THE ROLE OF LICENSE-EXEMPT EXCESS ELECTRICITY GENERATION IN TÜRKİYE'S ECONOMIC GROWTH

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ABSTRACT

THE ROLE OF LICENSE-EXEMPT EXCESS ELECTRICITY GENERATION IN TÜRKİYE'S ECONOMIC GROWTH

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Türkiye, with ample sunlight, wind and hydroelectric resources, and well-suited for the development of renewable energy projects due to its geographic and climate characteristics, aims to enhance its installed capacity by increasing the proportion of electricity generated from renewable resources. The unique model of license-exempt electricity generation, primarily employed by renewable power plants, presents investors with the opportunity to generate electricity for their self-consumption needs without obtaining a generation license and to sell excess electricity to the authorized supply company, subject to certain constraints. This study explores the relationship between license-exempt excess electricity generation and economic growth. Utilizing data from 81 cities in Türkiye over the period 2015-2021, we employ the System GMM method to estimate the empirical model. The findings reveal a statistically significant positive impact of license-exempt excess electricity generation on economic growth.

Keywords: License-exempt electricity generation, energy, growth, system GMM

ÖZ

LİSANSSIZ İHTİYAÇ FAZLASI ELEKTRİK ÜRETİMİNİN TÜRKİYE'NİN EKONOMİK BÜYÜMESİNE ETKİSİ

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Coğrafi konumu ve iklim özellikleri sayesinde güneş, rüzgâr ve hidroelektrik gibi yenilenebilir enerji kaynakları bakımından avantajlı bir durumda olan Türkiye, yenilenebilir kaynaklardan üretilen elektriğin payını artırarak kurulu gücünü artırmayı hedeflemektedir. Çoğunlukla yenilenebilir enerji santralleri için kullanılan lisanssız elektrik üretim modeli, yatırımcılara üretim lisansı almadan öz tüketim ihtiyaçlarını karşılamak için elektrik üretme ve ürettikleri ihtiyaç fazlası elektriği belirli kısıtlamalara tabi olarak görevli tedarik şirketine satma imkânı tanımaktadır. Bu çalışmada, lisanssız ihtiyaç fazlası elektrik üretimi ile ekonomik büyüme arasındaki ilişki, Türkiye'deki 81 ilin 2015-2021 yılları arasındaki verileri esas alınarak sistem GMM yöntemiyle analiz edilmiştir. Analiz, lisanssız ihtiyaç fazlası elektrik üretiminin ekonomik büyüme üzerinde istatistiksel olarak anlamlı pozitif bir etkisi olduğunu ortaya koymaktadır.

Anahtar Kelimeler: Lisanssız elektrik üretimi, enerji, büyüme, sistem GMM

To my father, İsmail Özgür Yılmaz, for always encouraging me to become the best version of myself.

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LIST OF ABBREVIATIONS

ADF:	Augmented Dickey – Fueller
Amending Regulation:	The Regulation Amending the Electricity Market License-Exempt Electricity Regulation, (OG Number: 31920, Date: 11 August 2022)
BRIC:	Brazil, Russia, India, and China
Constitutional Court Decision, 1994:	Constitutional Court Decision dated 9.12.1994 and numbered E. 994/43, K. 994/42-2.
DTI:	Department of Trade and Industry in the United Kingdom
ECM:	Error Correction Model
EIA	Environmental impact assessment.
Electricity Market Law:	Electricity Market Law No. 6446
EMRA:	Energy Market Regulatory Authority
EMRA Board Decision No. 11098:	EMRA Board Decision No. 11098
Environmental Impact Assessment Regulation:	Environmental Impact Assessment Regulation, (OG Number: 29186, Date: 25 November 2014)
EPA:	Environmental Protection Agency.
Et al:	And others
GDP	Gross Domestic Product
GW	Gigawatt
GMM:	Generalized method of moments

G7:	Germany, Japan, Canada, the United Kingdom, the United States, France and Italy
G8:	Group of Eight (Germany, Italy, Japan, Russia, France, US, UK and Canada)
IEA:	International Energy Agency
IPS:	Im, Pesaran and Shin
kWh:	Kilowatt hours.
Law No. 4628:	Electricity Market Law No. 4628
Law No. 3096:	Law No. 3096
License-Exempt Regulation:	Electricity Market License-Exempt Electricity Generation Regulation, (OG Number: 28783, Date: 2 October 2013)
Licensing Regulation:	Regulation re Electricity Market Licensing (OG Number: 28809, Date: 2 November 2013)
LSDV:	Least-squares dummy variables.
MENR:	Ministry of Energy and Natural Resources.
MW:	Megawatt
OECD:	Organisation for Economic Co-operation and Development
OG	Offical Gazette
OLS:	Ordinary least squares.
Presidential Decision No. 1044:	Presidential Decision No. 1044
Q:	Quarter
Regulation on the Commissioning of Electricity Generation and Storage Facilities:	Regulation on the Commissioning of Electricity Generation and Storage Facilities, (OG Number: 31044, dated 19 February 2020)

Renewable Energy Law	Renewable Energy Law No. 5346
SAARC:	South Asian Association for Regional Cooperation
TEA:	Turkish Electricity Authority
TEİAŞ:	Turkish Electricity Transmission Corporation
UK:	United Kingdom
US:	United States
USD:	United States Dollar
YEKA:	Renewable Energy Resource Areas
YEKDEM:	The renewable energy support mechanism provided under the Renewable Energy Law.

CHAPTER 1

INTRODUCTION

The global shift towards sustainable energy has placed renewable energy at the center of discussions on economic growth and environmental sustainability. As the early installed renewable power plants have matured and reached the end of their operational lifespans, there has been an increasing examination of the benefits and drawbacks associated with these technologies. Solar and wind energy are widely regarded as natural and inexhaustible sources that significantly reduce carbon dioxide emissions unlike fossil fuels.

Solar energy offers numerous benefits: it is a sustainable alternative to fossil fuels, has a low environmental impact, and can be harnessed by any country. However, it also presents certain drawbacks. Solar energy production is limited to daylight hours, requires substantial land areas, and some solar technologies depend on rare materials. The metals used in solar panels pose negative impacts on both the environment and human health. In addition, the challenges associated with recycling solar panels at the end of their lifespan and the hazardous chemicals they contain pose significant environmental risks.

Türkiye has adopted a cautious approach in shifting from exhaustible fossil fuels to renewable energy sources. Historically, energy policies were designed to ensure a timely, reliable, and adequate energy supply to back the anticipated economic and social development. This approach aimed to rapidly activate domestic resources and enhance investments in the energy sector through state and private sector collaboration. Consequently, Türkiye has prioritized diversifying its energy sources to meet its needs, striving to fully utilize domestic resources such as lignite and hard coal. However, the pressure regarding climate crisis and the harmful effects of non-renewable energy resources leave countries no choice but shift from fossil energy sources to clean energy sources. Concerns over energy security brought on by the war between Russia and Ukraine have prompted countries to rely less on imported fossil fuels, whose prices have skyrocketed, and more on renewable energy sources like solar and wind according to IEA (2022). In the face of these crises, Türkiye’s energy sector has to quickly adapt to fulfill market demands. While 2023 marked the 100th anniversary of the Republic of Türkiye, renewable energy sources and their influence on Türkiye’s economic growth became more important than ever. Moreover, Türkiye’s ratification of the Paris Agreement and its 2053 Net Zero goal underscore its commitment to reducing carbon emissions and transitioning to renewable energy sources. In this respect, it is among the priorities of the government to increase the share of renewable energy sources in electricity generation. The Türkiye National Energy Plan 2022 outlines a strategic focus on enhancing the share of intermittent renewable energy sources, specifically wind and solar, in the overall electricity generation mix. This initiative is designed to capitalize on Türkiye’s existing flexibility opportunities and vast renewable energy potential. In alignment with these objectives, the plan sets forth ambitious targets for 2035, anticipating a substantial increase in installed capacities. The wind power sector is projected to reach 29.6 GW, comprising 24.6 GW onshore and 5 GW offshore. Simultaneously, solar power is expected to contribute significantly, reaching an installed capacity of 52.9 GW. Furthermore, the plan underscores the commitment to diversifying the renewable energy portfolio by increasing installed capacities in hydroelectric power plants to 35.1 GW and in geothermal and biomass power plants to 5.1 GW, reflecting Türkiye’s comprehensive approach towards sustainable and resilient energy infrastructure.

Various efforts have been made in the past in Türkiye to transform energy systems to renewable energy, one of them being license-exempt electricity model which paves the way for electricity generation for self-consumption through renewable sources. Under the Electricity Market Law and the supplementary legislation enacted thereunder, in particular, the Licensing Regulation, EMRA is responsible for regulating the licensing regime and activities related to the electricity market. In Turkish electricity market, individuals who want to generate electricity from a power plant project must incorporate a company and apply for an EMRA generation license. However, with the license-exempt generation model introduced by EMRA in 2010, it became possible for real and legal persons to develop and operate power plants, which meet the certain criteria set out in the License-Exempt Regulation, without a need to obtain a generation license from EMRA.

With the license-exempt generation model, the following targets were aimed to be achieved by the EMRA under the License-Exempt Regulation:

- The consumers should be able to meet their electricity needs from the generation facility which is the closest to their consumption facility.
- The small-scale generation facilities should contribute to Türkiye's economy while ensuring supply security.
- The transmission and distribution costs and losses should decrease with the distributed generation model.

License-exempt generation, mostly based on renewable sources, has an extensive implementation in Türkiye since 2015. According to the information provided by EMRA (EMRA January 2024 Report), Türkiye has a license-exempt installed capacity of 10.865,39 MW in total as of January 2024 and most of the license-exempt installed capacity comes from renewable sources as indicated in the Figure [1].

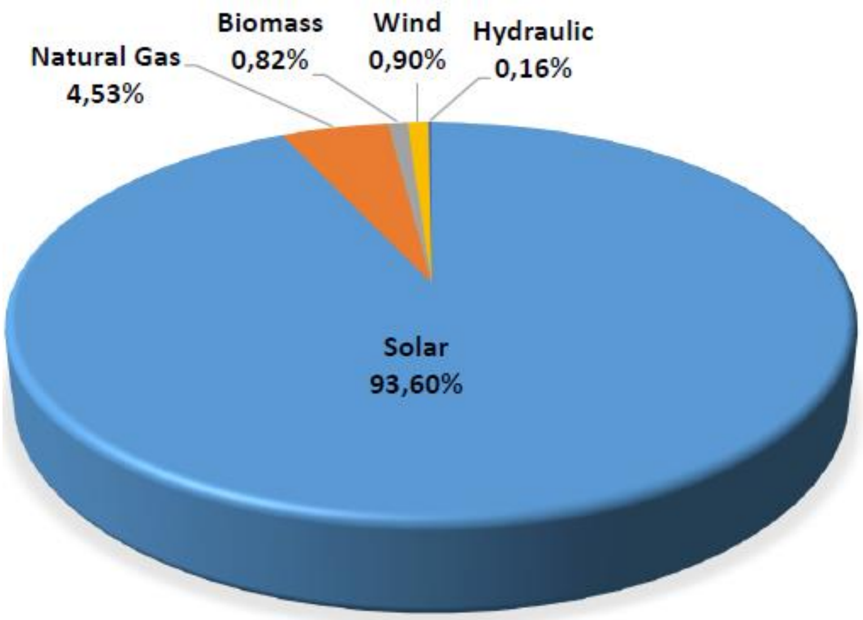

Figure 1. The percentages of installed capacities of the license-exempt facilities based on the types of resources

The implementation of the license-exempt electricity generation model marked a pivotal legal milestone in the Türkiye's electricity market. In a strategic move to incentivize consumers, a purchase guarantee was instituted, allowing them to sell any surplus energy from their self-generated electricity, exceeding their personal consumption, under YEKDEM (Renewable Energy Support Mechanism) at a determined price. This measure aimed to encourage consumers to actively participate in electricity generation. The distribution of license-exempt excess electricity, categorized by resource types and purchased by authorized supply companies, is detailed in Figure [2] below, as reported in the EMRA January 2024 Report. Furthermore, the figures displaying the provincial distribution of excess license-exempt electricity purchased by the authorized supply company since 2015 are provided in Appendix-1 of this thesis.

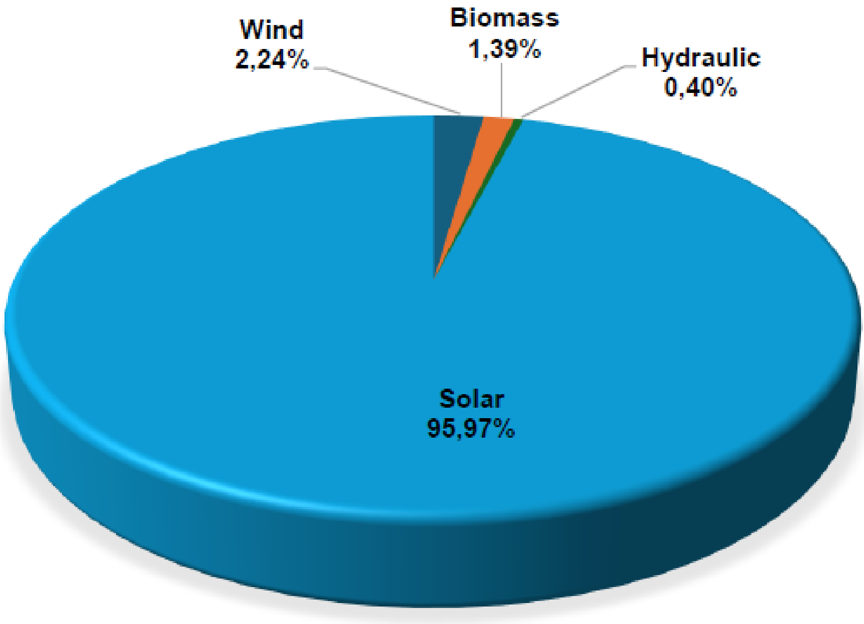

Figure 2. Percentages of the license-exempt excess electricity which were purchased by the authorized supply company based on the types of resources

On 11 August 2022, Amending Regulation and EMRA Board Decision No. 11098 entered into force and the sale of excess electricity became subject to major limitations imposed by EMRA. Prior to this date, the authorized supply company in the corresponding distribution region would purchase the entire surplus electricity for the initial 10 years of the power plant's operation, as stipulated by the purchase guarantee under the Renewable Energy Law and Presidential Decision No. 1044. The Amending Regulation introduced significant changes, imposing constraints on the sale of surplus electricity, a move that has faced considerable criticism from consumers and investors. The retroactive abolition of the purchase guarantee, as mandated by the Amending Regulation, has impacted consumers who relied on this guarantee to establish their license-exempt power plants through means such as bank loans or business models such as ESCO (Energy Service Company).

A country's development and the potential for economic expansion can be negatively impacted by a country's limited energy supply and an uncertain political climate. In this situation, supply sustainability is a key consideration (Samawi et al. (2017)). The fact that the purchase guarantee encouraged the consumers to establish their own power plants in the past and the potential deterring impact the Amending Regulation might have on Türkiye's economic growth motivated us to conduct this study.

The main research objective of this study is to understand the impact of license-exempt excess electricity generation on Türkiye's economic growth. In this regard, our hypothesis is that license-exempt excess electricity generation has a positive and significant impact on Türkiye's economic growth. For testing this hypothesis, we use a data set which includes 567 observations from 81 cities in period 2015-2021 and conduct a two-step System Generalized Method of Moments analysis. This research seeks to bridge multiple gaps in the current body of literature. Firstly, it uniquely focuses on the impact of license-exempt excess electricity generation on economic growth, a relatively unexplored area. Secondly, it uses province-level panel data, providing a more granular analysis compared to the commonly used country-level data. Finally, it utilizes the System Generalized Method of Moments (GMM) which addresses endogeneity issues, offering more robust conclusions.

The thesis' remaining sections are structured as follows: After this introduction, Chapter 2 presents a review of the literature. Chapter 3 provides the legal background of license-exempt electricity generation and sale of license-exempt excess electricity. Information on the data, model and descriptive statistics is detailed in Chapter 4. Chapter 5 explains the methodology. Results are presented in Chapter 6; Chapter 7 offers a summary of the key findings and recommendations.

CHAPTER 2

LITERATURE REVIEW

License-exempt electricity generation is widely used for self-consumption purposes in Türkiye. The owners of the license-exempt electricity generation facilities are allowed to sell the excess electricity amount exceeding the minimum self-consumption subject to conditions explained in Chapter 3 of this thesis. We study the impact of the excess electricity generated by license-exempt electricity generation facilities and sold to the authorized supply companies on Türkiye's economic growth. For this purpose, related previous studies are reviewed in this Chapter. This thesis categorizes the literature into three main sections: studies focusing on the license-exempt electricity generation, those analysing the production of renewable energy and its effects on economic growth, and research specifically focusing on how renewable energy consumption has an impact on economic growth.

2.1. License-Exempt Electricity Generation

In the literature, license-exempt electricity generation is often analyzed in the context of distributed/decentralized generation. License-exempt energy generation is the decentralized production of electricity, enabling persons to produce their own electricity without the requirement of obtaining a formal license or permission from a regulatory authority. Distributed generation is the production of energy at or in close proximity to the location where it is used, in contrast to centralized power facilities situated at a considerable distance from end users. Distributed generation systems are often of a lower magnitude and can be situated on roofs, within residential properties, or in close proximity to the end-users. Typical instances of distributed generation technologies encompass solar panels, wind turbines and micro-turbines. Distributed generation systems are commonly interconnected with the electrical grid, enabling them to either provide power to the local demand or surplus electricity back to the grid. In Türkiye, persons who generate renewable electricity from small-scale power generators are mostly excluded from these licensing obligations. License-exempt electricity generation is also considered as a form of decentralized electricity generation in the sense that it involves smaller, distributed sources of power generated closer to where it is consumed, reducing the need for long-distance transmission lines and large centralized power plants. License-exempt generation in Türkiye contributes to decentralization by allowing individual households, businesses, or communities to generate their own electricity.

The existing academic research on the correlation between license-exempt electricity generation/distributed electricity generation and economic growth seems to be limited. While numerous studies have explored distributed generation, renewable energy, grid integration, and economic growth, there is a significant lack of research that particularly investigates the impact of excess license-exempt electricity generation on economic development.

The absence of research in this area is noteworthy, given the substantial changes occurring in the worldwide energy sector towards clean and renewable sources of energy and importance of the decentralized generation. This thesis aims to thoroughly analyze the relation between license-exempt excess electricity generation and economic growth, to address the existing gap.

Being one of few studies which analyze decentralized electricity generation within an economic context, Klagge & Brocke (2012) analyze two instances of pioneering areas in Germany characterized by the dynamic growth of decentralized electricity generation from renewable sources and conclude that decentralized electricity generation from renewable sources has the potential to have a crucial role in fostering local economic development, both in rural areas and their corresponding urban centers. Heinbach et al. (2014) presents a comprehensive examination of the scope and dispersion of value-added and employment impacts resulting from renewable energy at the local level. The results underscore that the adoption of renewable energy holds substantial promise in generating both value added and employment across Germany's renewable energy sector, including regions traditionally devoid of manufacturing industries. Recognizing and understanding these effects can serve as a valuable input for local decision-making, fostering acceptance, and motivating efforts to advance decentralized renewable energy generation.

The existing research also focuses on the importance and benefits of distributed electricity generation in promotion of the renewable energy and barriers preventing the development of the distributed electricity generation.

Allan et al. (2015) emphasizes that technical developments, regulatory difficulties, and emissions reduction initiatives have changed the power supply structure and transmission and distribution networks. The development of renewable power production technologies, competition in the electricity market, worries over aging infrastructure, and capacity limits have increased interest in distributed electricity generation. Distributed generation includes a wide range of small-scale, low carbon or efficient technologies closer to the end user than traditional generation. Such technologies may reduce transmission and distribution costs and eliminate the need for infrastructure and capacity increases. Wang & Zhong (2009) examines the conditions of distributed generation in China and its suitability in tackling specific obstacles in the nation's energy sector. The study emphasizes that rapid economic growth in China resulted in a substantial increase in electricity demand and distributed electricity generation can alleviate energy shortages in China. Sharma & Bartels (1997) analyzes the expansion in decentralized power generation in Australia and identifies geography and customer activities as the driving forces behind this expansion.

In the literature, there are various barriers identified as preventing the development of the distributed electricity generation. (Garlet et al., 2019) categorizes these barriers as (i) technical (quality of the systems, lack of understanding the advance technologies, architectural structure), (ii) economic (cost of systems, long investment return periods, lack of attractive financing) (iii) social (consumer culture, inadequate understanding of technology), (iv) managerial (inadequate or disregarded postpurchase support offered by firms implementing systems and unsuccessful marketing strategies and adverse public perception)and (v) political (instability in the politics, overabundance of bureaucratic processes, insufficient implementation of the incentives, insufficiently established guidelines for the execution, inadequacy in energy compensation mechanisms.)

DTI Report (2007) provides that while there are exemptions in the United Kingdom for distributed generation facilities with a net capacity below a certain threshold, the licensing requirements for generating and supplying energy to the network create challenges for small electricity generators. Although restrictions ensure the stability and safety of the grid, they impose higher costs on smaller generators.

According to the US EPA, distributed generation can contribute to ensuring the provision of clean and dependable power to more customers while simultaneously diminishing power losses along transmission and distribution lines, when linked to the lower voltage distribution lines of the electric utility.

2.2. Renewable Energy Generation and Growth Relationship

Most of excess electricity that is not subject to licensing requirements is mostly generated from renewable energy sources. Although there may be a lack of research explicitly investigating the correlation between excess license-exempt excess power generation and economic growth, an analysis of more comprehensive studies on renewable energy generation and its impact over economic growth yields significant information.

Renewable energy sources have become increasingly prominent as substitutes for conventional fossil fuels. Numerous studies have identified a positive correlation between the generation of renewable energy and economic growth. Bayraktutan et al. (2011) investigates the correlation between economic growth and the generation of electricity derived from renewable sources in OECD members spanning the years 1980 to 2007, employing a panel-data method. The findings suggest a two-way causality between these variables. Increasing electricity production from renewable sources is found to promote sustainable development and support continuous long-term economic growth.

Armeanu et al. (2017) investigate the impact and causal relationship between renewable energy generation and sustainable economic growth in the European Union member countries from 2003 to 2014. Utilizing fixed-effects regression models on panel data, the study confirms a positive correlation between overall renewable energy use and GDP per capita, as well as between specific types of renewable energy and economic growth. Moreover, co-integrating regressions confirm this positive association. The analysis reveals a 1% rise in primary renewable energy generation leads to a 0.05%–0.06% increase in GDP per capita.

Atems & Hotaling (2018) assesses the how electricity generation impacts economic growth, utilizing panel data from 174 countries for the period 1980–2012 and employing the System GMM. The study reveals a positive and statistically significant relationship between renewable electricity generation and economic growth.

Singh et al. (2019) examines the link between the generation of renewable energy and the expansion of the economy, with a focus on the unique impacts on both advanced and emerging economies. By employing the Fully Modified Ordinary Least Square regression model to analyze a dataset consisting of 20 nations from both categories, the analysis covers time between 1995 and 2016. The results reveal a strong and statistically significant correlation between the generation of renewable energy and economic growth in both developed and developing countries within the selected time period. Moreover, findings emphasize that the influence of renewable energy generation on economic growth is more significant in developing countries as opposed to developed ones.

Ohler & Fetters (2014) investigate the causal link between economic growth and the generation of electricity from different type of renewable sources in 20 OECD members spanning the period from 1990 to 2008. Utilizing a widely employed panel ECM, the study reveals several key findings such as mutual causality between aggregate renewable energy generation and real GDP and biomass, hydroelectric, and waste electricity generation exert the most significant impact on real GDP in the long run.

There are also various studies which examine the relationship between renewable electricity generation and growth in context of Türkiye. Şerifoğlu (2021) examine the long-term relationship between renewable energy generation and economic growth in Türkiye for the periods from 2013: Q2 to 2020: Q2, employing Ordinary Least Square and Dynamic Ordinary Least Square methods. The results obtained from both methods indicate a positive impact of total renewable energy generation on economic growth. Furthermore, the findings suggest that energy generation from geothermal and biomass exhibits the most substantial influence on economic growth.

Korkmaz & Develi (2012) explore the causality between consumption of energy, energy production, and Gross Domestic Product using annual data from Türkiye for the period 1960-2009. The Johansen cointegration test and vector error correction model were employed for the causality analysis. The empirical findings indicate a long-term relationship between the variables during the examined period. Similarly, Erdoğan et al. (2018) investigates the relationship between renewable energy generation and economic growth in Türkiye for the period between 1998-2015, employing the Johansen Cointegration test and Vector Error Correction Model. The findings reveal that economic growth serves as the long-term driver of renewable energy production, and these two variables are determined to be cointegrated.

Özbek & Apaydın (2020) take a look at the impact of renewable energy generation on economic growth during the period 1990-2017. Employing the Autoregressive Distributed Lag method, the research utilizes data on gross domestic product, capital stock, employment, and renewable energy generation in Türkiye. The findings indicate that increases in capital stock, employment, and renewable energy production have a positive effect on economic growth.

While majority of the studies conclude renewable energy generation positively affects economic growth, Venkatraja (2019) concludes that declining proportion of renewable energy in the overall energy composition may have played a role in fostering faster economic growth within the BRIC region in his study where data covers time between 1990-2015. This suggests that in BRIC countries, an increase in the share of renewable energy relative to total energy could potentially have a negative impact on economic growth.

From the review of existing literature, it is evident that while a substantial number of studies assert a positive relationship between renewable energy generation and economic growth, there is no unanimous consensus.

2.3. Renewable Energy Consumption and Growth Relationship

Extensive literature exists that delves into the relationship between renewable energy consumption and economic growth. According to Apergis & Payne (2010) and Bhattacharya et al. (2016), the correlation between energy consumption and economic growth can be classified into four hypotheses:

i. The feedback hypothesis, proposing bidirectional causation between renewable energy consumption and economic growth. This theory suggests that every change in energy use will have a consequential impact on economic development, but with an inverse relationship.
ii. The growth hypothesis, suggesting a unidirectional causation from renewable energy consumption to economic growth. The growth hypothesis suggests that energy serves as a significant input in the growth process and energy conservation efforts in this scenario will adversely affect economic growth.
iii. The conservative hypothesis, indicating a unidirectional causation from economic growth to renewable energy consumption. Given these circumstances, the implementation of conservation policies will have no impact on economic development.
iv. The neutrality hypothesis, suggesting no causal link between renewable energy consumption and economic growth. It suggests that energy consumption and economic growth are independent of each other, implying that changes in one do not have any significant impact on the other.

Over the past decades, the literature has yielded diverse findings across countries for each of these hypotheses.

2.3.1. The Literature Supporting the Feedback Hypothesis

A range of studies exploring the relationship between renewable energy consumption and economic growth support the feedback hypothesis.

Apergis & Payne (2010), explores the causal relationship between renewable energy consumption and economic growth across 13 Eurasian countries from 1992 to 2007 using a multivariate panel data approach. The heterogeneous panel co-integration test shows a long-run equilibrium relationship among real GDP, renewable energy consumption, real gross fixed capital formation, and the labour force. Error correction models reveal bidirectional causality between renewable energy consumption and economic growth in both the short and long run, supporting the feedback hypothesis of their interdependent relationship.

Destek & Aslan (2017) assesses the impact of renewable and non-renewable energy consumption on economic growth across 17 emerging economies from 1980 to 2012. Utilizing annual data, a bootstrap panel causality approach is employed to account for cross-section dependency and country-specific heterogeneity. Results indicate that, feedback hypothesis is confirmed only for Greece and South Korea.

Shakouri & Khoshnevis Yazdi (2017), covering 1971–2015 in South Africa, investigates the links among economic growth, renewable energy consumption, energy consumption, capital fixed formation, and trade openness using the auto-regressive distributed lag bound testing approach. Results indicate co-integration among the variables, implying a long-term relationship. Granger causality testing reveals bidirectional causality between renewable energy consumption and trade openness impacting economic growth, supporting the feedback hypothesis.

2.3.2. The Literature Supporting the Growth Hypothesis

The second group of the studies which investigate the relationship between renewable energy consumption and economic growth support the growth hypothesis.

Inglesi-Lotz (2016) supports the growth hypothesis, as the study, which utilizes annual data from 34 OECD countries from 1990 until 2010 and employs fixed-effects model, shows that renewable energy consumption or its proportion in the overall energy composition on economic growth is both positive and statistically significant.

Aslan (2016) explores the causal relationships among economic growth, biomass energy consumption, employment, and capital in the United States from 1961 to 2011. Employing the Autoregressive Distributed Lag bounds testing approach for cointegration, the analysis estimates long and short-term relationships among these variables. The results reveal that biomass energy consumption has a positive influence on economic growth in the long run and short run for the U.S. Furthermore, the Granger causality outcomes demonstrate a unidirectional causation from biomass energy consumption to real GDP, supporting the growth hypothesis.

Al-Mulali et al. (2013) analyzed the long-term relationship between renewable energy consumption and GDP growth in various income-level countries. Their findings showed that 79% of the countries had a positive bidirectional relationship, supporting the feedback hypothesis. In contrast, 19% showed no significant long-term connection, supporting the neutrality hypothesis. Additionally, 2% exhibited a unidirectional relationship from GDP growth to renewable energy consumption, confirming the conservation hypothesis. Overall, the results supported the growth hypothesis for the relationship between renewable energy consumption and GDP growth.

2.3.3. The Literature Supporting the Conservative Hypothesis

Furuoka (2017), used both homogeneous and heterogeneous panel methods to investigate the link between renewable and non-renewable electricity consumption and economic development in Estonia, Latvia, and Lithuania from 1992 to 2011. The results showed a unidirectional causality from economic development to renewable electricity consumption, supporting the conservation hypothesis.

Cho et al. (2015) examines and contrasts the long-term causal relationship between renewable energy consumption and economic growth in developed and less-developed countries. Using data from 1990 to 2010 for 31 OECD (developed) and 49 non-OECD (less-developed) countries, a multivariate panel vector error correction model was applied. The results indicate that the conservation hypothesis holds true for developed countries, suggesting that renewable energy has not significantly contributed to their economic growth. In contrast, the feedback hypothesis is supported for less-developed countries, indicating that renewable energy plays a crucial role as a production input, and economic growth leads to increased renewable energy consumption.

Besel et al. (2016) explored the connection between energy consumption and economic growth in the G8 countries from 1989 to 2015, employing the Dumitrescu and Hurlin Granger Causality method. The findings supported conservation hypothesis in G8 countries throughout the studied period.

Chen et al. (2018) investigated the causal link between energy consumption and economic growth across twenty-nine Chinese provinces through panel Granger causality analysis. Their results indicated bidirectional causality in 16 provinces, unidirectional causality in 11 provinces, and no causality in 2 provinces. However, applying critical bootstrap values led to the conclusion that the conservation hypothesis holds true for China.

2.3.4. The Literature Supporting the Neutrality Hypothesis

Payne (2009), by using US annual data spanning from 1949 to 2006, assesses the causal relationship between renewable and non-renewable energy consumption and real GDP. Conducting Toda-Yamamoto causality tests, the findings indicate a lack of Granger-causality between both renewable and non-renewable energy consumption and real GDP. This supports the neutrality hypothesis, suggesting that neither renewable nor non-renewable energy consumption significantly influences the direction of causation with real GDP.

Menegaki (2011), examines the link beteen economic growth and renewable energy in 27 European countries from 1997 to 2007. Utilizing a random effect model and incorporating final energy consumption, greenhouse gas emissions, and employment as additional variables, the findings do not support a direct causal relationship between renewable energy consumption and GDP. The cointegration factor suggests a weak or non-existent link between economic growth and renewable energy consumption in Europe, supporting the neutrality hypothesis.

Tugcu et al. (2012) investigates causal relationship between the renewable energy consumption and real GDP in G-7 countries from 1980-2009, employing Hatemi-J causality tests. The results support neutrality hypothesis for France, Italy, Canada and U.S.A and feedback hypothesis for England and Japan.

2.4. Research Gap

This thesis contributes to the existing literature in several ways. Firstly, it diverges from much of the current research, which focus on the causal relationship between the economic growth and renewable energy generation/consumption, by specifically examining the impact of license-exempt excess electricity generation on economic growth. Recognizing that license-exempt electricity generation increases in Türkiye day by day, the study addresses the necessity of investigating the broader implications of this type of electricity generation on growth. Secondly, the study uses province level panel data contrary to most of the existing studies utilizing country-level data. Lastly, the study departs from previous methodologies that primarily employ Granger causality and/or cointegration tests. Instead, it utilizes the System Generalized Method of Moments (GMM) to estimate the effect of excess license-exempt electricity generation on growth. This approach is deemed appropriate for addressing endogeneity issues arising from the joint determination of electricity generation and various other regressors in the model.

CHAPTER 3

LEGAL BACKGROUND

3.1. A Brief History of Electricity Generation in Türkiye

The structuring of the electricity sector has been an issue that long occupied the agenda of the countries. Türkiye has tried different methods to solve the electricity supply problems that arise as a result of demand increasing day by day. Electricity generation began in Türkiye in 1902 with installation of a hydroelectric power plant in Tarsus, Mersis, marking the start of a sector that experienced significant advancements during the 20th century. Before 1970, the electricity sector functioned under concessions and erratic procedures. Established in this pivotal year, the Turkish Electricity Authority (TEA) unified the nation's energy generation, transmission, and distribution into a state monopoly. This change marked the beginning of centralized governance and strategic management in Türkiye's electrical power industry. The generation facilities under the ownership of Etibank, General Directorate of State Hydraulic Works, Iller Bank and municipalities were transferred to TEA. Additionally, in 1982, the distribution facilities previously owned by municipalities were also handed to TEA. The electricity generation under state monopoly underwent a significant transformation in 1984 with the enactment of Law No. 3096, introducing the Build-Operate-Transfer (BOT) model, which allowed for the participation of private companies in the sector. The Turkish Constitutional Court has long recognized electricity generation, transmission, distribution, and commerce as public services (Constitutional Court Decision, 1994). Subsequently, in the year 2001, Law No. 4628, which led to the establishment of the Energy Market Regulatory Authority (EMRA) and the separation of public institutions in the electricity market based on their functions, was enacted. These significant structural reforms have aimed to reconfigure the electricity market, rendering it more efficient, subject to regulation, transparent, and reliable. These efforts and regulations have been implemented to establish a more effective and trustworthy electricity market. Law No. 4628 aimed to create a competitive electricity market by dissolving vertically integrated market structures. It paved the way for liberalized energy production and sales, increasing competition, while regulating transmission and distribution activities.

In 2018, a notable shift took place in Türkiye's energy generating sector. The Turkish Electricity Trading and Contracting Company (TETAŞ), which handles wholesale electricity sales, has been merged with the Turkish Electricity Generation and Transmission Corporation (EÜAŞ). As a result, the power sector now consists of three separate state-owned entities that focus on power generation, transmission, and distribution. The entities involved in the Turkish electricity sector are the Turkish Electricity Transmission Corporation (TEİAŞ), which supervises transmission operations, the Turkish Electricity Generation Corporation (EÜAŞ), which is responsible for power generation and wholesale electricity trading, and the Turkish Electricity Distribution Corporation (TEDAŞ), which handles distribution activities. Electricity market activities continue to be performed in this way from this date until today.

3.2. License-Exempt Electricity Generation

Since 2001, there have been a series of substantive amendments to the legislation and regulations governing the energy market in Türkiye. The majority of these amendments have been implemented to guarantee a more efficient and extensive utilization of renewable energy sources. The amendment to the Renewable Energy Law in 2011 and the subsequent implementation of regulations enabling license-exempt electricity generation have led to a significant increase in the number of solar power plants, which constitute a prominent kind of renewable energy in Türkiye. Thanks to the implementation of initiatives like YEKDEM and YEKA, Türkiye has started to put itself into a position of prominence among nations actively engaged in the generation of electricity derived from renewable energy sources.

In Türkiye, legislation pertaining to electricity generation, transmission, and distribution were established through the Electricity Market Law, while the regulatory framework for electricity generation from renewable energy sources was introduced by Renewable Energy Law. Renewable Energy Law aims to promote the widespread utilization of renewable energy resources for the purpose of electricity generation, with the objective of ensuring the secure, economic, and sustainable integration of these resources into the national economy. In this respect, the provisions concerning license-exempt electricity generation were incorporated in Article 14 of Electricity Market Law and Article 6/A of Renewable Energy Law. Subsequently, in alignment with these regulations, the License-Exempt Regulation was implemented. Accordingly, two distinct methods have been envisaged for electricity generation, namely licensed and license-exempt. Under Electricity Market Law, a generation license must be obtained by any legal entity wishing to engage in electricity generation activities. However, certain types of power plants are not required to establish a company and obtain license from EMRA for electricity generation.

3.2.1. The Exemption Categories under License-Exempt Regulation

The license-exempt electricity generation, a unique mode of generation in the electricity market, is a result of a self-consumption-oriented approach. For this reason, there are a limited number of exemption categories listed in the License-Exempt Regulation. These exemption categories are indicated in Table [1].

Table 1. The Exemption Categories under License-Exempt Regulation

The Relevant Clause of the License-Exempt Regulation	The Exemption
Article 5(1)(a)	Distress groups
Article 5(1)(b)	Power plants that are not connected to a transmission or distribution network
Article 5(1)(c)	Power plants utilizing renewable energy sources with a maximum installed capacity of 1 MW or up to the installed capacity upper limit decided by the President in accordance with Article 14 of the Electricity Market Law (this limit has been raised to 5 MW with Presidential Decision No. 1044)

Table 1. (continued)

Article 5(1)(ç)	Power plants utilizing renewable energy sources that measure both their generation and consumption at the same spot and that consume all of their power output without putting it into a transmission or distribution network
Article 5(1)(d)	Cogeneration plants that fall within the MENR -determined efficiency value category
Article 5(1)(e)	Micro-cogeneration plants
Article 5(1)(f)	Generation facilities created for the disposal of sludge from municipal treatment plants and solid waste facilities
Article 5(1)(g)	If technically possible and provided that the General Directorate of State Hydraulic Works grants approval, power plants utilizing hydraulic resources, built on water and waste water transmission lines maintained by municipalities by legal entities with more than half of their capital directly or indirectly owned by the municipality
Article 5(1)(ğ)	Power plants utilizing renewable energy sources established and operated by the General Directorate of State Hydraulic Works or irrigation associations with the permission of General Directorate of State Hydraulic Works, the electricity subscription of which belongs to the General Directorate of State Hydraulic Works or irrigation associations in order to meet the electricity needs of agricultural irrigation facilities, the installed power of which is limited to the contractual power in the connection agreement of the agricultural irrigation facility or to the aggregate contractual power in case there is more than one generation facility.
Article 5(1)(h)	Power plants utilizing renewable energy sources installed in the same or different measuring point as their consumption facilities, (i) limited to two times the amount of their contractual power set out in the relevant connection agreement for municipalities and their affiliates, industrial facilities and agricultural irrigation facilities, and (ii) limited to the contractual power in the relevant connection agreement for other persons

Table 1. (continued)

Article 5(1)(ı)	Power plants utilizing renewable energy resources installed with the approval of General Directorate of State Hydraulic Works on immovable properties that are under the responsibility of irrigation unions in respect of operation, maintenance, repair and management, and on other immovable properties owned or in the possession of General Directorate of State Hydraulic Works or irrigation unions established in the same or different measuring point as their consumption facilities, provided that the installed capacity of the power plant is limited to the contractual power in the relevant connection agreement
Article 5(1)(i)	If technically possible and provided that the General Directorate of State Hydraulic Works grants approval, power plants installed by the legal entities established by special provincial administrations on the pressure piped irrigation network and classical canalized network or on the water resource of the network serving only the purpose of irrigation operated by the special provincial administration.

3.2.2. Requirements for Consumption Facilities

License-exempt electricity generation facilities must have at least one electricity subscription (consumption facility) which fulfills the conditions set out in the License-Exempt Regulation. This requirement comes from the main aim of the License-Exempt Regulation, which is to meet self-consumption needs. The consumption facility connected with the generation facility must be completed by the generation facility's commissioning date if there is none at the time of application. The License-Exempt Regulation outlines specific conditions that consumption facilities must meet, including:

i. All consumption facilities associated with the license-exempt generation facility must consume energy as of the date of commissioning of the relevant generation facility at the latest.

ii. As per Article 28(1) of the License-Exempt Regulation, electricity generated by a license-exempt generation facility must be consumed by facilities owned by the same individual or entity.

iii. Both generation and consumption facilities must be located within the same distribution region. However, electricity generated in generation facilities within the scope of Article 5(1)(h) of the License-Exempt Regulation can be consumed in consumption facilities owned by the same person without the requirement of being located within the same distribution region. Furthermore, generation facilities within the distribution license area of an Organized Industrial Zone can be associated with consumption facilities owned by the same person outside the Organized Industrial Zone distribution license area.

iv. Generation facilities under the exemption in Article 5(1)(c) of the License-Exempt Regulation must not exceed the contractual power limits specified in connection agreements associated with consumption facilities.

v. Under specific conditions, it is permitted to establish multiple license-exempt generation facilities for a single consumption unit, provided that both (i) the facilities are subject to the same set-off and support mechanisms and (ii) the cumulative installed capacity of these generation facilities connected to the same consumption unit remains below the 5 MW threshold, according to Article 5(4). Notably, an amendment effective from 11 August 2022, removed the requirement for generation facilities and their associated consumption facilities to be located within the same distribution area of Organized Industrial Zones. Consequently, individuals facing challenges in securing suitable land within an Organized Industrial Zone may now establish generation facilities outside the Organized Industrial Zone, in line with Article 28(2) of the License-Exempt Regulation.

vi. There should be no detection of illegal electricity consumption related to the subscription of the consumption facility associated with the generation facility. Otherwise, until consumption occurs, the generated energy will be assumed to be generated and delivered by the relevant supply company to the system, and no payment will be made by the responsible supply company for this energy. The energy provided to the system in this context will be considered a free contribution to the YEKDEM.

3.2.3. Application Procedure

For connection of the generation facility to the grid, individuals and legal entities seeking to engage in license-exempt electricity generation are required to submit their applications to the network operator. The network operator, depending on the nature of the connection, may be either TEİAŞ, a distribution company, or an Organized Industrial Zone distribution license holder. In the event that the facility is to be connected to the transmission system, the relevant network operator is TEİAŞ; conversely, should it be connected to the distribution system, the corresponding network operator would be the distribution company. As per Article 10 of the License-Exempt Regulation, applicants must provide the required information and documentation in their applications. Upon determination that all required information and documents are provided, a technical evaluation is conducted. The technical evaluation is conducted with the fundamental criterion of compliance with License-Exempt Regulation and relevant technical legislation, taking into account the measurement and protection system of the generation facility, and considering transmission or distribution network constraints at the connection point. After the technical evaluation, if there are multiple applications, they are then subjected to a prioritization evaluation. In the prioritization evaluation conducted by the relevant network operator, the following criteria are sequentially applied:

a. The utilization of renewable energy sources in the power plant
b. The classification of the production facility as a cogeneration plant.
c. The applicant's higher consumption volume within the last year, in comparison to other applications.
d. The superior contract capacity in the applicant's connection agreement, as opposed to other applications.
e. The absence of a prior application from the applicant that received a favorable connection opinion.

The results of the evaluation for applications without deficiencies in terms of documentation and technical aspects are published on the relevant network operator's website, including explanations related to technical evaluation, within the working day following the evaluation date. Following the publication of this evaluation, a call letter for the connection agreement is communicated to the concerned party by the operator.

The signing period for connection agreements has recently been revised through amendments to the License-Exempt Regulation, which entered into force on 14 May 2024. Now, those who receive a call letter after this date have one year to sign a connection agreement. The amendments also address those who received a call letter before 14 May 2024, dividing them into two categories: (i) If the remaining period on the call letter is less than 180 days as of 14 May 2024, it will be extended to 180 days, setting the new deadline at 14 November 2024. (ii) If the remaining period exceeds 180 days, the new deadline is one year from 14 May 2024, making it 14 May 2025.

Additionally, the right to request an extension for the call letter has been revoked. The amendments also eliminate the requirement to apply for the document required within the scope of the Environmental Impact Assessment Regulation within 30 days of receiving the call letter, to obtain project approval for the generation facility within 90 days, and, if applicable, for the connection line within 150 days. These processes can now be completed over a longer period, with all necessary permits, including the document required within the scope of the Environmental Impact Assessment Regulation and zoning permit, to be obtained within the acceptance period.

Previously, the document required within the scope of the Environmental Impact Assessment Regulation was requested during the connection agreement application. However, the recent amendment removed this requirement, while still necessitating project approval. This creates a discrepancy with the Environmental Impact Assessment Regulation, which mandates that project approvals cannot be granted without the document required within the scope of the Environmental Impact Assessment Regulation. A revision of the Environmental Impact Assessment Regulation is anticipated to address this contradiction.

It is crucial to note that if the relevant individuals or entities submit the following documents to the relevant network operator within the specified period, complete and in accordance with the procedures, the network operator is obliged to sign the connection agreement with them within thirty days:

- Project approval required within the relevant technical regulations for the construction of the power plant.
- Water usage agreement in hydro-based applications.

Individuals or legal entities establishing a power plant within the scope of the License-Exempt Regulation, as per Article 18 of the License-Exempt Regulation, must inform the relevant network operator that the power plant to be connected to the grid complies with the criteria defined in this License-Exempt Regulation and the conditions specified in the connection agreement. The readiness of the power plant for commissioning is documented and signed by the relevant network operator within fifteen days. This document is submitted to the MENR or the authorized institution by the MENR to apply for commissioning, and commissioning procedures are conducted according to the Regulation on the Commissioning of Electricity Generation and Storage Facilities.

3.2.4. Sale of Excess Generated Electricity

In license-exempt model, the owner of the generation facility is encouraged to utilize the generated electricity primarily for self-consumption. License-exempt electricity generators are restricted from selling excess electricity beyond their self-consumption through bilateral electricity sales agreements or in organized wholesale electricity markets. Hence, the fundamental principle is that license-exempt electricity generation is primarily intended for self-consumption purposes.

Yet, Article 6/A of the Renewable Energy Law provides a purchase guarantee for excess electricity generated in the license-exempt generation facilities falling under Article 5 of the License-Exempt Regulation. Accordingly, producers engaged in license-exempt electricity generation activities to meet their consumption needs can benefit from the price guarantee for a period of ten years if they feed the excess electricity they produce into the transmission or distribution system. In this context, it is mandatory for the electricity supplied to the transmission or distribution system to be purchased by the authorized supply company. The electricity purchased by the relevant companies is considered to have been produced within the scope of the YEKDEM and delivered to the system. In accordance with Presidential Decision No. 1044, the purchase rate for excess electricity is equivalent to the retail one-time active energy price set by EMRA for the corresponding subscription group. Settlements, invoicing, and payments occur on a monthly basis. The motive behind this purchase guarantee was to maximize the use of domestic and renewable energy sources, facilitating a smoother and more efficient execution of investments in solar energy. This reflects Türkiye’s ongoing commitment to harnessing renewable resources, particularly solar power.

In line with the above guarantee, the entire surplus electricity was purchased by the authorized supply company in the relevant distribution region during the initial 10 years of operation of the relevant generation facility until 11 August 2022. However, significant restrictions were imposed on the sale of excess license-exempt electricity with the Amending Regulation and EMRA Board Resolution No. 11098. Accordingly, the sale of excess electricity by owners of license-exempt electricity generation facilities who were entitled to an invitation letter to sign a connection agreement as a result of an application made after 12 May 2019 are capped at the annual consumption quantity. Any electricity generated beyond this limit will be contributed to the YEKDEM free of charge.

In cases where both generation and consumption occur at the same measurement point, the amount eligible for sale will be determined based on uncompensated raw consumption values obtained from a unidirectional meter installed next to the production meter. If the consumption quantity of the current year exceeds the previous year’s consumption, the energy eligible for sale can be up to the current year’s consumption amount. Any excess energy will be contributed to YEKDEM without charge and made available for all electricity consumers. No system usage fee will be imposed for the energy supplied to the grid by investors and left uncompensated. This practice does not apply to facilities in the residential subscriber group with capacities below 50 kW.

The Amending Regulation and EMRA Board Decision No. 11098 carry significant implications for investments in the energy sector. The original structure of the License-Exempt Regulation, before the Amending Regulation, allowed facilities to sell all excess electricity they generated. However, the Amending Regulation and EMRA Board Decision No. 11098 introduced a restriction on the sale of surplus electricity from license-exempt electricity-generating facilities. This limitation, specified in paragraph 16 added to Article 26 of License-Exempt Regulation, applies retroactively to applications submitted after 12 May 2019. According to this provision, the surplus electricity available for sale is capped at the facility's consumption amount. Therefore, individuals or entities who applied for an invitation letter after 12 May 2019, can only sell electricity up to the annual consumption of the associated facility. Any excess electricity generation beyond this limit will be contributed to YEKDEM as a free contribution.

EMRA Board Resolution No. 11098 offers detailed guidance on the incorporation of changes into the electricity market and also outlines the methodology for calculating annual consumption amounts at license-exempt electricity generation facilities. EMRA Board Resolution No. 11098 specifies the values considered during settlement and outlines the principles governing the excess production to YEKDEM. As per the EMRA Board Resolution No. 11098, the primary benchmark for establishing the quantity of electricity to be procured by the designated supplier company is the annual consumption from the preceding year. If the respective facility did not consume electricity during the previous year, the calculation of electricity consumption will be based on average monthly consumption values. Additionally, if the consumption in the current year surpasses that of the previous year, the data from the current year will be employed to determine the quantity of electricity available for sale.

EMRA provided a demonstrative scenario on its website: For instance, an individual who utilized 1 million kWh of electricity in the prior year will be eligible to sell a maximum of 1 million kWh of electricity in the current year, considering monthly netting. Payments for surplus electricity sales will commence from the first month of the year, and any generation surpassing the 1 million kWh limit will be treated as a free contribution to YEKDEM.

Investors have raised concerns about the limitations on surplus electricity sales and the introduction of free contribution to YEKDEM through the Amending Regulation. In response to the criticism, on 31 August 2022, the EMRA issued a statement providing clarification on the recent regulatory changes. EMRA underscored that the initial intent of the License-Exempt Regulation was to empower consumers to generate their own energy from solar sources. However, this objective was being misused by individuals or entities with nominal electricity consumption compared to their generation. Consequently, in an effort to address this issue, the Amending Regulation introduced restrictions on the purchase of excess electricity generated in the license-exempt generation plants.

EMRA contends that the regulatory changes were necessary to curb misuse and ensure that renewable plants, which inherently face grid integration challenges, are installed only by consumers with genuine energy needs. As a result, facilities attempting to produce without corresponding consumption will not be compensated for potential production quantities. Additionally, EMRA argues that these amendments are designed to protect legitimate electricity consumers and create opportunities for those with genuine consumption needs but face constraints in establishing production facilities due to capacity and space limitations. By dissuading investors, this Amending Regulation may cause a reduction in investments for license-exempt power plants. In conclusion, while the Amending Regulation sought to address the misapplication of the “generate as much as you consume” principle, it might have created a challenging landscape for investors in the renewable energy sector by removing previously established guarantee.

CHAPTER 4

DATA, MODEL AND DESCRIPTIVE STATICS

4.1. Data

This study is based on panel data collected from all 81 provinces of Türkiye spanning the period from 2015 to 2021, encompassing a total of 567 observations. The research duration is limited to seven years due to data availability constraints. Before 2015, the license-exempt electricity generation model was not extensively employed. However, after 2015, it gained widespread popularity, emerging as the primary choice for investors, especially those keen on investing in renewable energy. The evident shift in investor preferences towards license-exempt electricity generation after 2015 explains the limited presence of relevant data in EMRA's annual reports published prior to that year.

The variables used in the study are indicated in the table below:

Table 2. The Variables Used in the Study

Variable	Abbreviation	Type	Unit	Source
Gross Domestic Product per capita	GDP	Dependent variable	USD	TURKSTAT database
License-exempt excess electricity generation	LEEG	Independent variable	MWh	EMRA's annual reports
Total Exports	EXP	Control variable	USD	Turkish Exporters Assembly's database
The Number of Motor Vehicles	OTOBIN	Control variable	Per thousand people	TURKSTAT database
Total Electricity consumption	EC	Control variable	MWh	TURKSTAT database

All variables are log transformed.

This study aims to determine the impact of LEEG on GDP per capita, with an effort to control for the potential influence of EXP, OTOBIN, and EC, factors deemed significant in shaping the relationship between LEEG and GDP. The selection of these control variables is inspired by a thorough review of existing literature and data available at the city level in Türkiye.

Section 2.3.1 of this thesis examines studies investigating the correlation between electricity consumption and economic growth. Additionally, this section delves into the studies that guided the selection of other control variables.

Various studies in the literature, including works by Thornton (1996), Albiman Md & NN (2016), and Uysal & Sat (2019), establish a causal relationship between exports and economic growth. Notably, this relationship exhibits variations across different countries. In the SAARC countries, Sampathkumar & Rajeshkumar (2016) observe unidirectional causation from economic growth to export for Bangladesh and India, while Afghanistan and Sri Lanka exhibit bidirectional causation. Hatemi-J And & Irandoust (2000) conclude that Nordic economies share a long-term causal relationship between export growth and economic growth, with Denmark displaying unidirectional causality and Finland, Norway, and Sweden demonstrating bidirectional causality. The relationship in South Africa is more intricate, with Chang et al. (2013) identifying unidirectional causality from economic growth to exports in Mpumalanga, bidirectional causality in Gauteng, and no discernible causality in other provinces.

Consistent findings in existing research underscore a robust connection between GDP and the number of motor vehicles. Law et al. (2015) reveal an inverted U-shaped relationship between the motorcycle-to-passenger car ownership ratio and GDP, indicating an increase at lower income levels followed by a decrease at higher levels. The significance of this relationship is further emphasized by Santini & Poyer (2008) and Chamon et al. (2008). Santini assesses the causal relationship between motor vehicle output and GDP, while Chamon projects a rapid increase in car ownership in emerging markets as their GDP per capita rises.

This study benefits from advantages offered by panel data. According to Hsiao (2007) Panel data, compared to relying solely on cross-sectional or time-series data, offer more enhanced accuracy and measurability. Moreover, panel data encompass a broader spectrum of information and variables than standalone time-series or cross-sectional data. It enables the estimation and modelling of both common trends and unique behaviours across the entire dataset simultaneously.

Another important aspect of the data which requires attention is multicollinearity. Multicollinearity arises when there is strong correlation among two or more independent variables within a regression model. This correlation complicates the ability to discern the unique impact of each variable on the dependent variable. The strong correlation between variables impacts the reliability of the applied tests, as well as the consistency of the analysis and the accuracy of the calculation coefficients. Therefore, it is important to ensure that multicollinearity is minimum in the model. The Variance Inflation Factor (VIF) serves as a metric for assessing the degree of multicollinearity within a group of variables.

The correlation table of the variables and the VIF Multicollinearity test results are shown in Tables [3] and [4], respectively.

Table 3. Correlation Table

Variables	**(1) LOGGDP**	**(2) LOGLEEG**	**(3) LOGEXP**	**(4) LOGOTOBIN**	**(5) LOGEC**
(1) LOGGDP	1.000				
(2) LOGLEEG	0.007 (0.8718)	1.000			
(3) LOGEXP	0.039 (0.3498)	0.084** (0.0460)	1.000		
(4)LOGOTOBIN	-0.087** (0.0388)	0.173*** (0.0000)	0.196*** (0.0000)	1.000	
(5) LOGEC	-0.190*** (0.0000)	0.076* (0.0714)	0.117** (0.0052)	0.531*** (0.0000)	1.000

*indicates p <0.1; ** indicates p<0.05, **p<0.01

Based on the correlation table, it is evident that the correlation values between the variables are generally weak. Specifically, the correlation coefficients are mostly close to zero, indicating minimal linear relationships among the variables. According to the rule of thumb by Wooldridge (2015) and Gujarati & Porter (2009), if the correlation coefficient between two explanatory variables is above 0.8, it is typically considered indicative of multicollinearity. None of the correlations in our study exceed this threshold, suggesting that multicollinearity is not a severe issue here.

To further assess multicollinearity, the VIF test will be used to reassess the presence of strong correlation between variables in the model.

Table 4. Multicollinearity Test Results

	VIF	1/VIF
LOGOTOBIN	1.461	.685
LOGEC	1.394	.717
LOGEXP	1.043	.959
LOGLEEG	1.034	.967
Mean VIF	1.233	.

All VIF values of the variables remain below 5, which is the recognized threshold for multicollinearity in the literature by James et al. (2013) and Menard (2001). Hence, the model that has been constructed does not exhibit any issue of strong correlation between variables

4.2. Model and Hypotheses

The primary research objective is to investigate the impact of license-exempt excess electricity generation on economic growth at the provincial level in Türkiye. The study aims to determine whether there exists a statistically significant relationship between license-exempt excess electricity generation and economic growth. According to the License-Exempt Regulation, one of the key objectives of the license-exempt generation model is to ensure that small-scale generation facilities contribute to the country's economy while enhancing supply security. Through this analysis, we seek to validate the positive impact of license-exempt excess electricity generation on Türkiye's economy, specifically in terms of economic growth.

Furthermore, given that all the license-exempt excess electricity is generated from renewable energy sources such as solar, biomass, wind, and hydraulic, our study will also confirm that the contribution made to Türkiye's economy by license-exempt excess electricity generation is environmentally sustainable.

The hypothesis of this analysis is that there is a statistically significant positive relationship between the license-exempt excess electricity generation and economic growth. This hypothesis is rooted in the notion that the prospect of generating electricity and selling excess electricity to the grid serves as a compelling incentive for investors, particularly in the energy sector with a focus on renewable resources. Consequently, the instalment and operation of these generation facilities are expected to make substantial contributions to the economy.

This study is established using data from 81 provinces of Türkiye between period 2015 and 2021. The dynamic panel data model created in this context is specified in Equation [1].

$$LOGGDP_{it} = \beta_0 + \beta_1 LOGGDP_{it-1} + \beta_2 LOGLEE_{it} + \beta_3 LOGEXP_{it} + \beta_4 LOGOTOBIN_{it} + \beta_5 LOGEC_{it} + u_{it}$$

Equation [1]

In the model, each parameter β, represents the coefficients of the relevant estimated variables, i represents each panel, and t represents each time series. The β_0 parameter represents the constant value, u_{it} parameter represents the error term that shows the difference between the actual value and the predicted value for the model. $LOGGDP_{it-1}$ represent the dependent variable lag which is used to measure the impact of the preceding year's GDP per capita on the GDP per capita in the current year.

As further discussed in the Chapter 5, when dealing with the presence of a lagged dependent variable, traditional least square estimators become biased and inconsistent. Additionally, there may be a two-way relationship between the dependent variable and explanatory variables, leading to an endogeneity problem. These challenges can be addressed through the two-step system GMM estimation method. Including the lagged dependent variable assumes that the number of groups exceeds the total number of explanatory variables in the model.

4.3. Descriptive Statics

Descriptive statistical values for the variables in the model are presented in Table [5].

Table 5. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
LOGGDP	567	8.873	0.346	7.975	9.824	0.049	3.044
LOGLEEG	567	8.319	4.079	0.095	13.883	-0.933	2.706
LOGEXP	567	11.991	2.474	1.97	18.303	-0.471	3.885
LOGOTOBIN	567	4.592	0.772	1.946	5.67	-1.504	4.488
LOGEC	567	14.159	1.228	11.332	17.542	0.237	2.795

When the table is examined, the fact that there are a total of 567 observations in all variables can be considered as an important indicator that the study is a balanced panel. It should also be noted that the logarithms of the variables were taken so that the standard errors remained at a certain level and the values of the variables were close to each other considering the normal distribution. As observed in the table, the standard errors of the variables are low and their minimum and maximum values are close to each other. The descriptive statistics for the key variables in this study (LOGGDP, LOGLEEG, LOGEXP, LOGOTOBIN, and LOGEC) indicate that there are no outliers present in the data. This conclusion is supported by the fact that the minimum and maximum values for each variable are within a reasonable range. For example, LOGLEEG ranges from 0.095 to 13.883, and LOGEXP ranges from 1.97 to 18.303. These values do not indicate any extreme deviations.

The study also assesses the normal distribution of the data, a fundamental assumption crucial for statistical analysis and structural equation modelling according to Hair et al. (2010). Normality, as defined by Hair et al. (2010), pertains to the distribution shape of individual metric variables aligning with the benchmark of a normal distribution, essential for robust statistical methods. To evaluate normality, the study employed the Skewness and Kurtosis statistical methods. According to Hair et al. (2010), to satisfy normal distribution assumption Skewness and Kurtosis ratios must remain between the values that considered the variables have a normal distribution which are +2 and -2 for skewness and +7 and -7 for kurtosis, respectively.This study adhered to these criteria, finding that all item Skewness and Kurtosis values fell within the acceptable range, ensuring data normality for subsequent analyses.

CHAPTER 5

METHODOLOGY

5.1. GMM Estimation

This thesis employs the Generalised Method of Moments (GMM) for estimation purposes. GMM is a dynamic panel data estimator and relies on moment conditions derived from both model parameters and data, ensuring that their expected values are zero at the true parameters' values.

The GMM estimator was first introduced in the economic literature by Hansen (1982) and further refined by Hansen & Singleton (1982). Its reliance on weak assumptions have made it a go-to tool for both cross-sectional and panel estimation. GMM is considered a semi-parametric estimator because it relies on moment conditions instead of strict distributional assumptions. This approach yields more reliable parameter estimates, particularly in cases where traditional methods might introduce bias or inefficiency. Thus, GMM stands out for its robustness and flexibility, making it a preferred choice over fully parametric estimators.

GMM is generally used because of the following reasons Ullah et al. (2018):

(i) It effectively addresses endogeneity concerns inherent in dynamic panel models by accounting for correlation between lagged dependent variables and the error term.

(ii) It mitigates omitted variable bias, tackles unobserved panel heterogeneity, and corrects for measurement errors, enhancing the robustness and accuracy of the estimations.

GMM is an estimation tailored for scenarios characterized by Roodman (2009):

- Dynamic panel models, where panels consist of small $\boldsymbol{T}$ and large $\boldsymbol{N}$, i.e. $\boldsymbol{N}$ (number of cross-sections or groups) > $\boldsymbol{T}$ (time span)

- Linear functional relationship between variables
- Dynamic left-hand side variables, influenced by their own past occurrences.
- Independent variables that are not strictly exogenous, implying correlation with past and possibly current error terms
- Models where arbitrarily distributed fixed effects, heteroscedasticity and autocorrelation within panels or groups are present.

This thesis follows the Generalized Method of Moments (GMM) approach in the econometric model due to several reasons. First of all, the number of cross-sections (N = 81) exceed the number of time units (T=7). Moreover, we aim to account for the dynamic nature of GDP. Additionally, disturbances in the data are prone to heteroscedasticity and serial correlation, which cannot be adequately addressed by simple cross-sectional regression.

There are two types of the GMM estimators: (i) Difference GMM and System GMM. Several rules of thumb are suggested in the literature. Bond & Hoeffler (2001) proposes the first rule of thumb, which suggests that to decide between difference and system GMM, the following initial dynamic model should be initially estimated using pooled OLS and LSDV approach (i.e., employing the fixed effects approach):

$$lnY_{it} = \Phi lnY_{it-1} + \beta X'_{it} + (\eta_i + \varepsilon_{it}) \qquad \textit{Equation [2]}$$

In this Equation [2], the pooled OLS estimate for Φ serves as an upper-bound estimate, while the corresponding fixed effects estimate acts as a lower-bound estimate. If the difference GMM estimate closely aligns with or falls below the fixed effects estimate, it indicates downward bias due to weak instrumentation. In such cases, opting for a system GMM estimator is better. Additionally, utilizing the system GMM is advantageous when a variable exhibits a random walk.

When the dependent variable displays persistence and is nearly a random walk (i.e. Φ >1), employing the difference GMM estimator can result in both biased and inefficient estimates of Φ, especially when the time series length (T) is short. The second rule of thumb, as proposed by Blundell & Bond (1998), attributes this poor performance of the difference GMM estimator to the utilization of inadequate instruments. To mitigate this issue, they advocate for the adoption of a system GMM estimator.

5.2. Difference GMM

Arellano & Bond (1991) explains that Difference GMM corrects endogeneity by differencing all regressors and eliminating fixed effects. Nonetheless, this initial difference transformation possesses a drawback: it subtracts the previous observation from the contemporaneous one, thereby amplifying discrepancies in any unbalanced panel. Consequently, the application of the difference GMM approach may somewhat attenuate the results.

In the Difference GMM framework, the initial model is denoted by Equation [3]:

$$lnY_{it} = \Phi lnY_{it-1} + \beta X'_{it} + (\eta_i + \varepsilon_{it})$$

The transformed model, Equation [4], is obtained as follows:

$$\Delta lnY_{it} = \Phi \Delta lnY_{it-1} + \beta \Delta X'_{it} + \Delta\varepsilon_{it}$$

By first differencing the regressors, the fixed effect is eliminated since it remains constant over time. However, the issue of endogeneity persists. Equation [4] can be rearranged to yield:

$$\Delta u_{it} = \Delta\eta_i + \Delta\varepsilon_{it} \qquad \text{Equation [5]}$$

Alternatively, Equation [6] is derived as:

$$u_{it} - u_{it-1} = (\eta_i - \eta_i) + (\varepsilon_{it} - \varepsilon_{it-1}) = (\varepsilon_{it} - \varepsilon_{it-1}) \qquad \text{Equation [6]}$$

As unobserved fixed effects are assumed to remain constant between periods, they are no longer included in the equation. Instead, the first-differenced lagged dependent variable is instrumented with its previous levels. This implies that Equation [4] now captures the changes in the dependent variable.

In a subsequent study, Alonso-Borrego & Arellano (1999) shows that when the number of time periods is limited and the dependent variable exhibits high persistence, the difference GMM method may introduce significant sample bias. Hence, in this thesis, we utilize the system GMM instead of the difference GMM approach.

5.3. System GMM

System GMM (Generalized Method of Moments) is often considered superior to difference GMM, particularly in dynamic panel data models, due to its ability to address issues related to endogeneity, serial correlation, and unobserved heterogeneity more effectively. There is a consensus between Arellano & Bover (1995), Blundell & Bond (1998), and Roodman (2009) regarding the superiority of System GMM over difference GMM. According to Blundell & Bond (1998), when time series exhibit persistence and the number of observations is limited, first-differenced GMM estimators may yield unsatisfactory results. This comes from the fact that lagged levels of the series offer weak instruments for the differenced equations. Moreover, unlike difference GMM, which eliminates cross-country variation in levels by differencing to remove country-specific effects, System GMM retains this information. This is crucial as it preserves valuable variation across countries, allowing for a more comprehensive analysis of the determinants of economic phenomena.

Arellano & Bover (1995) and Blundell & Bond (1998) highlight that System GMM rectifies endogeneity by incorporating a larger set of instruments, leading to notable improvements in efficiency. Furthermore, it adjusts these instruments to ensure their lack of correlation with the fixed effects. System GMM constructs a system consisting of two equations: the initial equation and its transformed version.

In System GMM, orthogonal deviations are employed. Rather than subtracting the previous observation from the contemporaneous one, it subtracts the average of all future available observations of a variable. This approach ensures computability for all observations except the last for each individual, irrespective of the number of gaps, thus minimizing data loss.

The initial model in System GMM, as denoted by Equation [7], is as follows:

$$lnY_{it} = \Phi lnY_{it-1} + \beta X'_{it} + (\eta_i + \varepsilon_{it})$$

When Equation [7] represents a random walk model and Y demonstrates persistence, the application of the difference GMM estimator often results in both biased and inefficient estimates of Φ, particularly in cases where the time series length (T) is limited. Blundell & Bond (1998) attribute the underperformance of the difference GMM estimator in such scenarios to the utilization of inadequate instruments.

System GMM is a suitable econometric technique under the following conditions: (i) One equation is formulated in levels, employing first differences as instruments and (ii) the second equation is presented in first-differenced form, with levels serving as instruments.

This approach utilizes an increased number of moment conditions, which can enhance the precision of estimates. Monte Carlo simulations provide empirical evidence suggesting that, particularly in scenarios characterized by short time series and persistent dependent variables, employing System GMM leads to reductions in small sample bias and gains in estimation precision.

The two-step system GMM estimator effectively addresses issues related to heteroscedasticity and serial correlation by incorporating a weighting matrix derived from the residuals. This approach enhances the efficiency and robustness of the estimation process, leading to more reliable parameter estimates. In our analyses, we employed two-step system GMM estimators due to these distinct advantages.

5.4. GMM Diagnostics

5.4.1. Tests for instruments validity

The Hansen test and Sargan tests are used to check the validity of the instruments. In Hansen test, the null hypothesis is that all overidentifying restrictions are valid. In other words, instruments are uncorrelated with the error term. Failure to reject this null hypothesis give support to the choice of the instruments and we have support for validity of dynamic panel model specification. The alternative hypothesis, on the other hand, is that the instruments are invalid, meaning they are correlated with the error term. According to Roodman (2009), instrument validity is established when Hansen p-value is between 0.1 and 0.25.

Similar to the Hansen test, the Sargan test is utilized to assess the exogeneity and validity of the instruments. However, it's worth noting that while the Hansen J statistic incorporates an optimal weighting matrix, the Sargan test statistic lacks robustness against heteroskedasticity or autocorrelation. Consequently, for our analysis, we will primarily rely on interpreting the Hansen statistic in Chapter 6.

5.4.2. Test for autocorrelation/serial correlation of the error term

In the Arellano-Bond test, the null hypothesis is that there is no autocorrelation present in the first-differenced errors of the dynamic panel data model. In other words, it assumes that the errors are not correlated with each other across time periods. Failing to reject this null hypothesis suggests that the original error term is serially uncorrelated, indicating that the moment conditions are accurately specified (i.e., when the value of AR(2) exceeds 0.05).

5.5. GMM over Other Panel Data Estimation Techniques

Panel data analysis offers various regression techniques to obtain precise estimations tailored to specific research goals. Among these techniques, Ordinary Least Squares (OLS) and Least Squares Dummy Variable (LSDV) models have been prominently utilized in empirical research. However, these estimation techniques often suffer from bias, particularly due to dynamic panel bias. System GMM is particularly advantageous in dynamic panel models where the lagged dependent variable is included as a regressor, providing more robust and reliable estimates for policy analysis and causal inference. Table 6 provides a comparison of System GMM with other panel data estimation techniques, OLS, LSDV and Fixed Effects.

Table 6. Comparison of System GMM with Other Estimation Techniques

Criteria	OLS	LSDV	Fixed Effects	System GMM
Assumption Violations	Assumes no correlation between error term and regressors; often violated in panel data	Assumes no correlation within entities; often violated with endogenous regressors	Assumes no correlation within entities; suffers from Nickell bias	Handles endogeneity by using internal instruments
Dynamic Panel Bias	Suffers from dynamic panel bias with lagged dependent variables	Suffers from Nickell bias in small samples with lagged dependent variables	Suffers from Nickell bias in small samples with lagged dependent variables	Addresses dynamic panel bias effectively
Endogeneity	Struggles with endogeneity, leading to biased estimates	Struggles with endogeneity, leading to biased estimates	Struggles with endogeneity, leading to biased estimates	Uses lagged levels and differences as instruments to address endogeneity
Unobserved Heterogeneity	Does not account for individual-specific effects	Accounts for individual-specific effects but can lead to loss of degrees of freedom	Accounts for individual-specific effects but can lead to loss of degrees of freedom	Controls for individual-specific effects by differencing the data

Table 6. (continued)

Efficiency	Often inefficient due to assumption violations	Loss of degrees of freedom reduces efficiency	Loss of degrees of freedom reduces efficiency	Exploits additional moment conditions for efficiency gains
Consistency	Inconsistent in presence of endogeneity and dynamic panel bias	Inconsistent in presence of endogeneity and Nickell bias	Inconsistent in presence of endogeneity and Nickell bias	Provides consistent estimates in presence of endogeneity and dynamic relationships
Applicability	Simple and easy to interpret	Suitable for static models but problematic for dynamic panels	Suitable for static models but problematic for dynamic panels	Best for dynamic panel data models with endogenous regressors

Before conducting System GMM analysis, this study employed fixed effects model to analyze the relationship between license-exempt excess electricity generation and economic growth. The fixed effects model controls for unobserved heterogeneity by allowing individual-specific intercepts. However, it does not account for potential endogeneity and dynamic relationships within the data, as it excludes lagged dependent variables. This limitation can lead to biased estimates, particularly when explanatory variables are endogenous or when past values of the dependent variable influence current values.

To address these limitations, we utilize the System GMM method, which includes lagged dependent variables and employs internal instruments to mitigate endogeneity. The System GMM model provides more reliable and consistent estimates, capturing the dynamic nature of the data.

The differences observed between the fixed effects results which are reported in Appendix-1 and System GMM results highlight the importance of accounting for endogeneity and dynamic panel bias. While the fixed effects model offers initial insights, the System GMM analysis provides a more accurate understanding of the relationships, justifying its inclusion in this study. By presenting both models, we demonstrate the robustness of our findings and adhere to best econometric practices as recommended by Arellano & Bond (1991) and Blundell & Bond (1998).

CHAPTER 6

RESULTS

The study begins by assessing the stationarity of all variables before starting formal analysis. Table [7] presents the results of IPS and ADF panel unit root tests, two extensively utilized methods in the literature, applied to the variables.

Table 7. Unit Root Test Results

None		ADF		IPS		Trend	ADF		IPS	
		t-stat	Prob	t-stat	Prob		t-stat	Prob	t-stat	Prob
LOGGDP	Level	-16.393	0.000	-28.10	0.000	Level	-8.713	0.000	-1.1	0.000
LOGLEEG	Level	-39.998	0.000	-2.1	0.000	Level	-21.724	0.000	-3.8	0.000
LOGEXP	Level	-3.047	0.001	-18.99	0.000	Level	5.066	0.000	-51.02	0.000
LOGOTOBIN	Level	-2.991	0.001	-34.42	0.000	Level	-68.78	0.000	-4.7	0.000
LOGEC	Level	-0.53	0.000	-10.65	0.000	Level	-2.165	0.015	-1.1	0.000

When the level values of the variables are examined, it becomes evident that all probability values are below the critical threshold of 0.05. Consequently, the fundamental hypothesis of unit root tests that the series are non-stationary at the level, can be rejected at the 5% critical level. Hence, all series exhibit stationarity at level I(0).

Following the confirmation of data stationarity for all variables, we proceed with dynamic model system GMM for analysis. As mentioned in the previous section, we use the GMM model, which excels in handling panel data and circumvents econometric issues associated with such data. By employing the GMM model, we anticipate obtaining consistent and reliable results compared to fixed effects or OLS, as it effectively controls for endogeneity. Furthermore, we proceed with the application of the two-step system GMM over difference GMM due to its higher reliability and efficiency. Difference GMM may exhibit asymptotic weakness, and the instruments it employs can be biased. Therefore, we selected the two-step system GMM for analysis in this study to ensure the attainment of reliable and efficient results. Additionally, we have conducted over-identifying restriction tests proposed by Arellano & Bond (1991), the outcomes of which further validate the instruments utilized in our analysis. The results of the 2 STEP System GMM dynamic analysis are presented in Table [8] below.

Table 8. System GMM Analysis Results

Dependent Variable: LOGGDP	
LOGGDP(-1)	0.927*** (333.15)
LOGLEEG	0.0004*** (2.74)
LOGEXP	0.002*** (5.44)
LOGOTOBIN	-0.008*** (-3.95)
LOGEC	0.004** (2.16)
cons	0.577*** (20.16)
Observations	486
F-test	7110000.00
AR(1)	0.041
AR(2)	0.09
Hansen Test	0.179

Following the GMM analysis, it is evident that the AR(1) value is statistically significant at the 5 percent level, while the AR(2) value is statistically insignificant. Consequently, we conclude the absence of autocorrelation issues within our Two-step

System GMM model. The Arellano-Bond tests are employed to assess serial correlation in the idiosyncratic error term, conducted on first-differenced errors. If the errors at the level are serially uncorrelated, it implies negative first-order serial correlation in first differences but no higher-order serial correlation. Thus, we reject the null hypothesis of no first-order serial correlation in first differences (AR(1) test) but do not reject the null hypothesis of no higher-order serial correlation in first differences (AR(2) test).

In our System GMM estimation, LOGGDP(-1), LOGLEEG, and LOGEXP are treated as endogenous variables due to potential simultaneity and reverse causality issues. The dynamic nature of the model necessitates the inclusion of a lagged dependent variable (LOGGDP(-1)), which is correlated with past error terms, leading to endogeneity. Similarly, license-exempt excess electricity generation (LOGLEEG) and total exports (LOGEXP) can both influence and be influenced by GDP, creating a simultaneity issue. The number of motor vehicles (LOGOTOBIN) and total electricity consumption (LOGEC) are assumed to be exogenous or predetermined. The number of motor vehicles in a given year is unlikely to be immediately affected by the current year's economic performance. While economic growth can influence vehicle ownership, this effect is typically observed over a longer period rather than within the same year. Total electricity consumption is also constrained by supply factors, including infrastructure capacity and regulatory environments, which are not directly influenced by short-term GDP fluctuations. GMM-type instruments derived from lagged levels of the endogenous variables are used to address endogeneity and ensure consistent estimation. The Hansen test results fall within the desired thresholds between 0.1 and 0.25 as suggested by Roodman (2009), confirming the absence of an overidentification problem and validity of instruments. Furthermore, the non-rejection of the null hypothesis in the Hansen test signifies that the test statistics support a properly specified model. Moreover, the number of instruments is fewer than the number of groups, which eliminates concerns regarding overfitting bias.

The statistically significant high coefficient value of 0.927 for LOGGDP(-1) is a noteworthy outcome from dynamic estimation. This suggests that 93% of the change in the dependent variable can be accounted for by its own lagged value from the preceding period, which aligns with logical expectations.

The findings reveal that a one percent rise in the LOGLEEG variable corresponds to a 0.0004 percent increase in LOGGDP. Despite the limited impact of LOGLEEG, its statistically significant and positive coefficient underscores its importance. This supports our hypothesis that the license-exempt excess electricity generation have a positive impact on Türkiye’s economy economic growth. Furthermore, it confirms the achievement of one of the key objectives outlined in the License-Exempt Regulation, which aims to ensure that small-scale generation facilities contribute to the country’s economy.

It is worth noting that license-exempt electricity generation is a relatively recent model, with its adoption growing steadily over time. In our study, we specifically focused on analysing the impact of excess license-exempt electricity sold to the grid. Consequently, it is important to recognize that excess generation represents only a fraction of total license-exempt electricity generation. Put simply, not all license-exempt electricity generated is fed back into the grid, and our analysis is confined to examining this subset of generation. Therefore, its limited impact on GDP per capita holds considerable importance at this stage.

Additionally, both LOGEXP and LOGEC exhibit positive and statistically significant effects on LOGGDP. A one percent increase in LOGEXP results in 0.002 percent increase in LOGGDP. Our findings support Taghavi et al. (2012), Abugamea (2015) and Hamdan (2016) who concluded that exports have positive effect on the economic growth. Export activities generate income for domestic producers, leading to increased economic activity and higher GDP. This positive impact underscores the economic benefits of trade openness, market diversification, and export-oriented policies in stimulating economic growth.

Moreover, our analysis reveals that a one-unit increase in LOGEC leads to a 0.004-unit increase in LOGGDP. This outcome supports the growth hypothesis which suggests that energy consumption drives GDP growth. Higher levels of electricity consumption often indicate increased industrial activity, production, and manufacturing output. This contributes directly to economic growth and GDP per capita. Therefore, our findings contribute to the literature supporting this hypothesis, details of which are elaborated in Chapter 2.3.2 of this thesis.

Lastly, our analysis indicates that a one percent increase in the LOGOTOBIN results in a 0.008 percent decrease in LOGGDP. In the literature, vehicle ownership is mostly analysed based on the GDP per capita. In other words, most studies focus on understanding how changes in GDP per capita influence motor vehicle sales. Therefore, we are not able to compare our finding with the existing literature. However, we interpret this finding as higher motor vehicle ownership per capita could indicate a concentration of wealth among a smaller segment of the population. In countries where income inequality is significant, a higher concentration of wealth among fewer individuals may not significantly boost overall GDP per capita. Furthermore, increased motor vehicle ownership is often associated with urban areas where infrastructure and living costs are higher. This concentration can lead to disparities in wealth distribution and may not necessarily translate into broad-based economic growth reflected in GDP per capita.

CHAPTER 7

CONCLUSIONS

The main goal of this study is to assess whether license-exempt excess electricity generation positively affects economic growth. In order to conduct the empirical analysis, we utilize data covering the period from 2015 to 2021 from various sources such as EMRA’s annual reports, TURKSTAT database and Turkish Exporters Assembly’s database encompassing 81 provinces in Türkiye. As the number of groups is larger than time span, the empirical model is run by the two step System GMM dynamic panel technique which allows controlling for the possible endogeneity of all independent variables.

Our research findings offer insights into the relationship between license-exempt excess electricity generation and economic growth. Notably, in Türkiye, where such generation is largely derived from renewable energy sources, our analysis reveals a positive and statistically significant relationship between license-exempt excess electricity generation and GDP per capita. These results indicate the potential of license-exempt electricity generation to contribute to economic growth. This finding holds particular significance in light of the restrictions imposed on the sale of license-exempt electricity generation in August 2022. Prior to these restrictions, the sale of license-exempt excess electricity generation served as a motivating factor for investors who are interested in renewable energy projects. The introduction of these restrictions potentially poses a challenge to the renewable energy projects, which in turn could impede economic growth. While the current positive impact of the license-exempt electricity generation on economic growth may seem limited, it is important to recognize that license-exempt electricity generation model is still relatively new, having seen extensive application only over the last decade. With significant potential for expansion in the future, the positive influence of license-exempt electricity generation on economic growth could substantially increase over time.

The rationale behind the restrictions imposed on the sale of license-exempt electricity generation is to address concerns about the potential impact of unregulated electricity generation on the stability of the grid and encourage more coordinated and regulated development of renewable energy projects, ensuring that they integrate smoothly into the existing electricity infrastructure. While these objectives are valid, it is essential to acknowledge that allowing the sale of excess electricity has historically served as a valuable mechanism for financing renewable energy projects. By restricting the ability of individuals or communities to sell excess electricity back to the grid, a crucial source of revenue for these projects is diminished. This reduction in potential revenue streams can make it more challenging for renewable energy developers to recoup their initial investments and achieve financial viability. Furthermore, the sale of excess electricity not only provides financial incentives for individuals to invest in renewable energy systems but also promotes greater adoption and participation in decentralized energy generation.

It is also crucial to acknowledge most of licence-exempt electricity is generated from the renewable resources. The shift towards renewable energy has been closely associated with job creation, technological advancement, and enhanced energy security, all pivotal factors in fostering economic growth. Moreover, the environmental benefits linked with renewable energy deployment—including reduced greenhouse gas emissions and air pollution—contribute significantly to a nation's overall well-being and can positively impact its economic performance. Governments worldwide are increasingly recognizing the economic advantages of investing in renewable energy, leading to the formulation of policies and incentives to drive its widespread adoption. The development of renewable energy infrastructure not only addresses environmental concerns but also positions Türkiye favourably in the global transition towards clean energy. Without the option to sell excess electricity, the attractiveness of investing in renewable energy systems may diminish for many potential stakeholders. This could slow down the pace of renewable energy deployment and hinder progress towards national or regional clean energy targets. In essence, while the restrictions on license-exempt excess electricity generation aim to address grid stability concerns and promote regulated development, they create barriers to entry and hinder the financial viability of renewable energy projects. Therefore, policymakers should carefully balance grid stability objectives with the need to incentivize and support renewable energy investments to ensure a smooth transition to a more sustainable energy future. Revising these restrictions could support continued growth in renewable energy deployment and economic benefits associated with it. Furthermore, policymakers can also develop flexible regulatory frameworks that balance grid stability with the promotion of renewable energy. By allowing controlled sale of excess electricity, regulators can mitigate concerns while fostering an environment conducive to renewable energy investments. This could include tiered pricing mechanisms or capacity limits that align with grid capacity.

Our study is pioneering in its focus on the impact of license-exempt excess electricity generation on economic growth, a topic that has received limited attention in existing literature. This research stands out in several key aspects. First, by concentrating on license-exempt excess electricity generation, our study explores an area that has not been extensively examined. This novel focus sheds light on how decentralized, small-scale energy production can influence broader economic dynamics. Second, we utilize province-level panel data from all 81 provinces of Türkiye, spanning from 2015 to 2021. This approach allows us to conduct a more detailed and localized analysis compared to the more commonly employed country-level data, which often masks regional variations and specific local factors. By examining data at the provincial level, we can better understand the diverse impacts of license-exempt electricity generation across different regions. Third, our study employs the System Generalized Method of Moments (GMM), a sophisticated econometric technique that effectively addresses potential endogeneity issues. Endogeneity, which arises when explanatory variables are correlated with the error term, can bias estimates and undermine the validity of conclusions. The System GMM method mitigates this problem by using internal instruments, thereby producing more reliable and robust results. Overall, these innovative aspects of our study contribute to a deeper understanding of the relationship between license-exempt excess electricity generation and economic growth, providing valuable insights that can inform policy decisions and future research in this emerging field.

For future research on the relationship between license-exempt electricity generation and economic growth, we recommend investigating the specific effects of the restrictions imposed on the sale of license-exempt electricity generation in 2022. Unfortunately, our study could not explore this aspect due to the unavailability of relevant data and the relatively short time frame since the implementation of these restrictions, which has only been in effect for nearly two years. This limitation highlights the need for ongoing data collection and analysis to fully understand the long-term impact of these regulatory changes on economic growth and the renewable energy sector in Türkiye.

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APPENDICES

A. FIXED- EFFECTS ESTIMATION RESULTS

Table 9. Hausman Test Results

Dependent Variable LOGGDP	**Fixed Effects Coefficient**	**Random Effects Coefficient**
LOGLEEG	0.019 *** (5.88)	0.061 *** (16.58)
LOGEXP	0.151 *** (13.68)	0.153 *** (11.74)
LOGOTOBIN	1.676 *** (11.42)	0.224 *** (4.14)
LOGEC	0.859 *** (13.45)	-0.122 *** (-3.27)
cons	-11.777 *** (-11.47)	8.53 *** (20.27)

Test Statistic	**Value**
Chi²	474.17
Prob > Chi²	0.000

From the Hausman test results above, it can be seen that prob>chi² is less than 0.05. This demonstrates that the null hypothesis should be rejected, and the fixed effects model is more appropriate for this study.

Diagnostic Tests

Table 10. Modified Walt Test for Heteroskedasticity

Chi2	Prob>chi2
1140.13	0.000

The Modified Wald Test is applied to test for heteroskedasticity. The null hypothesis in the Modified Wald Test is that there is no heteroskedasticity. The test result indicates that the null hypothesis should be rejected, and we should conclude that there is heteroskedasticity present in the model.

Table 11. Wooldridge Autocorrelation Test

F	Prob>F
117.117	0.000

The Pesaran Cross-Sectional Test is used to test for cross-sectional dependence in the model. The null hypothesis is that there is no cross-sectional dependence. The results indicate that the null hypothesis should be rejected, and there is cross-sectional dependence in the model.

Table 12. Pesaran Cross-Sectional Dependence Test

Statistic	Prob>F
75.73	0.000

The Pesaran Cross Sectional Test is commonly used to test cross-sectional dependence in the model. The null hypothesis is that there is no cross-sectional dependence. The results indicate that the null hypothesis should be rejected and there is cross-sectional dependence in the model.

The diagnostic test results demonstrate that the model exhibits heteroskedasticity, autocorrelation and cross-sectional dependence. If a fixed effects model exhibits these problems, Driscoll and Kraay (1998) standard errors for coefficients estimated by fixed-effects regression should be used.

Table 13. Fixed Effects Estimation with Driscoll-Kraay Standard Errors

Dependent Variable **LOGGDP**	**Fixed Effects Coefficient**
LOGLEEG	0.020 ** (6.76)
LOGEXP	0.152 ** (4.93)
LOGOTOBIN	1.676 *** (6.72)
LOGEC	0.859 *** (7.24)
cons	-11.777 ** (-4.12)

B. PROVINCIAL DISTRIBUTION OF LICENSE-EXEMPT EXCESS ELECTRICITY PURCHASED BY THE AUTHORIZED SUPPLY COMPANY

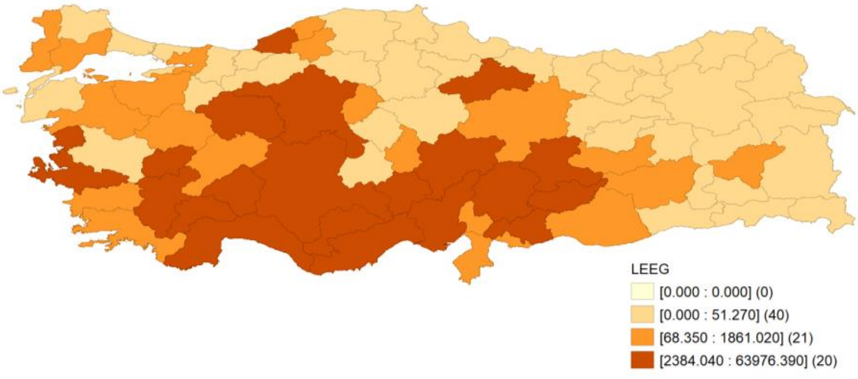

Figure 3. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2015.

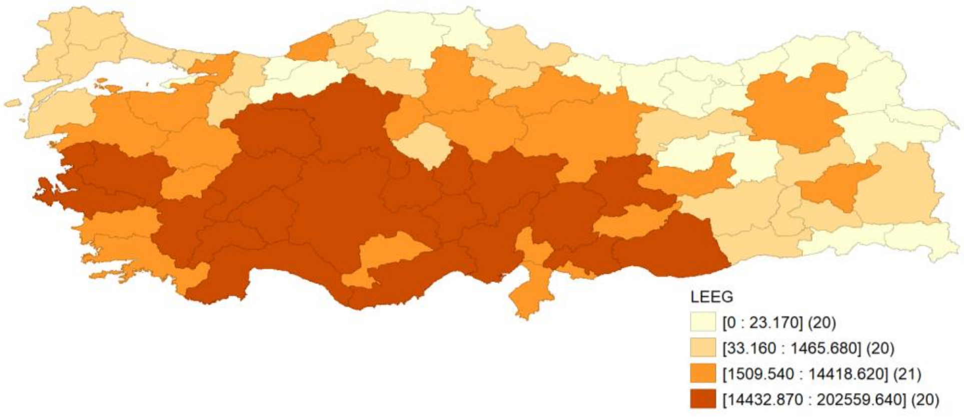

Figure 4. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2016.

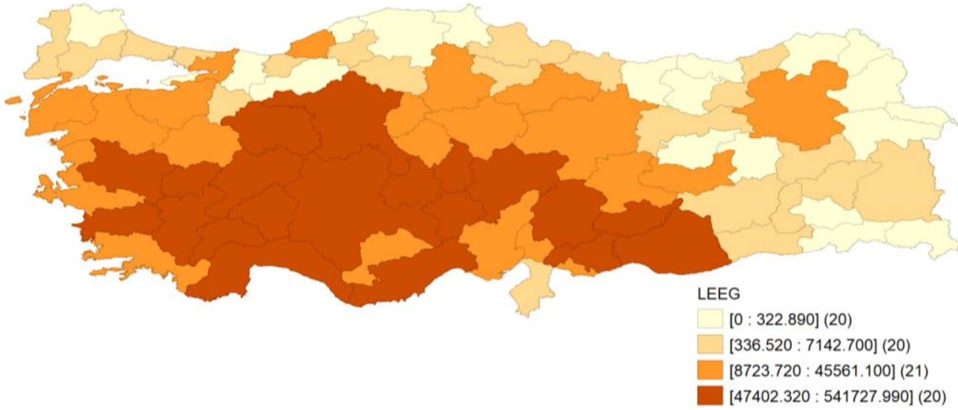

Figure 5. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2017.

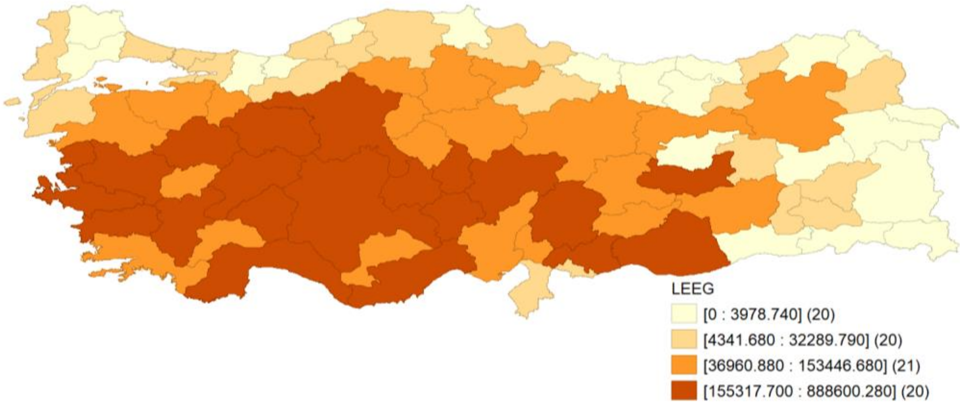

Figure 6. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2018.

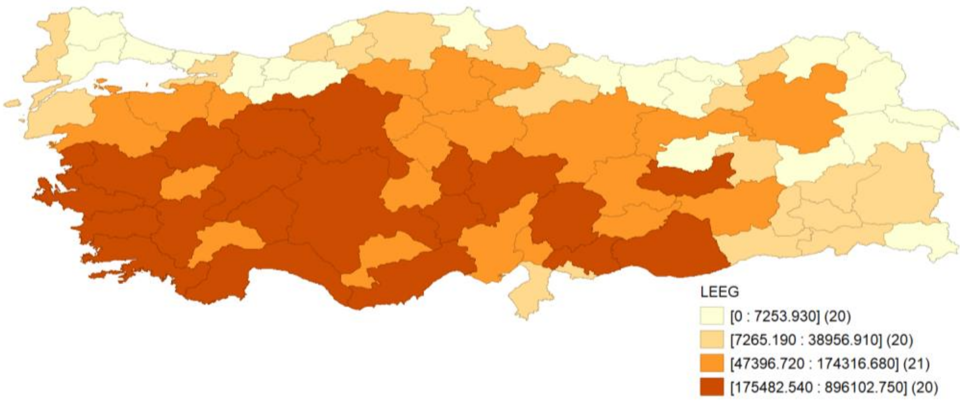

Figure 7. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2019.

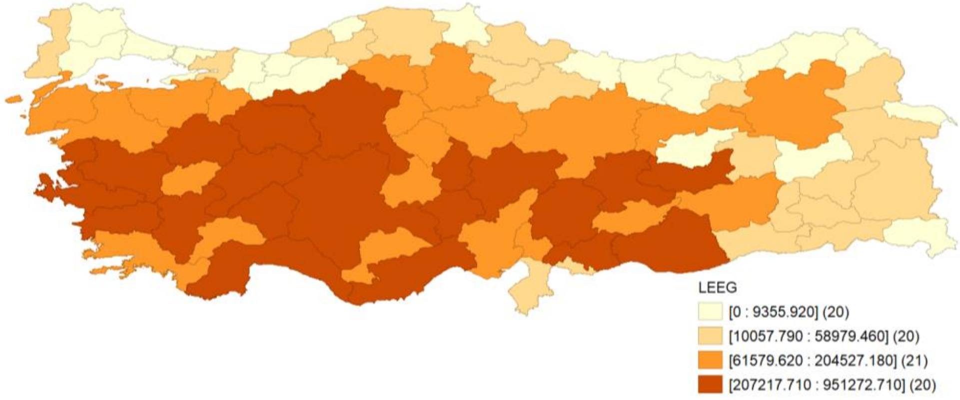

Figure 8. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2020.

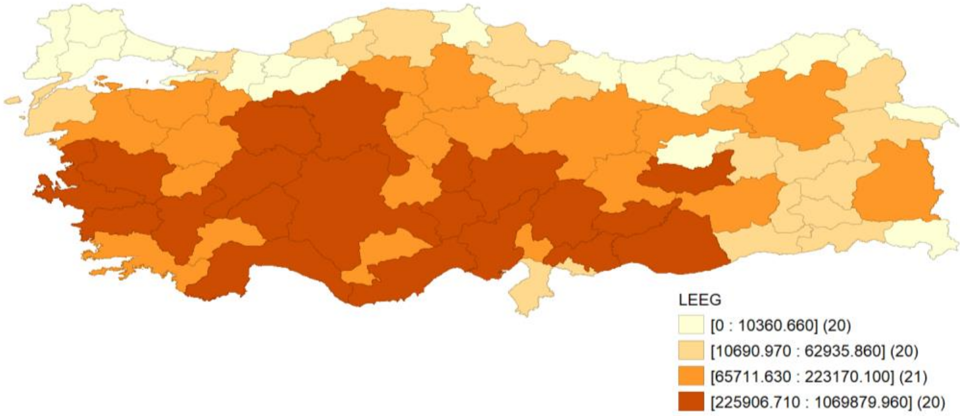

Figure 9. Provincial distribution of license-exempt excess electricity purchased by the authorized supply company in 2021.

C. TURKISH SUMMARY / TÜRKÇE ÖZET

Yenilenebilir ve sürdürebilir enerjiye yönelik küresel değişim, yenilenebilir enerjiyi ekonomik kalkınma ve çevresel sürdürülebilirlik konusundaki tartışmaların ön sıralarına yerleştirmiştir. Türkiye Cumhuriyeti'nin 2023 yılında 100. yılını kutladığı bu dönemde, ülkenin ekonomik büyümesinde yenilenebilir enerjinin önemi daha da önem kazanmıştır. İklim değişikliği kaygıları ve fosil kaynaklarının zararlı etkileri, ülkeleri daha temiz alternatifleri değerlendirmeye teşvik etmektedir. Ek olarak, Rusya-Ukrayna savaşının neden olduğu enerji güvenliği sorunları, ithal fosil yakıtlara bağımlılığın getirdiği riskleri ortaya çıkarmıştır ve bu da güneş ve rüzgâr gibi yenilenebilir kaynakların önemini bir kere daha ortaya koymuştur.

Bu gelişmeler ışığında Türkiye'nin enerji sektörü, pazar taleplerini karşılayacak şekilde hızla gelişmektedir. 2022 yılında yayımlanan Türkiye Ulusal Enerji Planı, devletin elektrik üretiminde yenilenebilir enerjinin payını artırma konusundaki kararlılığının altını çizmektedir. Planda, Türkiye'nin 2053 Net Sıfır Emisyon Hedefi esas alınarak 2035 yılı için önemli hedefler belirlenerek rüzgâr, güneş, hidroelektrik, jeotermal ve biyokütle enerji santrallerinin kurulu güçlerinin artırılması açıklanmaktadır.

Türkiye'de yenilenebilir enerji santrallerinin kurulu gücünde artışı sağlayan en önemli gelişmelerden biri lisanssız elektrik üretim modelidir. Lisanssız Elektrik Üretim Yönetmeliği'nde lisanssız elektrik üretimin amaçlarından birinin arz güvenliğinin sağlanmasında küçük ölçekli üretim tesislerinin ülke ekonomisine kazandırılması olduğu ifade edilmektedir. Bu model ile, bireylerin ve işletmelerin lisans almaya gerek kalmadan kendi tüketimleri için elektrik üretmelerine olanak tanınmakta, dağıtılmış enerji üretimini teşvik edilmekte ve iletim ve dağıtım maliyetleri azaltılmaktadır. Bu model kapsamında ihtiyaç duyulan tüketimi aşan enerji fazlası, Yenilenebilir Enerji Destekleme Mekanizması (YEKDEM) kapsamında yetkili tedarik şirketi tarafından satın alınmaktadır.

Ancak 11 Ağustos 2022 tarihinde Resmi Gazetede yayımlanan 4 Ağustos 2022 tarihli ve 11098 sayılı EPDK Kurul Kararı ile Elektrik Piyasasında Lisanssız Elektrik Üretim Yönetmeliğinde Değişiklik Yapılmasına Dair Yönetmelik doğrultusunda, ihtiyaç fazlası elektriğin görevli tedarik şirketine satışına ilişkin önemli sınırlamalar getirmiştir. Buna göre, 12 Mayıs 2019 tarihinden sonra çağrı mektubu alan lisanssız elektrik üretim tesislerinde tüketim fazlası üretilen elektriğin satışını yıllık tüketim miktarı ile sınırlandırıldığı ve bu miktarın üzerindeki elektriğin Yenilenebilir Enerji Destekleme Mekanizmasına bedelsiz katkı olarak verileceği düzenlenmiştir.

Daha önce mevcut olan ihtiyaç fazlası elektriği satın alma garantisi, tüketicileri lisanssız elektrik üretim tesisleri kurmaya teşvik etmekteydi. Bu garantiyi geriye dönük olarak kaldıran yeni düzenlemeler, üretim tesislerini kurmak için banka finansmanı kullanan ve ihtiyaç fazlası elektrik satışından elde ettiği bu finansmanın geri ödemesinde kullanan yatırımcılar tarafından eleştirilmiştir.

Bu gelişmeler göz önüne alındığında, çalışmamız lisanssız ihtiyaç fazlası elektrik üretiminin Türkiye'nin ekonomik büyümesi üzerindeki etkisini araştırmaktadır. Hipotez, lisanssız ihtiyaç fazlası elektrik üretiminin Türkiye'nin ekonomik büyümesi üzerinde olumlu ve anlamlı bir etkiye sahip olacağı yönündedir. Çalışma, 2015 ile 2021 yılları arasında 81 şehrin verilerini kullanmakta ve hipotezi test etmek için dinamik panel veri analizi yönteminden yararlanarak İki Aşamalı Sistem Genelleştirilmiş Momentler Tahmincisi (GMM) kullanmaktadır.

Lisanssız elektrik üretimi, genellikle güneş ve rüzgar gibi yenilenebilir kaynaklardan, üretim lisanslarına ihtiyaç duymadan küçük ölçekli, dağıtılmış enerji üretimini ifade eder. Merkezi elektrik üretimine alternatif olan bu model, toplum düzeyinde enerji üretimini ve sürdürülebilirliği teşvik etmektedir. Dağıtılmış üretime odaklanan çalışmalar, bu yöntemin yerel ekonomileri destekleyebileceğini ve istihdam fırsatları yaratabileceğini öne sürmektedir. Örneğin, Klagge ve Brocke (2012) Almanya'da merkezi olmayan elektrik üretiminin yerel ekonomik büyümeye katkıda bulunduğu vakaları analiz ederken, Heinbach vd. (2014), yenilenebilir enerjinin yerel düzeyde istihdam ve katma değerli etkilerini ortaya koymuştur. Bu çalışmalar dağıtılmış enerjinin ekonomiye faydalarını ispatlamaktadır.

Lisanssız elektriğin çoğunun yenilenebilir kaynaklardan elde edildiği göz önüne alındığında, yenilenebilir enerji üretimi ile ekonomik büyüme arasındaki ilişkiyi araştıran çalışmaları incelemek çalışmamız için yol gösterici olmuştur. Bu konuda pozitif bir korelasyon olduğunu gösteren çok sayıda çalışma vardır. Bayraktutan vd. (2011), 1980'den 2007'ye kadar OECD ülkelerinde yenilenebilir enerji üretimi ile ekonomik büyüme arasında çift yönlü bir ilişki bulmuştur. Armeanu vd. (2017), AB ülkelerinde yenilenebilir enerji üretimi ile kişi başına düşen GSYİH arasındaki bağlantıyı araştırmıştır ve pozitif bir ilişkiyi doğrulamıştır. Bu pozitif ilişkiyi destekleyen diğer bir çalışma olan Ohler ve Fetters (2014), 20 OECD ülkesinde yenilenebilir enerji üretimi ile reel GSYİH arasında çift yönlü bir ilişki olduğunu tespit etmiştir. Ancak bazı çalışmalar alternatif hipotezi desteklemektedir. Venkatraja (2019), toplam enerji üretiminde yenilenebilir enerji oranının azalmasının BRIC bölgesinde daha hızlı ekonomik büyümeyi destekleyebileceğini göstermiştir. Türkiye'deki çalışmalar da yenilenebilir enerji üretimi ile ekonomik büyüme arasında pozitif bir bağlantı olduğunu gösteriyor. Şerifoğlu (2021), Türkiye'de toplam yenilenebilir enerji üretiminin ekonomik büyüme üzerinde olumlu bir etkisi olduğunu bulurken, Korkmaz ve Develi (2012) ve Erdoğan vd. (2018), yenilenebilir enerji üretimi ile GSYİH büyümesi arasında uzun vadeli bir ilişki olduğunu ortaya koymuştur.

Yenilenebilir enerji tüketimi ve ekonomik büyümeye ilişkin literatür, dört hipoteze ayrılan çeşitli bulgular sunmaktadır: feedback (geri bildirim) hipotezi, büyüme hipotezi, koruyucu hipotezi ve tarafsızlık hipotezi.

- Geri bildirim hipotezi, yenilenebilir enerji tüketiminin ekonomik büyümeyi etkilediği ve bunun tersinin de geçerli olduğu çift yönlü bir ilişki olduğunu öne sürmektedir. Örneğin, Apergis ve Payne (2010) bu ilişkiyi 1992-2007 yılları arasında 13 Avrasya ülkesinde ortaya koyarken, Destek ve Aslan (2017) bazı gelişmekte olan ekonomilerde bu hipotezi doğrulamıştır.
- Büyüme hipotezi, yenilenebilir enerji tüketiminden ekonomik büyümeye doğru tek yönlü bir ilişki önermektedir. Inglesi-Lotz (2016), 34 OECD ülkesinde bu hipotezi desteklerken Aslan (2016), Amerika Birleşik Devletleri'nde biyokütle enerji tüketiminin ekonomik büyüme üzerinde olumlu bir etkiye sahip olduğunu tespit etmiştir.

- Koruyucu hipotezi, ekonomik büyümeden yenilenebilir enerji tüketimine doğru tek yönlü bir nedensellik olduğunu göstermektedir. Furuoka (2017) bu ilişkiyi Estonya, Letonya ve Litvanya'da gözlemlerken, Cho vd. (2015) bunu gelişmiş ülkeler için doğrulamıştır.
- Tarafsızlık hipotezi, yenilenebilir enerji tüketimi ile ekonomik büyüme arasında nedensel bir bağlantı olmadığını öne sürmektedir. Payne (2009), Amerika Birleşik Devletleri'nde enerji tüketimi ile reel GSYİH arasında Granger nedensellik bulmazken, Menegaki (2011) 27 Avrupa ülkesinde zayıf veya hiç olmayan bir bağlantı tespit etmiştir.

Çalışmamız, Türkiye'de lisanssız elektrik üretimi fazlası ve bunun ekonomik büyüme üzerindeki etkisine odaklanarak mevcut literatüre katkıda bulunmaktadır. Çoğu çalışma yenilenebilir enerji üretimi/tüketimi ile ekonomik büyüme arasındaki daha geniş ilişkiye odaklandığından bu çalışma, literatüre daha özel bir perspektifte bu ilişkiyi değerlendirerek katkı sunmaktadır. İl düzeyinde panel veri ve Sistem GMM yöntemini kullanarak, bu ilişkiye dair tespitler sağlamayı ve Türkiye'de yenilenebilir enerji projelerinde yaygın olarak kullanılan lisanssız elektrik üretiminin ekonomik etkilerine ilişkin bulguları ortaya koymayı amaçlıyoruz.

Türkiye'de elektrik üretimi 1902 yılında Mersin'in Tarsus ilçesinde kurulan hidroelektrik santraliyle başlamıştır. 1970 yılına kadar elektrik sektörü imtiyazlar ve dağınık bir yapı ile karakterize edilmiştir. 1970 yılında üretim, iletim ve dağıtımı devlet tekelinde birleştiren Türkiye Elektrik Kurumu (TEK) kuruldu. Bu hamle elektrik sektöründe merkezi ve stratejik yönetimi beraberinde getirmiştir. 1984 yılında 3096 sayılı Kanun ile sektör özel sektöre açılmaya başlamış ve özel şirketlerin Yap-İşlet-Devret (YİD) modeliyle elektrik üretimine katılmasına olanak sağlanmıştır. 2001 yılında 4628 sayılı Kanun ile Enerji Piyasası Düzenleme Kurumu (EPDK) kurulmuştur ve elektrik faaliyetleri üretim, iletim ve dağıtım için farklı kuruluşlara ayırarak rekabet ve düzenleyici denetim teşvik edilmiştir. TEK ise 1993 yılında Türkiye Elektrik Üretim İletim A.Ş. (TEAŞ) ve Türkiye Elektrik Dağıtım A.Ş. (TEDAŞ) olarak yeniden yapılandırılmıştır. TEAŞ, iletim, üretim ve ticaret faaliyetlerinin ayrıştırılması amacıyla 2001 yılında Elektrik Üretim A.Ş. (EÜAŞ), Türkiye Elektrik Ticaret ve Taahhüt A.Ş. ve Türkiye Elektrik İletim A.Ş. (TEİAŞ) olarak üçe ayrılmıştır. 2018 yılında ise TETAŞ, EÜAŞ bünyesine dahil olmuştur. Günümüzde ise üretim faaliyetleri için EÜAŞ, iletim faaliyetleri için TEİAŞ, piyasa işletimi için EPİAŞ, dağıtım faaliyetleri için TEDAŞ ana aktörler olarak elektrik piyasasında karşımıza çıkmaktadır.

Lisanssız elektrik üretimi kavramı, Türkiye elektrik piyasasını serbestleştirmeyi ve yenilenebilir enerjiyi teşvik etmeyi amaçlayan daha geniş enerji sektörü reformlarının bir parçası olarak ortaya çıkmıştır. Bu modelin yasal dayanağı 2010'lu yılların başında Türkiye Elektrik Piyasası Kanunu ve destekleyici düzenlemelerde yapılan değişikliklerle oluşturulmuştur. Lisanssız üretim, yenilenebilir enerji kaynaklarının kullanımını ve öz tüketimi teşvik eder. Amaç, belirli türdeki enerji santrallerinin lisans düzenlenmeden çalışmasına izin vererek yenilenebilir enerjiye geçişi desteklemektir. Lisanssız Elektrik Üretim Yönetmeliği, maksimum 5 MW kurulu güce sahip yenilenebilir enerji santralleri, kojenerasyon ve mikro kojenerasyon tesisleri ve elektrik üretiminin lisans gerektirmediği diğer özel durumlar dahil olmak üzere çeşitli muafiyet kategorilerini listelemektedir. Belirli istisnalar dışında, öz tüketim ihtiyaçlarının karşılanabilmesi için tüketim tesislerinin üretim tesisleri ile ilişkilendirilmesi ve aynı dağıtım bölgesinde yer alması gerekmektedir. Bağlantı anlaşmalarında sözleşmeye konu olan güç limitleri aşılmamalıdır, kaçak elektrik tüketimi olmamalıdır. Lisanssız Elektrik Üretim Yönetmeliği, belirli koşullar altında tek bir tüketim tesisi için birden fazla üretim tesisine izin vermektedir.

Lisanssız elektrik üretime ilişkin başvurular ilgili şebeke işletmecisine yapılmaktadır. Teknik değerlendirme yapılır ve birden fazla başvuru olması durumunda önceliklendirme değerlendirmesi yapılır. Başarılı başvurular, proje onayı, ve diğer gerekli belgeler için bir zaman çizelgesi içeren bir bağlantı anlaşması imzalamaya davet edilir. Bağlantı anlaşması imzalandıktan sonra üretim tesisinin işletmeye alınması ve belirlenen kriterleri karşılaması gerekmektedir.

Lisanssız elektrik üreticilerinin, ürettikleri elektriği kendi tüketimleri için kullanmaları teşvik edilmektedir. Ancak ihtiyaç fazlası elektrik belli koşullar altında görevli tedarik şirketine satılabilmektedir. 5346 sayılı Yenilenebilir Enerji

Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun kapsamında EPDK tarafından TL kuruş/kWh olarak ilan edilen kendi abone grubuna ait perakende tek zamanlı aktif enerji bedeline eşdeğer fiyatla ihtiyaç fazlası elektriğe on yıl süreyle satın alma garantisi sağlanmaktadır. 2022 yılında yapılan değişiklikler, özellikle de 11098 sayılı EPDK Kurul Kararı, lisanssız ihtiyaç fazlası üretilen elektriğin satışına sınırlamalar getirmiştir. Bu değişiklik, 12 Mayıs 2019 tarihinden sonra çağrı mektubu alan lisanssız elektrik üretim tesislerinde tüketim fazlası üretilen elektriğin satışını yıllık tüketim miktarı ile sınırlandırmakta ve bu miktarın üzerindeki elektriğin YEKDEM'e bedelsiz katkı olarak verilmesini öngörmektedir. Bu değişikliklerin amacı lisanssız elektrik üretim modelinin suistimal edilmesinin önüne geçmek ve öz tüketim amacını muhafaza etmektir. Ancak son yıllarda ihtiyaç fazlası elektriğin satışı lisanssız yenilenebilir enerji projeleri için bir finansman kaynağı haline gelmiştir ve bu şekilde finansman kullanan yatırımcılar için mağduriyet yaratmıştır. Söz konusu değişikliklerin, hukuki öngörülebilirlik riski yaratması ve proje fizibilitesi üzerindeki potansiyel etkileri nedeniyle yenilenebilir enerji yatırımlarında caydırıcı bir etki yaratabilecektir.

Bu çalışmada Türkiye'nin 81 ilinden 2015-2021 yılları arasındaki veriler incelenerek 567 gözlem elde edilmiştir. Analize konu verilerin azlığı sebebiyle veri seti yedi yılla sınırlıdır. Lisanssız elektrik üretim modelinin Türkiye'de 2015 yılından sonra yaygınlaşması, Enerji Piyasası Düzenleme Kurumu'nun (EPDK) yıllık raporlarında 2015'ten önce ilgili verinin bulunmamasını açıklamaktadır. Bu çalışma, lisanssız ihtiyaç fazlası elektrik üretiminin (LEEG) ekonomik büyüme üzerindeki etkisini, toplam ihracat, motorlu taşıt sayısı ve toplam elektrik tüketimi kontrolleri ile araştırmaktadır.

Çalışmada aşağıdaki değişkenler kullanılmaktadır:

- Kişi başına düşen GSYİH (GDP): TÜİK'den alınan, ABD doları cinsinden ölçülen bağımlı değişken.
- Lisanssız ihtiyaç fazlası elektrik üretimi (LEEG): EPDK'nın yıllık raporlarından elde edilen, MWh cinsinden ölçülen birincil bağımsız değişken.
- Toplam İhracat (EXP): Türkiye İhracatçılar Meclisi'nden alınan, ABD doları cinsinden ölçülen kontrol değişkeni

- Motorlu Taşıt Sayısı (OTOBİN): Bin kişi başına ölçülen ve TÜİK'den alınan bir diğer kontrol değişkeni
- Toplam Elektrik Tüketimi (EC): Yine TÜİK'ten alınan ve MWh cinsinden ölçülen bir diğer kontrol değişkeni

Ölçeklendirmede ve normal dağılımda tutarlılığı sağlamak için tüm değişkenler log dönüşümüne tabi tutulmuştur.

Çalışmanın temel amacı, Türkiye'de lisanssız ihtiyaç fazlası elektrik üretimi ile ekonomik büyüme arasında istatistiksel olarak anlamlı bir ilişki olup olmadığını tespit etmektir. Hipotez pozitif bir ilişkinin varlığını öne sürmektedir ve artan ihtiyaç fazlası lisanssız elektrik üretiminin yenilenebilir enerji sektöründeki yatırımcı teşvikleri tarafından yönlendirilen ekonomik büyümeye yol açtığı düşünülmektedir. Ayrıca lisanssız elektrik üretiminin yenilenebilir kaynaklardan geldiği göz önüne alındığında, çalışma aynı zamanda bu katkının çevresel sürdürülebilirliğini de araştırmaktadır.

Çalışmada aşağıdaki denkleme sahip bir dinamik panel veri modeli kullanılmaktadır:

$$LOGGDP_{it} = \beta_0 + \beta_1 LOGGDP_{it-1} + \beta_2 LOGLEE_{it} + \beta_3 LOGEXP_{it} + \beta_4 LOGOTOBIN_{it} + \beta_5 LOGEC_{it} + u_{it}$$

Burada β tahmin edilen değişkenlerin katsayılarını, i her paneli, t her zaman serisini, u_{it}ise hata terimini temsil etmektedir. $LOGGDP_{it-1}$ ise bağımlı değişkenin gecikmeli değerini temsil etmektedir.

Model güvenilirliğini teyit etmek için bağımsız değişkenler arasında çoklu bağlantı olup olmadığını incelememiz gerekir. Varyans Büyütme Faktörü (VIF), bağımsız değişkenler arasındaki çoklu bağlantının varlığını değerlendirmek için kullanılır ve 5 eşiği potansiyel sorunları gösterir. Çalışma, tüm VIF değerlerini 5'in altında olduğunu göstermektedir ve bu da modelimizde bir çoklu bağlantı sorunu olmadığını göstermektedir. Aşağıdaki korelasyon tablosu da değişkenler arasındaki zayıf korelasyon olduğunu göstermektedir.

Tablo 1. Çoklu Bağlantı Testi Sonuçları

	VIF	1/VIF
LOGOTOBIN	1.461	.685
LOGEC	1.394	.717
LOGEXP	1.043	.959
LOGLEEG	1.034	.967
Mean VIF	1.233	.

Tablo 2. Korelasyon Tablosu

Değişkenler	**(1) LOGGDP**	**(2) LOGLEEG**	**(3) LOGEXP**	**(4) LOGOTOBIN**	**(5) LOGEC**
(1) LOGGDP	1.000				
(2) LOGLEEG	0.007 (0.8718)	1.000			
(3) LOGEXP	0.039 (0.3498)	0.084** (0.0460)	1.000		
(4) LOGOTOBIN	-0.087** (0.0388)	0.173*** (0.0000)	0.196*** (0.0000)	1.000	
(5) LOGEC	-0.190*** (0.0000)	0.076* (0.0714)	0.117** (0.0052)	0.531*** (0.0000)	1.000

Değişkenlere ilişkin tanımlayıcı istatistikler aşağıdaki Tablo 3'te gösterilmektedir. Çalışmada her değişken için 567 gözlem yer almaktadır ve bu da dengeli bir panelin varlığına işaret etmektedir. Normalliği değerlendirmek için çarpıklık ve basıklık değerleri incelenmektedir. Çarpıklık için -2 ile +2 ve basıklık için -7 ile +7, kabul edilebilir aralıklardır. Çalışmamızdaki tüm değişkenler bu aralıklar içerisinde yer almakta olup, bu da güvenilir istatistiksel analiz için önemli bir varsayım olan normal bir dağılıma işaret etmektedir.

Tablo 3: Tanımlayıcı İstatistikler

Değişkenler	Göz.	Ort.	Std. Sap.	Min.	Max.	Çarpıklık	Basıklık
LOGGDP	567	8.873	0.346	7.975	9.824	0.049	3.044
LOGLEEG	567	8.319	4.079	0.095	13.883	-0.933	2.706
LOGEXP	567	11.991	2.474	1.97	18.303	-0.471	3.885
LOGOTOBIN	567	4.592	0.772	1.946	5.67	-1.504	4.488
LOGEC	567	14.159	1.228	11.332	17.542	0.237	2.795

Çalışmamız, dinamik veri analizi için dinamik bir panel veri tahmincisi olan Genelleştirilmiş Momentler Yöntemi'ni (GMM) kullanmaktadır. GMM, beklenen değerlerin gerçek parametre değerlerinde sıfır olmasını sağlamak için hem model parametrelerinden hem de verilerden türetilen moment koşullarına dayanmaktadır. Bu yöntem yarı parametriktir, katı dağılım varsayımları yerine moment koşullarına dayanır, sağlam ve esnek parametre tahminleri sunar. GMM tahmincisi ilk olarak Hansen (1982) tarafından ortaya atılmış ve Hansen ve Singleton (1982) tarafından geliştirilmiştir. İçsellik problemine karşı sağlamlığı, ihmal edilen değişken yanlılığı, gözlemlenmeyen panel heterojenliği ve ölçüm hataları nedeniyle yatay kesit ve panel tahmininde popüler bir seçim haline gelmiştir.

GMM ayrıca özellikle geniş kesitli ve daha küçük zaman aralığına sahip dinamik panel modelleri için uygundur. Roodman'a (2009) göre GMM'nin uygulanabileceği temel senaryolar şu şekildedir:

- Küçük T'ye (zaman aralığı) ve büyük N'ye (kesit veya grup sayısı) sahip dinamik panel modelleri.
- Değişkenler arasındaki doğrusal fonksiyonel ilişkiler.
- Geçmişteki olaylardan etkilenen dinamik bağımlı değişkenler.
- Geçmiş ve mevcut hata terimleriyle ilişkili endojen bağımsız değişkenler.
- Paneller içinde değişen varyans ve otokorelasyon.

Kesit sayısının (N = 81) zaman birimi sayısını (T = 7) aştığı göz önüne alındığında, GMM, GSYİH'nin dinamik doğasını ele almak ve değişen varyans ve seri korelasyona yatkın verilerdeki bozuklukları yönetmek için seçilmiştir.

İki tür GMM tahmincisi vardır: Fark GMM ve Sistem GMM. Aralarında karar vermek için Bond ve Hoeffler (2001), birleştirilmiş OLS ve En Küçük Kareler Kukla Değişkeni (LSDV) yaklaşımını kullanarak başlangıç dinamik modelinin tahmin edilmesini önerir. Fark GMM tahmininin, sabit etkiler tahminiyle aynı hizada olması veya bu tahminin altına düşmesi durumunda, zayıf enstrümantasyondan dolayı aşağı yönlü eğilimi gösterirse, Sistem GMM tahmincisi tercih edilir. Ek olarak, bağımlı değişken kalıcılık gösterdiğinde veya neredeyse rassal yürüyüş izlediğinde, Fark GMM taraflı ve verimsiz tahminler üretebilir, bu da Sistem GMM'i daha iyi bir seçim haline getirir. Fark GMM, tüm regresörlerin farkını alarak sabit etkileri ortadan kaldırır, ancak dengesiz panellerdeki tutarsızlıkları artırabilir. Bu dezavantaj, zaman aralıkları sınırlı olduğunda ve bağımlı değişken yüksek kalıcılık gösterdiğinde örneklem yanlılığına yol açabilir. Bu araştırma, bu sorunları çözmek için Sistem GMM yaklaşımını benimser.

Arellano & Bover (1995) ve Blundell & Bond (1998) tarafından da ifade edildiği üzere Sistem GMM, daha etkili tahminler sunar ve daha geniş bir araç seti kullanır. İki denklemden oluşan bir sistem yaratır: biri araç olarak birinci farkları olan seviyelerde, diğeri araç olarak seviyeleri olan birinci farkı alınmış formdadır. Bu yapı, değişken varyans ve seri korelasyonu etkili bir şekilde ele alır. Sistem GMM, bir değişkenin gelecekteki mevcut tüm gözlemlerinin ortalamasını çıkararak veri kaybını en aza indiren ortogonal sapmaları kullanır. Bu yaklaşım özellikle zaman periyodlarının sayısı sınırlı olduğunda ve bağımlı değişken yüksek düzeyde kalıcılık gösterdiğinde avantajlıdır.

Araçların geçerliliğini değerlendirmek ve otokorelasyonu veya seri korelasyonu tespit etmek için çeşitli tanı testleri kullanılır. Hansen testi araç geçerliliğini kontrol ederken, Arellano-Bond testi, birinci fark hataları içindeki otokorelasyonu inceler. 0,05'i aşan bir p değeri, otokorelasyonun olmadığını gösterir; bu da doğru moment koşullarına ve seri olarak ilişkisiz hata terimlerine işaret eder.

Çalışmamızda tüm değişkenler için durağanlık kontrolü amacıyla IPS ve ADF panel birim kök testleri kullanılmıştır. Tablo 4, tüm değişkenlerin I(0) düzeyinde durağan olduğunu ve tüm olasılık değerlerinin 0,05 eşiğinin altında olduğunu gösteren sonuçları sunmaktadır.

Tablo 4. Birim Kök Testi Sonuçları

Trend Olmadan		ADF		IPS		Trend	ADF		IPS	
		t-stat	Prob	t-stat	Prob		t-stat	Prob	t-stat	Prob
LOGGDP	Level	-16.393	0.000	-28.10	0.000	Level	-8.713	0.000	-1.1	0.000
LOGLEEG	Level	-39.998	0.000	-2.1	0.000	Level	-21.724	0.000	-3.8	0.000
LOGEXP	Level	-3.047	0.001	-18.99	0.000	Level	5.066	0.000	-51.02	0.000
LOGOTOBIN	Level	-2.991	0.001	-34.42	0.000	Level	-68.78	0.000	-4.7	0.000
LOGEC	Level	-0.53	0.000	-10.65	0.000	Level	-2.165	0.015	-1.1	0.000

Durağanlık teyit edildikten sonra sistem GMM tahmincisi ile bağımsız değişkenlerin katsayıları tahmin edilmiştir.Tablo 5, GMM analizinin sonuçlarını göstermektedir.

Tablo 5. GMM Analiz Sonuçları

Bağımlı Değişken: LOGGDP	
LOGGDP(-1)	0.927*** (333.15)
LOGLEEG	0.0004*** (2.74)
LOGEXP	0.002*** (5.44)
LOGOTOBIN	-0.008*** (-3.95)
LOGEC	0.004** (2.16)
cons	0.577*** (20.16)
Gözlemler	486
F-test	7110000.00
AR(1)	0.041
AR(2)	0.09
Hansen Test	0.179

AR(1) %5 düzeyinde istatistiksel olarak anlamlıdır, AR(2) ise anlamlı değildir, bu da 2 adımlı Sistem GMM modelinde otokorelasyonun olmadığını gösterir. Gecikmeli bağımlı değişkenin anlamlı katsayısı (LOGGDP(-1) 0,927), önceki değerine bağlı olarak GSYİH'deki %93'lük değişimi açıklamaktadır.

Bağımsız değişkenlere ilişkin sonuçlar şunları göstermektedir:

- LOGLEEG (Lisanssız İhtiyaç Fazlası Elektrik Üretimi): LOGGDP üzerinde istatistiksel olarak pozitif ve anlamlıdır; LOGLEEG'deki %1'lik artış, LOGGDP'de %0,0004'lük bir artışa yol açmaktadır. Bu durum, lisanssız ihtiyaç fazlası elektrik üretiminin ekonomik büyümeye katkıda bulunduğu hipotezini desteklemektedir.
- LOGEXP (İhracat): LOGEXP'deki %1'lik bir artış, LOGGDP'deki %0,002'lik bir artışa sebep olmaktadır ve bu durum ihracat ile ekonomik büyüme arasındaki pozitif ve anlamlı ilişkiyi doğrulamaktadır.
- LOGEC (Enerji Tüketimi): LOGEC'deki 1 birimlik bir artış, LOGGDP'de 0,004 birimlik bir artışa karşılık gelmektedir ve enerji tüketiminin GSYİH büyümesini yönlendirdiği büyüme hipoteziyle uyumludur.
- LOGOTOBIN (Araç Sahipliği): LOGOTOBIN'deki %1'lik bir artış, LOGGDP'de %0,008'lik bir düşüşe sebep olmaktadır; ve bu durum mevcut literatürle tutarlı olmayan bir bulgudur.

Bu çalışmanın temel amacı Türkiye'de lisanssız ihtiyaç fazlası elektrik üretiminin ekonomik büyüme üzerindeki etkisini incelemektir. 2015 ile 2021 yılları arasındaki 81 il verisini ve 2 adımlı Sistem GMM dinamik panel tekniğini kullanan analiz, lisanssız ihtiyaç fazlası elektrik üretimi ile kişi başına düşen GSYİH arasında istatistiksel olarak pozitif ve anlamlı bir ilişkinin mevcut olduğunu ortaya koymaktadır. Bu durum lisanssız ihtiyaç fazlası elektrik üretiminin ekonomik büyümeye katkı sağlayabileceğini göstermektedir. Ancak lisanssız ihtiyaç fazlası elektriğin satışına ilişkin olarak Ağustos 2022 tarihinde getirilen kısıtlamalar bu olumlu etkiyi engelleme potansiyeline sahiptir. Bu kısıtlamalar şebeke güvenliğini sağlamayı amaçlamaktadır ancak yenilenebilir enerji projelerinin geliştirilmesine mani olabilir, bu projelerin mali sürdürülebilirliklerini azaltabilir ve potansiyel olarak

Türkiye'de yenilenebilir enerjinin hedeflenen düzeyde ilerlemesini engelleyebilir. İhtiyaç fazlası elektriğin satışı, tarihsel olarak yenilenebilir enerji yatırımları için mali bir teşvik sağlamıştır ve bunun sınırlandırılması, dağınık enerji üretiminin yaygınlaşmasını yavaşlatabilir.

Kısıtlamalara rağmen, lisanssız elektrik üretimi, iş yaratma, teknolojik ilerleme ve enerji güvenliğini artırmadaki rolü nedeniyle önemini korumaya devam etmektedir. Karbon emisyonlarının azaltılması gibi çevresel faydalara olan katkısı, önemini daha da vurgulamaktadır.

Gelecekteki araştırmalar spesifik olarak 2022 yılında getirilen kısıtlamalarının etkilerini araştırmalıdır; ancak mevcut durumda veri sınırlamaları bu çalışmada bu analizlerin yapılmasını engellemiştir. Politika yapıcılar, şebeke güvenliği endişelerini yenilenebilir enerjiyi desteklemeye yönelik teşviklerle dengelemeli ve daha sürdürülebilir bir enerji geleceğine sorunsuz bir geçiş sağlamalıdır.

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