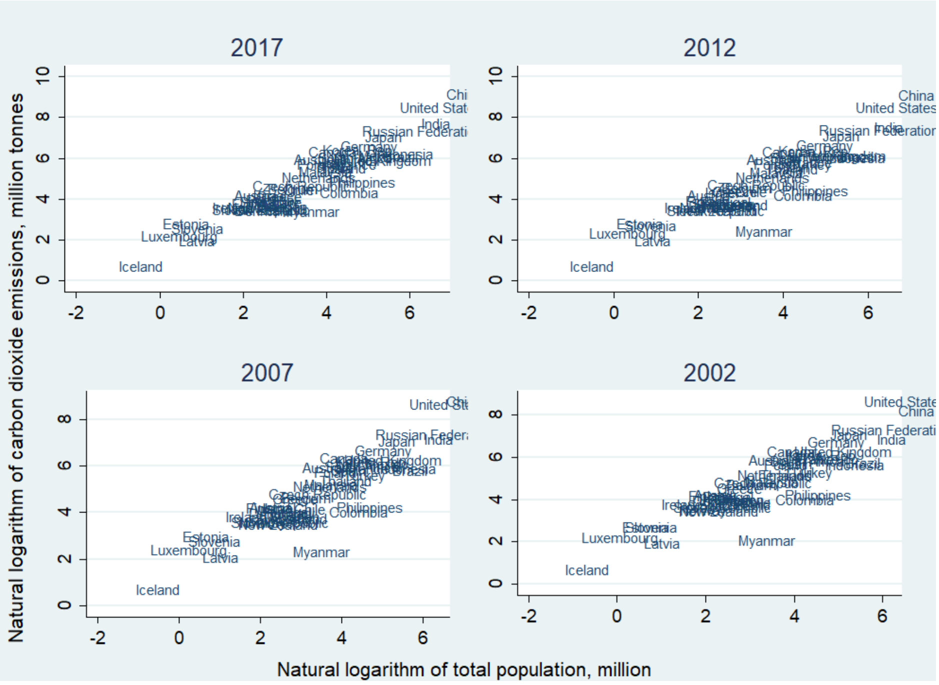

Figure 6-10. Scatterplot of lnCO2 and Natural Logarithm of Population

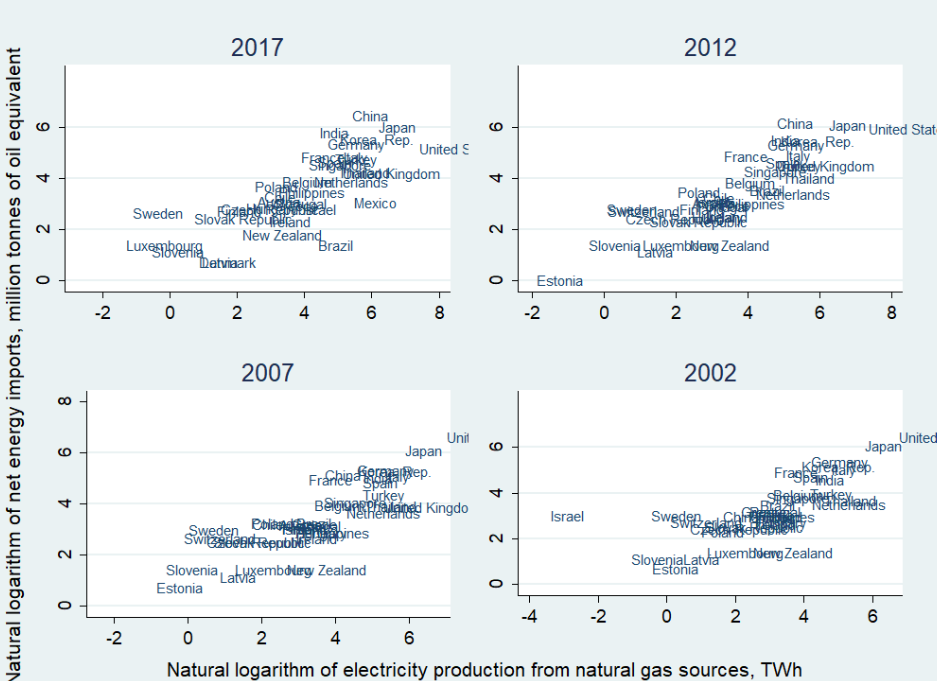

Figure 6-11. Scatterplot of lnEI and Natural Logarithm of Electricity Generation by Gas

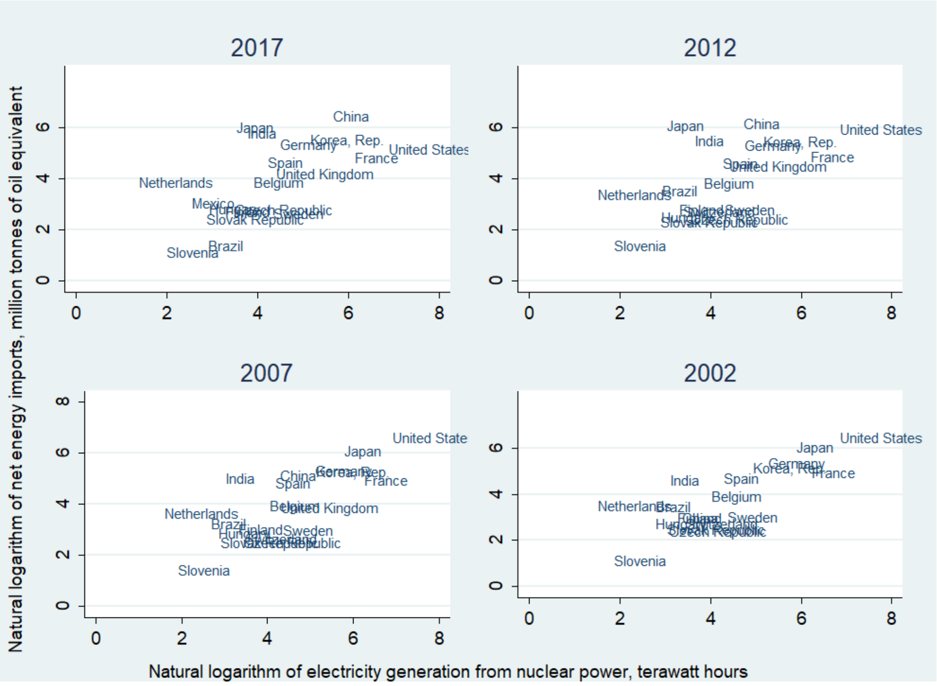

Figure 6-12. Scatterplot of lnEI and Natural Logarithm of Electricity Generation by Nuclear Power

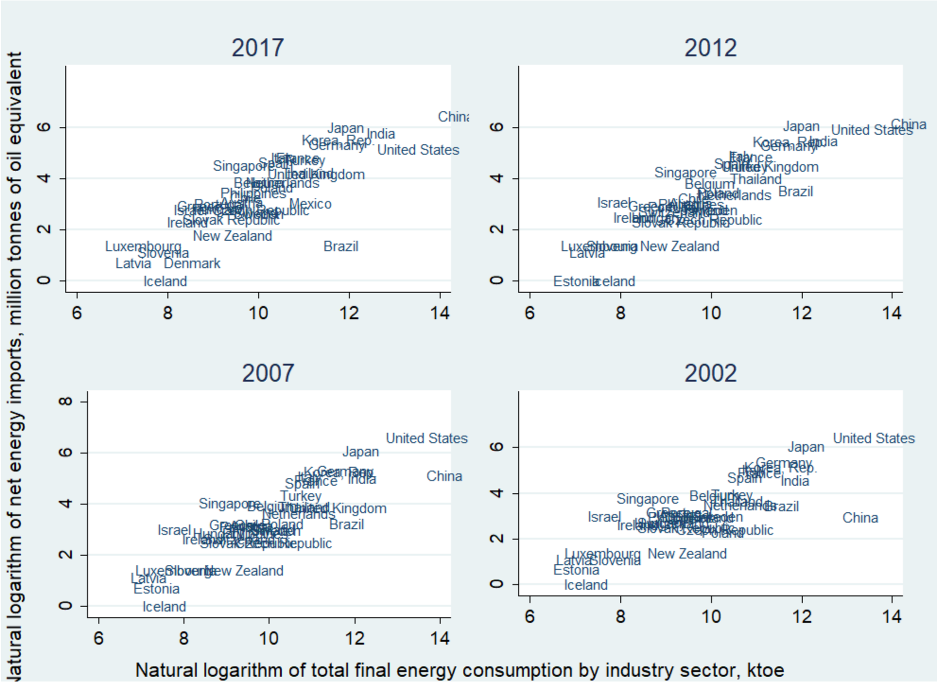

Figure 6-13. Scatterplot of lnEI and Natural Logarithm of Energy Consumption by Industry Sector

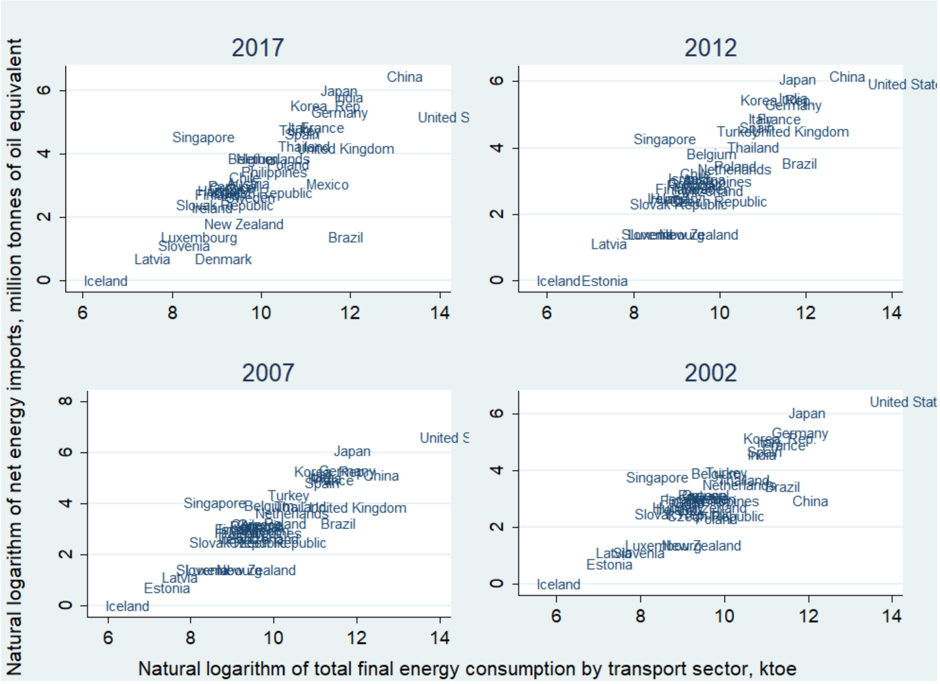

Figure 6-14. Scatterplot of lnEI and Natural Logarithm of Energy Consumption by Transport Sector

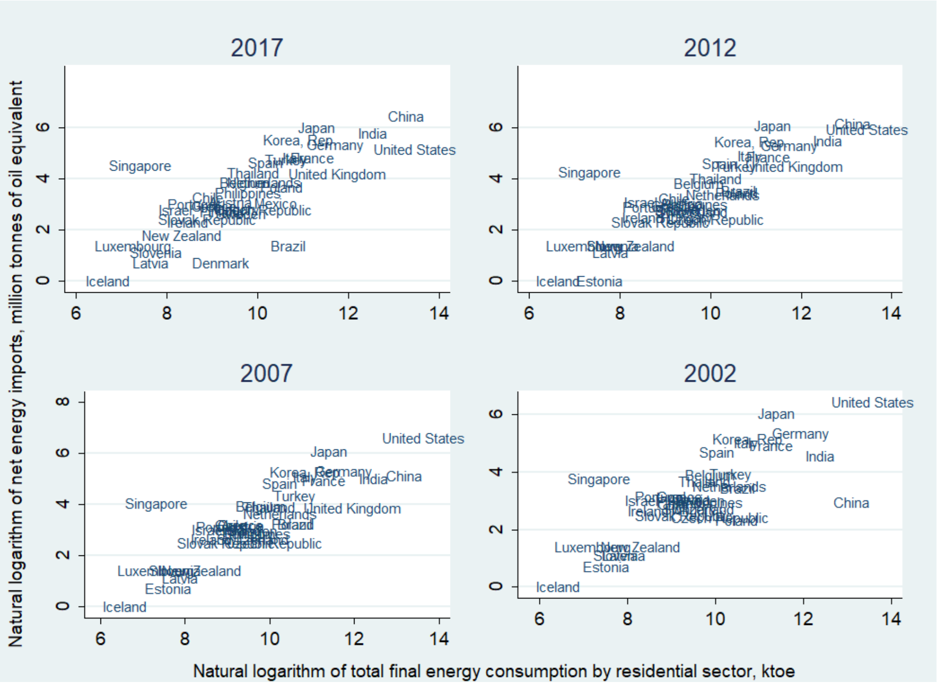

Figure 6-15. Scatterplot of lnEI and Natural Logarithm of Energy Consumption by Residential Sector

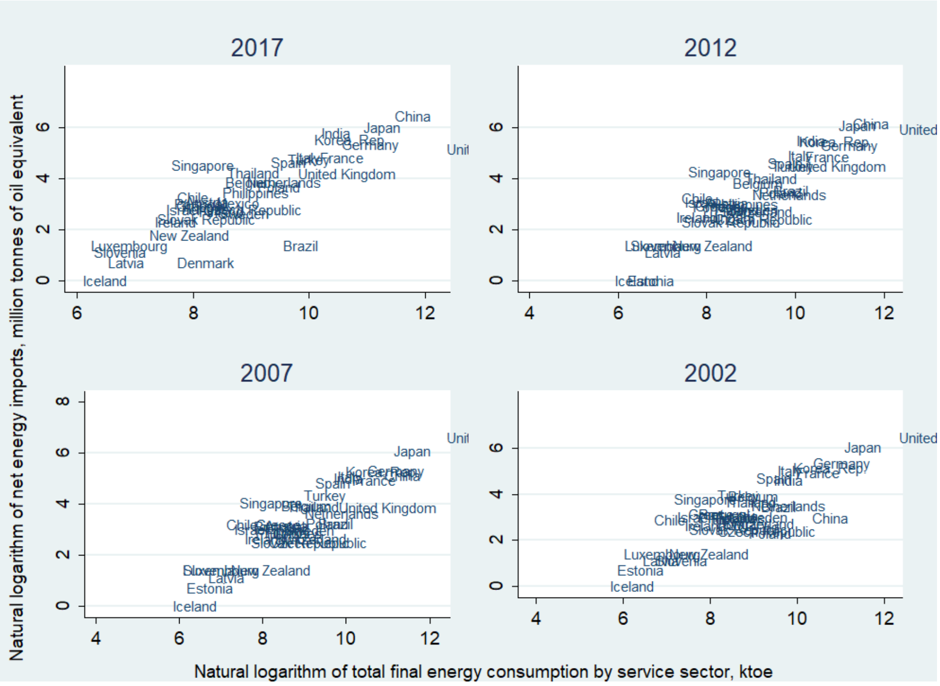

Figure 6-16. Scatterplot of lnEI and Natural Logarithm of Energy Consumption by Service Sector

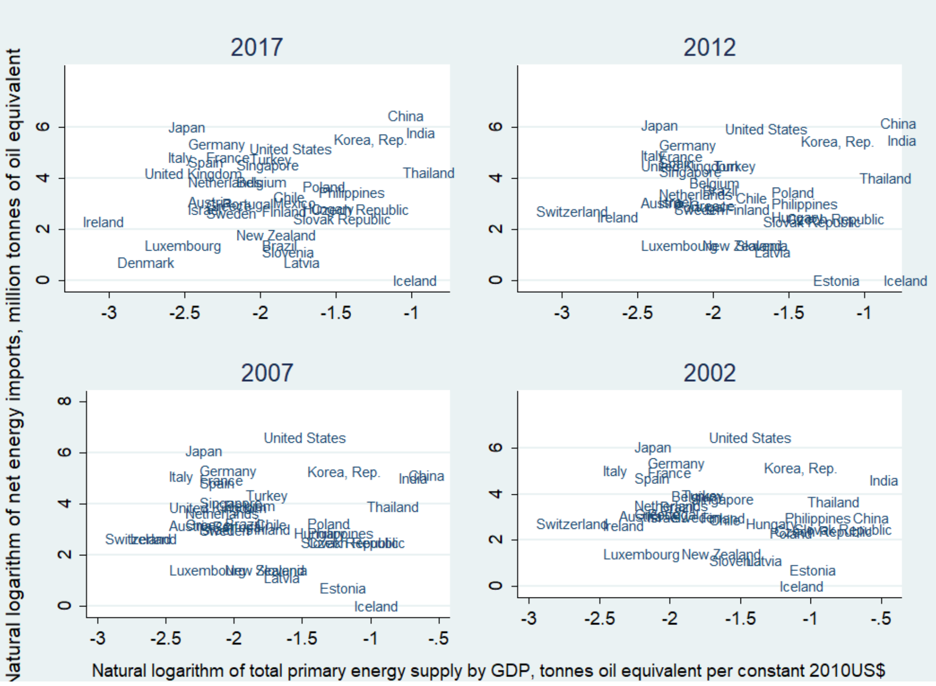

Figure 6-17. Scatterplot of lnEI and Natural Logarithm of Energy Intensity

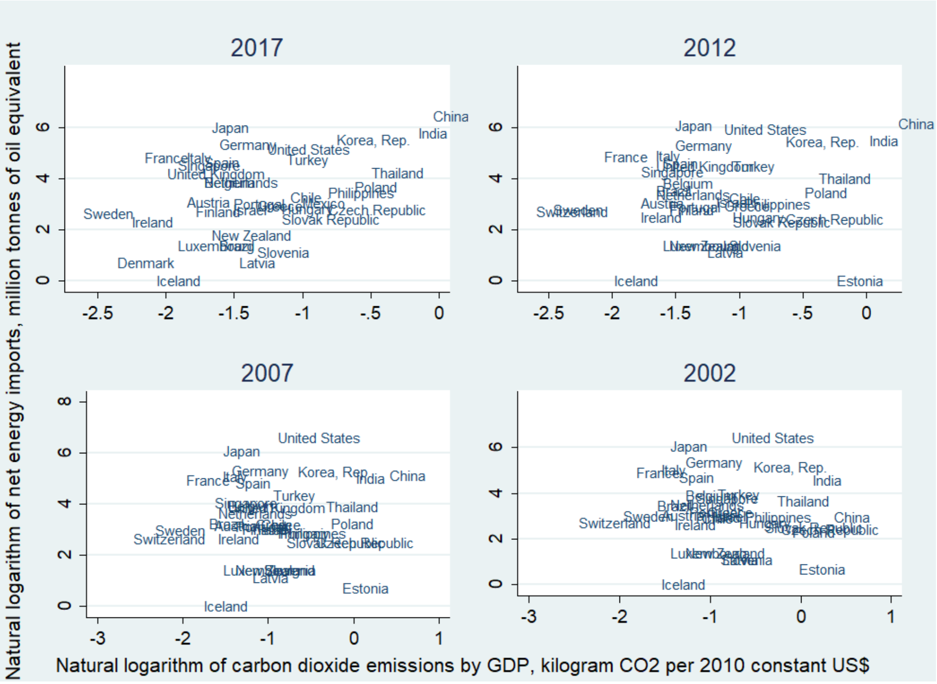

Figure 6-18. Scatterplot of lnEI and Natural Logarithm of Carbon Intensity

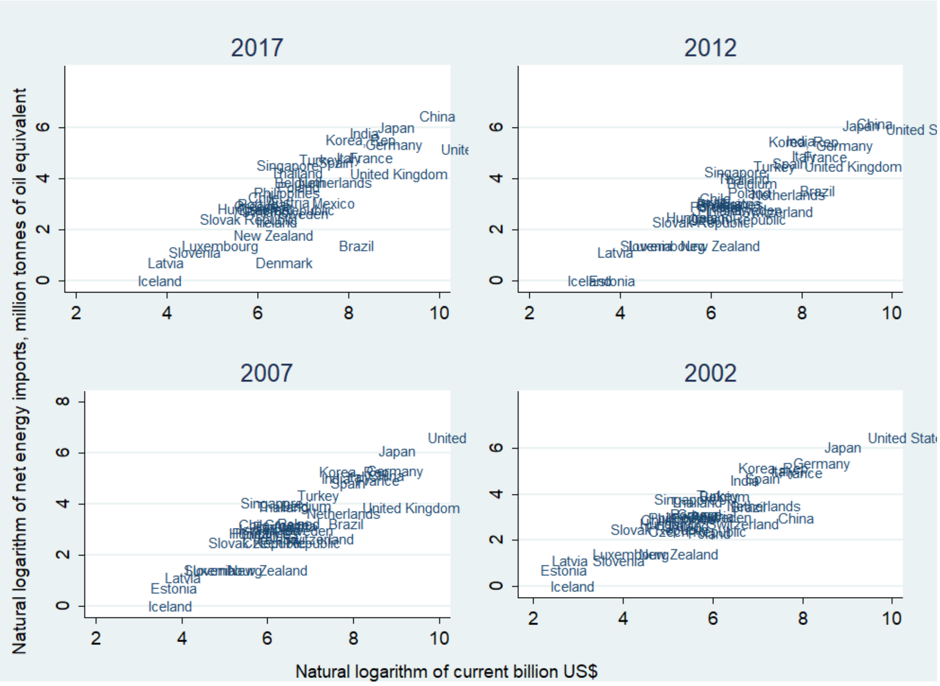

Figure 6-19. Scatterplot of lnEI and Natural Logarithm of Gross Domestic Product

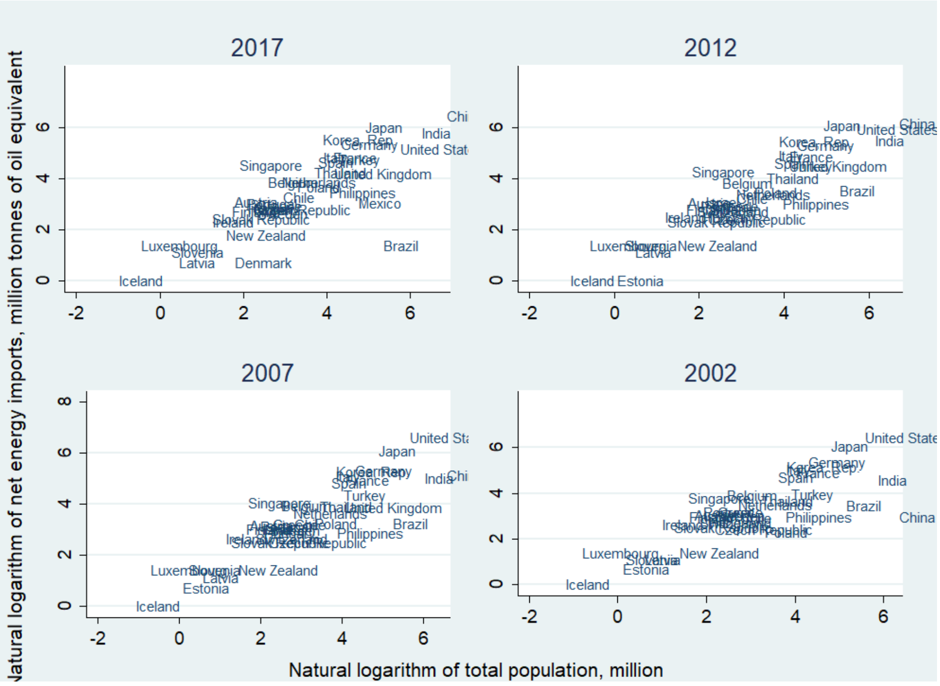

Figure 6-20. Scatterplot of lnEI and Natural Logarithm of Population

CURRICULUM VITAE

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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	UHOH Environmental Sciences	2012
MS	BOKU Environmental Sciences	2012
BS	METU Environmental Engineering	2008
High School	Mamak Anadolu High School, Ankara	2000

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2021-current	Çınar Consultancy, Ankara, TR	Technical Office Coordinator
2020-2021	Alter International, Ankara, TR	Environmental Expert
2019-2020	G ve M Mühendislik, Erbil, Iraq	HSE Advisor
2019-current	Sigun Ekolojik Consultancy, Ankara, TR	Cofounder
2017-2019	TANAP IPTM, Kars-Erzurum, TR	Lead Env. Specialist
2016-2017	2U1K Consultancy, Ankara, TR	Env. Engineer
2013-2017	Typsa Engineering, Karabük, TR	Env. Monitoring Expert
2009-2010	Uni. Stuttgart, IER, Stuttgart, DE	Student Assistant
2008-2009	PPM Consultancy, Ankara, TR	Environmental Eng.

FOREIGN LANGUAGES

Advanced English, Intermediate French and German

PUBLICATIONS

1. Gül, M. H. H., Gülbaz, S., September 2013, Effect of Vegetation on the Availability of Water in Ankara under the Expected Impacts on Climate Change, poster session presented at MESAEP 17th International Symposium on Environmental Pollution and Its Impacts on Life of Mediterranean Region, İstanbul, Turkey
2. Gülbaz S., Kazezyilmaz Alhan C.M., Vanolya M.M, Gül H.H.M., "Investigation of Land Use Effects by Using a Hydrodynamic Model for Ankara Stream Watershed", **River Basins 2017, Vienna, Austria, June 19-29, 2017**, pp.36-36