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INSTITUTE OF SOCIAL SCIENCES

INTERNATIONAL FINANCE DEPARTMENT

THE EFFECT OF INFORMAL ECONOMY ON ENVIRONMENTAL DEGRADATION

MASTER'S THESIS

Abdullah ARSLAN

ADVISOR

Assoc. Prof. Dr. Erdem KILIC

ISTANBUL, January 2024

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I hereby declare that this thesis is an original work. I also declare that, I have acted in accordance with academic rules and ethical conduct at all stages of the work including preparation, data collection and analysis. I have cited and referenced all the information that is not original to this work.

Abdullah ARSLAN

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ÖZET

KAYITDIŞI EKONOMİ'NİN ÇEVRESEL KİRLİLİK ÜZERİNDEKİ ETKİSİ

Bu tez, ekonominin daha az bilinen bir parçası olan Kayıtdışı Ekonomi'yi kapsamlı bir şekilde araştırmayı amaçlamakta ve sonunda Kayıtdışı Ekonomi ve Çevresel Kirliliğe etkisini analiz etmektedir. Kayıtdışı Ekonomi; tarihçesi, kapsamı, ölçüm yöntemleri, sebepleri ve etkileri ile birlikte açıklanmıştır. Ayrıca çevresel kirlilik kavramı; tarihçesi, ölçüm yöntemleri, ekonomik etkisi ve dışsallık etkileri gibi farklı perspektiflerden incelenmiştir. Bu gerekli kavramları açıkladıktan sonra, bir literatür incelemesi ve deneysel analiz, Kayıtdışı Ekonomi'nin çevresel kirlilik düzeyi üzerindeki etkisini anlamak için yapılmıştır. Sonuçlara göre, Kayıtdışı Ekonomi; özellikle gelişmemiş ülkeler için ekonominin önemli bir bölümünü oluşturur. Analize göre, çevresel kirlilik ve Kayıtdışı Ekonomi arasında negatif bir ilişki mevcuttur, yani daha yüksek bir Kayıtdışı Ekonomi, daha düşük çevresel kirlilik ile ilişkilendirilir.

Anahtar Kelimeler: Kayıtdışı Ekonomi, Çevresel Kirlilik

ABSTRACT

THE EFFECT OF INFORMAL ECONOMY ON ENVIRONMENTAL DEGRADATION

This thesis aims to provide comprehensive research on the lesser-known part of the economy, which is Informal Economy and, in the end, analyze the relationship between informal economy and environmental degradation. Informal Economy has been explained with its history, scope, measurement methods, causes and effects. In addition, the term environmental degradation has been analyzed from different perspectives such as its historical background, measurement methods, economic impact, and market failures. After explaining these necessary concepts, a literature review and empirical analysis has been conducted to understand the effect of informal economy on the level of environmental degradation.

According to the results, informal economy constitutes a sizable portion of the economy especially for non-developed countries. The analysis represents a negative relationship between environmental degradation and informal economy, meaning higher informal economy is associated with lower environmental degradation.

Keywords: Informal Economy, Environmental Degradation

LIST OF ABBREVIATIONS

GDP: Gross Domestic Product

EU: European Union

GNP: Gross National Product

ETS: Emission Trading System

ILO: International Labor Organization

CO_2: Carbon Dioxide

NO_2: Nitrogen dioxide

EKC: Environmental Kuznets Curve

UN: United Nations

PCA: Principal component analysis

ICLS: International Conference of Labour Statisticians

LCA: Life Cycle Assessment

WF: Water Footprint

EF: Ecological Footprint

MIMIC: Multiple Indicators and Multiple Causes

DGE: Dynamic General Equilibrium

RE: Random Effect Panel Regression

FE: Fixed Effect Panel Regression

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1. INTRODUCTION

Informality is a multisided concept, lacking a universally accepted definition due to its relevance across a range of disciplines including economics, culture, politics, sociology and so on. The diverse nature of these disciplines has led to varying interpretations of informality. In the realm of economics, the informal economy is described as all economic activities that operate beyond the purview of government regulation and taxation. Rafael La Porta and Andrei Schleifer, for instance, describe informal economic activities as "conducted by unregistered firms or registered firms that remain hidden from taxation" (La Porta & Schleifer, 2014).

Another perspective, provided by Cetintas and Vergil, defines the informal economy as comprising both legal and illegal production activities that remain absent from official statistical records. Within this framework, activities like gambling, drug trade, non-monetary goods and services transactions, and self-consumption-based production are considered integral to the informal economy (Cetintas and Vergil, 2011).

The International Labor Organization (ILO) offers its own definition, characterizing the informal sector as primarily consisting of small-scale economic activities conducted by self-employed individuals who either employ family labor or a small number of workers (ILO, 1991). This definition, however, should be viewed as an indicator of the broad features of the informal sector rather than a formal and comprehensive description.

In addition to the term "Informal Economy," various alternative expressions are used interchangeably, including Shadow Economy, Unregistered Economy, Black Economy, Unofficial Economy, Invisible Economy, Unrecorded Economy, and Subterranean Economy. In this research, we adopt the term "Informal Economy," aligning with the usage by the ILO. Nevertheless, it is advisable for researchers researching Informal Economy to search for other terms as well.

On the other hand, environmental degradation is one of the greatest challenges of our time. Even if environmental degradation is in its nature originates from a national level, problems expanded and created regional, international, and global problems

which became a threat for all the livings on the planets including human beings. Even if environmental degradation topics are extremely important for all the living, the idea of green growth and sustainable development had been ignored until the 1960s. Development was only perceived as economic growth back then. That means, Quantitative progress in economic performance is seen as development and qualitative change in the economy is ignored. As a result, Countries designed their development strategies and goals based on the idea of increasing economic performance qualitatively. Developing countries started to shift their economies from agricultural production into industrial production and trade which led to an increase in environmental degradation. The Brundtland Report made clear that the environment cannot be separated from growth and development plans of countries. The report emphasized that economic growth and social welfare can be obtained at the same time while providing sustainable solutions for the environment (Brundtland Report, 1987). The sustainability concept has gained importance after the Brundtland Report. It is a concept related to several disciplines such as economics, environment, agriculture, social planning, and architecture. Different disciplines defined sustainability in different manners. One general accepted definition of Sustainability is" Meeting our own needs without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987). This definition is set up in the Brundtland Report which is the outcome of Brundtland Commission. The Brundtland commission is established in 1983 by the UN to unite countries to pursue sustainable development by preventing deterioration of human and natural resources. (Brundtland Report, 1987). There was not much awareness regarding sustainability before the Brundtland commission.

The problem of environmental degradation cannot be solved by individual initiatives of countries. All the living organizations and non-living organizations are interconnected globally and cannot be separated from each other. As an example, India is only responsible for 7% of total greenhouse gas emissions in the world (Boden et al, 2017). Thus, individual action done by India to reduce environmental degradation is limited. For the case of air pollution, this is even more obvious since there are no borders for atmosphere. India's individual actions can be easily ineffective by greenhouse gas emissions done by other countries. In addition, environmental degradation is a problem caused by all the countries and threatens living and non-living

organizations in all the countries. Thus, necessary actions need to be discussed at a global level and all the countries must be responsible accordingly.

To limit environmental degradation, there have been discussions going on for years. As awareness regarding environmental issues increased after the Brundtland Commission, countries started to gather to discuss and limit environmental degradation by making collective agreements. Global agreements such as Kyoto Protocol or Paris Agreement are some of the recent proofs that countries understand the importance of environmental degradation and act collectively with other countries to grow sustainably.

In this manner, the connection between environmental degradation and the efficacy of environmental protection laws with their enforcement within a given country is widely recognized. The presence of an informal economy is one of the factors making it harder to enforce environmental laws and regulations. Therefore, it is important to explore the relationship between the environment and the informal economy, when designing and implementing environmental laws and regulations.

Since the importance of informal economy in this manner has been discovered more recently, there is a scarcity of comprehensive studies addressing this subject. Most research on environmental impact focuses on the formal determinants of the economy itself, whereas investigations into the influence of the informal economy on environmental degradation remain notably limited. Literature on the effect of formal economy determinants on the environment is wide and even widely accepted hypothesis are also Kuznets Curve Hypothesis (EKC), Brundtland Curve Hypothesis, Pollution Haven Hypothesis and so on. However, for informal determinants of the economy, literature has still limited scope. This study will contribute to the existing limited literature and will be a handbook for informality concept.

Recognizing and investigating the influence of the informal economy on environmental degradation is extremely important in shaping more potent environmental policies and comprehensively tackling environmental issues. Given the continued substantial presence of the informal economy across various regions, it is important to consider its environmental repercussions when designing more sustainable and impactful regulations and conservation strategies. This paper empirically

investigates the influence of informal economy on environmental degradation and contributes to the existing limited literature.

2. LITERATURE REVIEW

It is well known that environmental degradation is highly correlated with environmental protection laws and enforcement of the law within that country. The presence of an informal economy is one of the factors making it harder to enforce environmental laws and regulations. It is important to investigate the relationship between the environment and the informal economy and consider informal economy as well to design laws and regulations. Since the importance of informal economy in this manner has been discovered more recently, there are limited studies examining topic. Most of the studies examining environmental impact is explained through formal determinants of the economy itself. Research on the effect of informal economy on environmental degradation is left limited.

In their study, Blackman and Banister described informal sector as low technology and unlicensed micro enterprises leading a major source of pollution (Blackman and Banister, 1998). According to their analysis, clean technology tool usage can be increased in informal sector even if it is costly. In addition, support from local organizations and the community itself can ease the process to a cleaner informal economy (Blackman and Banister, 1998).

Chaudhuri builds a three-sector general equilibrium model with informal sector and explains that pollution generated by informal manufacturing entities are much higher than their formal counterparts. In addition, informal sector entities are described as subcontractors for formal entities for their processes which have negative impact on the environment (Chaudhuri, 2005). This idea of Chaudhuri is in correlation with Pollution Haven Hypothesis from an inter-country perspective.

According to Biswas et al, large informal sector size leads to environmental degradation more as the enforcement of laws and regulations in the informal sector is weak and informal entities may escape these regulations more easily. (Biswas et al, 2012). They also claimed that the negative impact of informal sector on the environment could be reduced by combatting corruption in the country.

Using an ARDL bound testing procedure, Baloch et al finds a strict co-integration between informal economy and environmental degradation. (Baloch et al, 2022). According to them, the effect of informal sector is not only limited to CO_2 emissions, but instead it is co-integrated with most of the variables related to environmental degradation.

According to Baksi and Bose, informal economy is dangerous especially for developing countries since corruption level is higher and regulations and effectiveness of the regulations are weak. (Baksi and Bose, 2021).

To sum up, among these limited studies, the effect of informal economy on environmental degradation is mostly examined using variables such as CO_2 emissions. In this manner, this study becomes more differentiated in terms of examining the relationship between informal economy and different variables such as NO_2 emissions per capita, Share of death by outdoor air pollution, energy intensity etc.

3. INFORMALITY CONCEPT

There is not a generally accepted definition of Informality since it is a topic related to disciplines such as economics, culture, politics and sociology and each discipline defines informality in a different aspect. In terms of economics discipline, informal economy can be defined as all the economic activities which are not subject to government regulation and taxation. Rafael La Porta and Andrei Schleifer describe informal economic activity as "conducted by unregistered firm or by registered firms but hidden from taxation" (La Porta & Schleifer, 2014).

Cetintas and Vergil described Informal economy as "All the legal and illegal production activities which are not reflected in official statistics." In this manner, activities such as gambling and selling drugs, goods & services transaction done without money exchange and production activities done only for self-consumption are seen as part of Informal economy (Cetintas and Vergil, 2011).

ILO (International Labor Organization) came with a definition stating that the informal sector was "made up of small-scale economic activities, consisting of self-employed persons who hire family labor or a few workers" (ILO, 1991). That is to say, the conception of Informality was mainly related to small scale employment activities at that time. This was not a formal definition/description of informal sector; it was just an indication of typical characteristics of informal sector.

There are other expressions which are also used instead of Informal Economy. These expressions are Shadow Economy, Unregistered Economy, Black Economy, Unofficial Economy, Invisible Economy, Unrecorded Economy, Subterranean Economy and etc. In this study, the term Informal Economy is used. The term Informal Economy is also being used by ILO. However, anyone who is doing research on Informal Economy should search for other terms as well.

3.1 History and Background of Informality

Studies on Informality go back to the 1940s. Sociologists and anthropologists

mainly did these studies to analyze the structure of society. Economic analysis of Informality left unexplained until late 1970s. The first study related to Informal economy is done by Gutmann in 1977 with his article "The Subterranean Economy". In this article, Gutmann pointed out the importance of Informal Economy and put the idea of the necessity for considering Informal Economy for the future (Gutmann, 1977). The study of Gutmann raised awareness regarding Informal Economy and the first international meeting is held in 1983 in Bielefeld-Germany. In this meeting, participant countries are informed that important macroeconomic figures of countries can be misleading since informal economy constitutes a big amount of the economy for most of the countries and it is not considered for policies of countries. The outcome of the conference is published by Gaertner in the study "The Economics of the Shadow Economy: Proceedings, Bielefeld, West Germany, October 1983" (Gaertner, 1983).

At the 15th International Conference of Labor Statisticians (ICLS) in 1993, statistical definition of informal sector was determined, and this was the first internationally agreed statistical definition of informal sector (ILO, 1993). The definition had more of an enterprise perspective on informality. Hussmanns and Mehran points out to this perspective ILO adopted by saying "ILO defined Informal Sector in terms of characteristics of enterprises (production units) where activities take place rather than the characteristics of the people involved in these activities." (Hussmans and Mehran, 1999). The term enterprise is used to point out any unit which is related to production activities. These production units do not only include units that hire people to work for them. They include self-employment activities as well. A family producing for the purpose of sale or a man selling food on the street is considered as a production unit and they are all referred as enterprise at the 15th ICLS (ILO, 1993). Production for own consumption is not defined as an informal activity at the 15th ICLS.

Several activities which are perceived as types of informal activities by some academics were not included in informal sector at the 15th ICLS. Agricultural activities, production for own use purposes, volunteering activities and several other activities were excluded in the Informal sector (ILO, 2013). According to ILO, the reason agricultural activities were excluded from the informal sector was to decrease costs resulting from informal sector surveys. ILO aimed to apply these surveys in a more practical and less costly manner (ILO, 2013).

In 2002, at the 17th ICLS, ILO proposed the definition of Informal Economy to reflect the concept of informality in a more comprehensive manner. The definition was "all economic activities by workers or economic units that are not covered or sufficiently covered by formal arrangements" (ILO, 2002). By this definition, the term informal sector was not replaced with informal economy. The term informal economy is proposed to have a different and comprehensive approach on informality. In addition to this, countries already collected data from 1993 on to measure the size of informal sector. Proposed concepts by ILO related to Informality can be summarized in the table below.

Avoiding confusion in terminologies

Within the statistical community, application of accurate terminology is important. To the layperson, the terms "informal sector", "informal economy", "employment in the informal sector" and "informal employment" might all seem to be interchangeable. They are not. The nuances associated with each term are extremely important from a technical point of view. The following can serve as an easy reference for the terminology associated with informality and their technical definitions:

(a) **Informal economy**
All economic activities by workers or economic units that are – in law or practice – not covered or sufficiently covered by formal arrangements (based on ILC 2002)

(b) **Informal sector**
A group of production units (unincorporated enterprises owned by households) including "informal own-account enterprises" and "enterprises of informal employers" (based on 15th ICLS)

(c) **Informal sector enterprise**
Unregistered and/or small-scale private unincorporated enterprises engaged in non-agricultural activities with at least some of the goods or services produced for sale or barter (based on 15th ICLS)

(d) **Employment in the informal sector**
All jobs in informal sector enterprises (c), or all persons who were employed in at least one informal sector enterprise, irrespective of their status in employment and whether it was their main or a secondary job (based on 15th ICLS)

(e) **Informal wage employment**
All employee jobs characterized by an employment relationship that is not subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits (based on 17th ICLS)

(f) **Informal employment**
Total number of informal jobs, whether carried out in formal sector enterprises, informal sector enterprises, or households; including employees holding informal jobs (e); employers and own-account workers employed in their own informal sector enterprises; members of informal producers' cooperatives; contributing family workers in formal or informal sector enterprises; and own-account workers engaged in the production of goods for own end use by their household (based on 17th ICLS)

(g) **Employment in the informal economy**
Sum of employment in the informal sector(d) and informal employment (f) outside the informal sector; the term was not endorsed by the 17th ICLS

Table 3.1. Terminologies related to Informality.

Source: (ILO, 2013)

In addition, 17th ICLS proposed the definition for informal employment as "All informal jobs, whether carried out in a formal enterprise, an informal household market enterprise or a household enterprise producing goods exclusively for own final use." (ILO, 2003). This definition of informal employment was not a replacement of the term

informal sector. The main reason informal employment is defined is to capture informal employment outside the informal sector.

The concept of informal employment and informal sector have differences among countries as well. Different countries have different laws and regulations for formality. Meeting several criteria can make an enterprise formal while there are additional requirements to meet in other countries to be listed as a formal enterprise. There are geographical and social differences as well. This is the reason ILO did not set a strict set of rules for all the countries for data collection process. Thus, data collected from different countries can be in different scopes.

3.2 Methods to Measure Informality

It is hard to measure informality since in its nature, informal economy cannot be observed. In other words, informal economy is a hidden part of the economy. Agents involved in informal economic activities would like to hide or they simply do not let authorities know about their activities as it could result in fines and becoming formal.

As mentioned above, the scope of Informal Economy is controversial. For some of the researchers, illegal activities such as drug traffic and gambling are considered as parts of Informal Economy. Cetintas and Vergil describes Informal Economy as "All the legal and illegal activities which are not reflected in official statistics" (Cetintas and Vergil, 2011). However, in this study, mostly legal part of informality is considered as Informal Economy and illegal activities are not considered.

As there is not a generally accepted definition of Informal Economy, there is not an accepted method to measure Informal Economy as well. Informal Economy in its nature is the hidden and unknown part of the economy. This makes it harder to estimate Informal Economy correctly. To measure informal economy in the most accurate way, different methods are suggested. All suggested methods have advantages and disadvantages, and they have quite different results for the same country and the same period. The most accepted methods are going to be presented in this study with their advantages and disadvantages.

3.2.1 Direct Methods

3.2.1.1 Survey Method

Surveys are used to collect data to estimate the size of informality and have more information about underlying reasons for informality. Using this method, information about employment conditions of agents is collected and agents are defined as working in the formal economy and working in the informal economy.

This method is widely being used to estimate the size of informal economy. Even in the US, surveys are being used to estimate informality in rural areas (Jensen et al, 1995). However, when it comes to getting reliable data, surveys may not be considered as a reliable source of information regarding informality. It is claimed that agents do not prefer to share information regarding their informal activities since they have the fear that they may have to pay taxes for their activities, or they could be subject to regulations based on the findings obtained by the surveys. Schneider claims that it is difficult to make an accurate estimate for informal economy based on surveys (Schneider, 2002).

3.2.1.2 Tax Method

Using Tax Method, it is aimed to estimate informal economy by comparing both declared taxes and the amount of tax needs to be paid. In other words, the difference between taxes that should be collected by all the taxable activities in GNP and the amount of tax collected is regarded as the missing part of the taxes which are the result of informal activities.

There are several problems with using this approach. Even though there are activities that are not subject to taxation in GNP, this method takes the assumption that all the activities in GNP are subject to taxation. In addition, there are tax exemptions for lots of economic activities which should not be included in the estimation. Only tax evasions which are done intentionally should be included in the estimation. By using this method, only tax declaring agents in the economy are taken into consideration for informality calculations. However, there are agents in the economy which do not even declare taxes. Schneider also points out to the fact that estimation built on tax investigations only presents a small portion of the informal economy since it

investigates tax evasion related informality, and it is dependent on how successful the authorities are in finding out tax evasion (Schneider, 2002).

As a result, using the Tax method is not seen as a good method to estimate Informal Economy. It does not provide a holistic view on the missing part of the economy. It only aims to calculate the informality resulting from tax evasion.

3.2.2 Indirect Methods

3.2.2.1 GNP Differences Method

There are different approaches to measure GNP for a country. These are Expenditure Method, Income Method, and Product Method.

In a country where there is no informal economy, GNP calculations would be equal using these three methods. If there is informal economy in the country, it is expected to have different results with different methods.

This method is based on the idea that individuals cannot hide their expenditures while they can hide their income. The difference between income and expenditure is regarded as a contribution to informal economy. However, this method is not accepted as a good method to estimate informality since the calculation for expenditure and income is not the same and there are other reasons leading to a difference between them as well.

3.2.2.2 Comparison of Labor Force and Employment

Using this method, it is aimed to estimate informal economy by comparing historical changes in employment and labor force in a country. In a country where there is no informal economy, employment percent in population and labor force percent in population are expected to be changed equally over time. In the case of informality, the latter increases more than the former since part of the employment is informal. This method has several problems as well. It is mainly focused on informal employment, and it does not reflect the overall informal economy. In addition, correct measurement of labor force is problematic as well. It could be the case that unemployed part of the labor

force could be unemployed indeed instead of working informally (Akbulak and Tahtakilic, 2003).

3.2.2.3 The Transactions Approach

This approach is based on the relationship between GNP and the volume of transactions occurring in the economy. Fisher Equation is used to define this method. M*V = P*T (with M meaning money, V meaning velocity, P meaning prices, and T meaning total transactions).

For a specific time, the value obtained by M*V and official GNP statistics should be equal where the economy is fully formal. The difference between these two calculations reflects the informal part of the economy. The velocity of money is assumed to be a fixed number and equal for informal and formal economy (Us, 2004). In addition, a base year should be assumed in which there is no informal economy.

Schneider and Buehn point out the difficulty for having precise volume of transactions especially difficulty resulting from cash transactions (Schneider and Buehn, 2013).

Schneider and Buehn found this method attractive, but they claimed that this method could lead to doubtful results since it is difficult to satisfy all the empirical requirements. (Schneider and Buehn, 2013)

3.2.2.4 Tanzi Method

As in the case of other monetary methods, Tanzi Method has the assumption that the velocity of money is the same for formal and informal economy and the transactions in the informal economy are held in cash (Eroglu, 2014).

This method is used to estimate the amount of money used in informal activities by measuring the sensitivity of money demand for income taxes (Cetintas and Vergil, 2011).

The method is criticized for taking the assumption that all the informal activities are held in cash which is not the real case.

Schneider and Enste challenged this approach by pointing out the fact that Tanzi selects a base year where there is no informal economy without any reasonable explanation. In addition, they argue that this approach fails to account for funds spent abroad (Schneider and Enste, 2002).

3.2.2.5 Electricity Consumption Method

Electricity consumption approach assumes that all the economic activities have a strong relationship with electricity consumption. The main logic is to calculate the necessary electricity consumption needed for the official GNP results. The difference between actual electricity consumption and calculated electricity consumption is interpreted as the result of informal economy.

This method is criticized by Schneider and Buehn as not all the informal economic activities require electricity consumption. Other energy sources such as gasoline, coal and solar could be used as well. In addition, they note that energy production and consumption are more efficient compared to previous periods, which makes historical comparison even harder (Schneider and Buehn, 2013).

Cetintas and Vergil also criticize this method claiming that most of the informal activities are not energy intensive activities. According to them, the increase in energy consumption could be the result of structural changes in the economy because of a transition to more energy intensive economic activities or energy intensity changes from country to country. In addition, they emphasize an upside for this method which is the ease to get reliable data. Especially for developing countries, the problem of reliable data collection is solved using this method (Cetintas and Vergil, 2011).

3.2.2.6 MIMIC (Multiple Indicators and Multiple Causes) Method

All the methods described so far try to estimate the size of informal economy using only one indicator. However, informal economy has a wide range of sources in production, labor market and money market which necessitates to use more than one indicator, in other words several indicators all together which have direct impacts on informal economy. Thus, the MIMIC method is being used for this purpose. This

method is focused on causes and effects of informal economy at the same time (Cetintas and Vergil, 2011).

The MIMIC model operates on the principle of establishing connections between unobserved variables and multiple observed variables. In the context of estimating the scale of the informal economy, the unobserved variable is the "Informal Economy," and it is estimated by the utilization of a covariance matrix of observed variables (Schneider and Buehn, 2010).

MIMIC Method is divided into two distinct parts: Measurement Model and Structural Model. In measurement model, unobserved variables (Informal Economy) are linked to observed variables. Thus, Measurement Model is used to determine reliability and significance of observed variables. In Structural Model, the relationship between unobserved variables and observed variables is determined. Considering these aspects of the method, Schneider et al describes the method as a confirmatory method rather than explanatory method since the model evaluates the consistency of a structural theory using data (Schneider and Buehn, 2010).

As a method to Estimate the size of the Informal Economy, MIMIC method is in some way different than other approaches. Using this approach, the indicators and causes of informal economy are reflected in the estimation with their different weights at the same time. This is an advantage for the model since other methods reflect only one indicator of informal economy. The flexibility to take different indicators according to different scenarios makes this method quite useful. Tedds and Giles also consider MIMIC approach better than other approaches as it makes it possible to take more than one indicator in the estimation process (Giles and Tedds, 2002).

The weakness of the method is the difficulty to get reliable data since there are several observed variables to be included in the model and it is difficult or not possible to get these data especially if the country is not a developed country. In addition, there are doubts about the significance of this statistical method. Schneider indicates that MIMIC method is more of an exploratory method rather than an explanatory method (Schneider, 2009).

3.2.2.7 DGE (Dynamic General Equilibrium)

Dynamic general equilibrium (DGE) is a database created by Elgin, Kose, Ohnsorge and Yu by applying a two-sector dynamic general equilibrium (Elgin et al, 2021). DGE estimate is available between 1950 to 2009 for 161 countries. Dataset consists of different informal economy estimates including model-based estimates and survey-based estimates. Considering that the DGE method does not rely on proxy variables for estimation and is backed by more robust economic rationale, it is the most accepted method to measure the share of informality in most of the related literature. In addition, The World Bank represents this dataset as an official data set available for informal economy estimates. This dataset is also available on the world bank website. Because of these reasons, this data set is going to be used as informal economy dataset in this thesis.

3.3 Causes of Informality

Before trying to estimate informality or addressing policies to decrease informality, it is necessary to determine the causes of informality. There are numerous reasons for informality which can be grouped as fiscal, economic, sociological, political, or legal reasons. Reliable data collection for economic and fiscal sources is not easy as explained in the informality estimation section of the study. However, it could be harder to obtain reliable data for sociological or political sources as the data is strongly dependent on people, so it could be unobjective. It is just necessary to mention this side of informality as well to explain how multidisciplinary the scope of informality is.

As explained, informality has a wide scope of sources from different disciplines. These sources vary from country to country. Economic policies, legal requirements, political stability, or unemployment level are not the same for all the countries. Thus, it is necessary to evaluate countries by considering these differences.

According to Us, rapid population growth in urban area as the result of migration to urban areas is a source of informality as it paves the way for unemployment (Us, 2004). She claims that the high unemployment in the cities lead to

informal employment as the entry and exit to a job is easier compared to official employment (Us, 2004). Thus, according to her points, we can say that high unemployment is one of the causes of informal employment since migration to cities leads to informal employment as the workers are ready to work informally to meet their basic needs in this competitive market. She also makes a remark that in countries where economic conditions are not enough to make a living, people have the incentive to work in a second job, which is mostly an informal job.

In most of the studies, the desire not to pay any tax and social security premiums are seen as the most important reason for informality. According to Schneider and Buehn, as the ratios of income taxes and social security contributions increases, the desire to not pay these taxes increases which lead to an increase in informal employment (Schneider and Buehn, 2013). There are number of studies statistically claiming that informal economy is linked to the levels of taxation (Us, 2004; Elgin and Erturk, 2019).

In addition to taxes and social security contributions, there are other costs which could make enterprises operate in the informal sector. Environmental laws & practices could lead to informality. As an example, the Emission Trading System (ETS) is used for the purpose of controlling greenhouse gas emissions in the EU. Each producing company has a predetermined emission right which cannot be exceeded. If the company wants to produce more and consequently emit more greenhouse gases, it must buy emission rights from other companies which produce less than their permitted level. Thus, overproduction is costly for companies. An enterprise would prefer to operate in the informal sector in order not to pay these extra costs.

Insufficient legal and monetary fines are another reason for informality. Enterprises and individuals may opt for informal employment if the fines are not heavy. They prefer to take the risk instead of paying taxes. Legal framework is not the same in all the countries. Some countries have heavier fines for tax evasion. As informality results in tax evasion, individuals and enterprises do not easily opt for informal employment in these countries.

In his study, Ilgin claims that the complex taxation structure leads to informal economy as well (Ilgin, 2002). As taxation and legal framework are wide concepts,

households do not have knowledge of requirements to satisfy. Having legal and tax advisement from the experts is costly and time consuming. Thus, they prefer not to deal with all these processes, and they operate in the informal sector.

High inflation rate is claimed to be another reason for informality. Us claims that high and continuous inflation results in inequality in taxation (Us, 2004). According to her, this is due to taxation from higher tax brackets as the price levels are increased in the economy (Us, 2004). Thus, inequality in taxation resulting from inflation leads to informality.

Lower income per capita level is another source of informal economy. Individuals with lower income would be more likely to work in any informal job compared to individuals with high income. This is because the priority for low-income individuals is to meet their basic living expenses by working formally or informally. In countries where income per capita is low, individuals tend to work at a second job, which is most often an informal job (Us, 2004). As the income level increases, people are more selective on employment conditions since they already have a high-income level. In addition, in lower income countries, the share of informal economy is generally higher (Ay, 2006).

Working for your own business could ease informality. As all the decisions taken by the owner have a direct impact on himself, instead of a shareholder, they may have the incentive to operate informally for cost reasons. In countries where own businesses or SME are intense, it is expected to have a bigger informal share of the economy (Guloglu et all, 2003).

As a summary, informal economy is mostly the result of the high tax levels and complex tax procedures. Competition in the job market and in the goods market results in an informal economy. A job seeking individual may be willing to renounce official employment to make her living in this highly competitive market. On the other hand, enterprises may be willing to hire employees informally and produce and sell some portions of their goods informally to decrease their costs and survive in this competitive market. This is especially common for SME's since they aim to make a profitable business in an environment where there are huge producers with cost advantages.

3.4 Effects of Informality

Some of the researchers claim that informal economy has a positive impact on the formal economy. Adam and Ginsburgh claim that in an environment where there are low market entry costs, informal economy is a booster for official GDP (Adam and Ginsburgh, 1985).

On the other hand, some of the researchers argue that informal economy has a negative impact on the formal economy. They point out one of the most important aspects of informal economy which is tax evasion. Informal activities in the economy mean less tax income for the government. It is expected to have less public spending by the government if the level of informality is high. Government cannot obtain necessary funding for its expenditures for social benefit. This also creates an unfair environment for the enterprises/individuals in the formal market since they pay their share of taxes, but they get less than their tax payments as other enterprises/individuals do not pay their share of tax. To increase the amount of taxes collected, governments can opt for an increase in tax ratios. However, this could result in even more informal enterprises as it creates incentive for formal enterprises/individuals to not pay taxes, in other words, to operate informally. Bulmer is one of the many researchers who thinks informal economy has mostly negative impacts on the economy (Bulmer, 2018).

The existence of informal employment incentivizes illegal immigration from one country to another. As individuals think that they can live in a foreign country by making their living in an informal job, they try to immigrate to these countries illegally. In a humanitarian point of view, some of them cannot survive in their way of migration. There are lots of incidents that the immigrants died in a boat while crossing a sea or in the border. From an economic point of view, too much immigration could harm the job market for both the sending country and the receiving country. This is because the sending country loses its labor force; on the other hand, existence of too much informal labor force in the receiving country could create incentive for enterprises to hire informal job seekers as they are less costly, and this could harm official employment as well.

In addition, informality could damage competition in the market. Taxpayers in the economy become relatively disadvantaged compared to informal competitors in the market as informal competitors do not pay any sort of taxes, they can reflect these advantages on their prices as an advantage. Informal competitor can dominate the market with its low-priced products. This makes it even harder for formal enterprises to survive in the market.

Informal enterprises do not pay social security contributions as well. Social security contributions are used within the social security system for the well-being of society, especially the poor ones. Health expenditures of individuals are covered with social security contributions. Retirement pensions are covered by this system as well. Thus, in the case of a high rate of informal economy, necessary funding for the health of the society cannot be fully provided by the social security system since the amount collected is limited. Retired people can get less salary than they should get. Thus, informal economy creates an unfair environment in terms of social security system.

4. ENVIRONMENTAL DEGRADATION CONCEPT

4.1 Concept and Definition

The environment is everything we have as living mechanisms to survive. The environment includes all biotic and abiotic elements that surround us such as water, soil, air, plants, animals and other living and non-living elements (Bourque et al, 2005). Environmental degradation is the damage incurred on all these elements.

Environmental degradation mostly results from negative effects of human activities on the environment. Air pollution as the result of industrial activities, transportation, heating, deforestation, water pollution resulting from industrial activities are several sorts of human activities leading to environmental degradation.

In addition, natural degradations on environment could occur. Natural events such as floods, droughts, volcano eruptions and earthquakes are types of environmental degradations caused by natural factors.

Environmental degradation is a huge problem for all the living as it has direct impacts on health & well-being of livings.

4.2 How to Measure Environmental Degradation

Human life is dependent on the environment they live in. However, humans deplete the environment the most. Increasing population creates a threat for the environmental resources as environmental degradation has increased with population growth in the past. Sustainability of environmental resources is crucial for human well-being, which requires correct policies to mitigate environmental degradation. To set clear policies and tools to improve environmental quality, it is important to measure environmental degradation in the most comprehensive and correct way.

Environment is a huge concept with a complexity of ingredients in it. Thus, it is hard to identify the boundaries of environment. This complexity makes it harder to measure environmental damage.

Impact on environment could be expressed in terms of value or measurement. It is possible to measure how much CO_2 is emitted in a single pipeline at a factory in a specific period. This is an example for the expression in terms of measurement. Determining a specific financial value to an impact is an example for the expression of environmental impacts in terms of value. Measurement method and valuation method are two different approaches, but they are interrelated as well. Valuation method in its nature uses measurement method and vice versa.

As explained, the concept of environment is too complex and there is not a generally accepted method to measure environmental impact. However, there are several types of environmental impact measurement methods proposed by academics which are widely used.

4.2.1 Ecological Footprint

An ecological footprint is a measurement tool which is used to represent the amount of productive land and sea area needed to regenerate the resources consumed. In other words, it is the area of land, soil and other productive elements needed to produce the same amount consumed. Thus, ecological footprint shows the productivity of the earth as well. (Goel et al, 2011) The concept of ecological footprint is proposed by Mathis Wackernagel and William Rees at the University of British Columbia in 1990 (Wackernagel, 1994).

Ecological Footprint is described in hectares globally, which makes it comparable all over the world. Carbon footprint is a specific type of ecological footprint measurement which is widely being used as well.

Ecological footprint calculation is one of the most suitable approaches to measure environmental impact since it considers all the activities of human effecting environment. In addition, ecological footprint is a single number which can be compared personally, locally, regionally, nationally, or globally. The calculation of ecological footprint is the same in all these different scenarios.

4.2.2 Carbon Footprint

Carbon Footprint is the amount of greenhouse gas emissions (in tons) emitted resulting from a production, a person, an event etc. Carbon footprint is a vital component of ecological footprint, and it is widely used as a measurement for environmental impact. If the carbon footprint is being expressed in ecological footprint calculations, the amount of carbon dioxide emissions is reflected as the amount of productive area needed to neutralize the emissions. (Footprint Network)

According to an initiative focused on footprint measurements, which is called Footprint Network, the majority of ecological footprint is derived from greenhouse gas emissions. That means carbon footprint makes the greatest portion in ecological footprint.

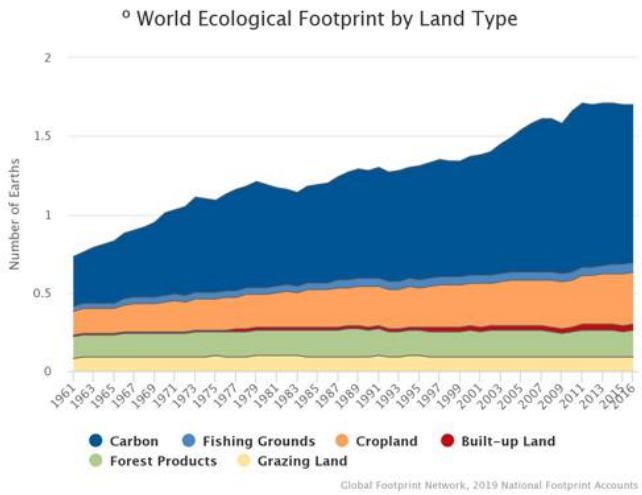

Figure 4.1. World Economic Footprint by Land Type

(Source: Footprint Data Foundation, 2023)

As illustrated in the graph, the majority of ecological footprint is derived from greenhouse gas emissions, and it has been increasing since 1960s while other components are much more stable.

4.2.3 Water Footprint

Water Footprint represents the amount of clean water used by an individual, group, firm, or country. It is a way to express how much water we need for our daily needs or how much a company needs clean water to produce a product. It can also be used to express how much water is being used from a river or reservoir by a country. This aspect of WF is important especially in terms of water related conflicts between countries.

WF helps policymakers to assess the consumption of water. Based on WF, water dependency of companies can be determined, and policies can be implemented to reduce water dependency. This is important for companies since they are subject to specific regulations for their products. As an example, labels on dishwashers show how much water is being used for a wash. This has an impact on the buying decisions of consumers. In some countries, there are specific amounts of water that a dishwasher cannot exceed. Thus, WF calculation is important for individuals and companies.

Water Footprint is different than Carbon Footprint as WF shows how much an individual demand from the environment while CF shows how much is supplied to environment.

4.2.4 Life Cycle Assessment

Life Cycle Assessment is the is a method to evaluate the environmental impact of a product / service in its entire lifecycle. LCA is not enough to fully address environmental impact. It can be more useful for a company to evaluate their environmental impact for a product to implement policies to produce more sustainable products. However, environment is a huge concept and the impact on environment cannot be limited to a product-based approach.

There are several difficulties with running LCA as well. LCA requires obtaining necessary data for a product throughout its entire life cycle. Obtaining reliable data is not easy, especially for long lasting products such as home appliances or automobiles. In addition, even if there are formats to make an LCA, most of the LCA’s are unique for a company or for a product. This makes the comparability of different LCA’s harder.

4.3 The Relationship between Growth and Environmental Degradation

Economic growth is commonly perceived as the most key factor causing environmental degradation. The main idea behind this logic is the more produced goods, the more pollution is emitted into the atmosphere. There are different studies accepting that economic growth leads to environmental degradation. On the other hand, there are studies which claim the opposite as well which say economic growth does not lead to more environmental degradation, it improves the quality of environment. Steve Cohen points out to the success of the US on decoupling GDP growth with the growth of environmental pollution. According to Cohen, the success of the US is related to command-and-control policies and regulations, direct and indirect government subsidies, and technologies that governments and businesses use. He gives the example of Los Angeles case where there was too much air pollution back in 1960s and it is controlled by policies and modern technologies even if the economy continued to grow (Cohen, 2011).

4.3.1 The Environmental Kuznets Curve

Green growth aims to achieve economic growth and development without damaging the environment. One well known hypothesis which explains the relationship between environmental degradation and economic growth is Environmental Kuznets Curve Hypothesis.

The idea of EKC was first discussed in the early 1990s by Grossman and Krueger (Grossman and Krueger, 1991) and the name EKC is first introduced by Panayotou in 1993 (Panayotou, 1993).

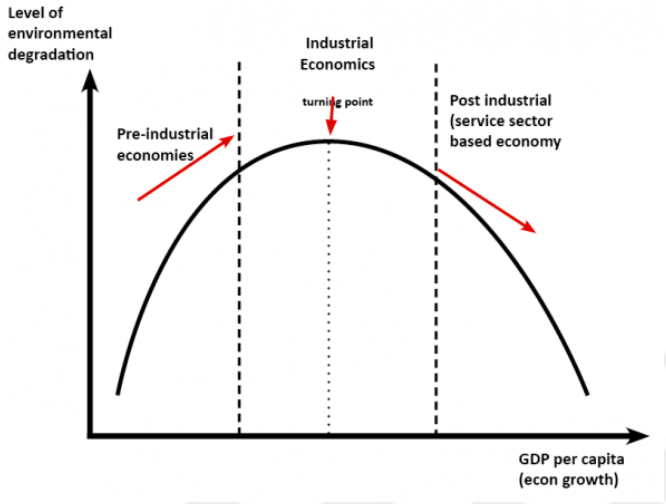

Figure 4.2. Environmental Kuznets Curve

(Source: Pettinger, 2013)

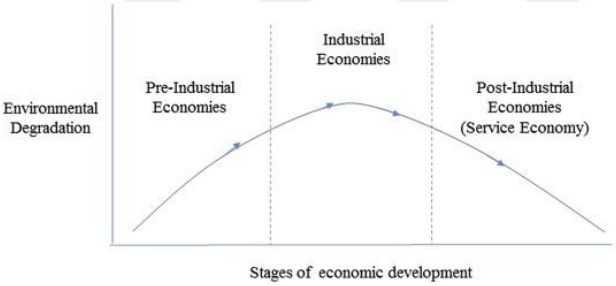

Figure 4.3. Stages of Economic Development vs Environmental Degradation

(Source: Katsoulakos et al, 2016)

EKC hypothesis claims that there is a U-shaped relationship between GDPs per capita and environmental degradation. Thus, up to a certain level, increase in GDP per capita leads to an increase in environmental degradation. After that point, an increase in GDP per capita reduces environmental degradation.

According to EKC, extremely poor countries do not cause much environmental degradation since their production is limited and their priority is to meet their basic needs, not the environment. As the country grows, economic activities expand as the result of industrialization & trade and consequently environmental degradation increases. The main reason trade and internationalization increases environmental

degradation is the increase in transportation of goods, services, and people since it causes more air pollution (Grossman and Krueger, 1991). As production increases, the need for energy increases which will lead to more energy consumption and thus air pollution as well.

Once a country has a certain GDP per capita, individuals start to compare the tradeoff between consuming more and environmental quality. Thus, environmental degradation continues to increase but at a diminishing rate. When GDP per capita is equal to the turning point on graph one, an increase in GDP per capita will result in improvement on the environment. Supporters of EKC hypothesis claims that this improvement is the result of increase in environmental awareness, effective environmental policies and regulations, technological improvements, structural change towards information intensive industries and higher environmental expenditures (Panayotou, 1993).

4.3.2 Brundtland Curve Hypothesis

Brundtland Curve is the representation of the ideas presented in Brundtland Report which was an important milestone for the topic of sustainability. There was not a curve in the Brundtland Report, but the ideas are represented in a curve by the academics, which is called Brundtland Curve.

The BCH is based on the idea that as GDP per capita increases, the level of environmental degradation decreases up to a certain point. After that, economic development does not result in environmental improvements. Thus, as the opposite of EKC hypothesis, BCH is a U-shaped curve. That means, the poor and rich pollute more. The optimal GDP per capita level is the middle-income level in terms of environmental degradation. According to BCH, poor countries emit more pollutants as they have the priority to meet their basic needs to survive. On the other hand, for developed countries, overconsumption is the reason for increased environmental degradation.

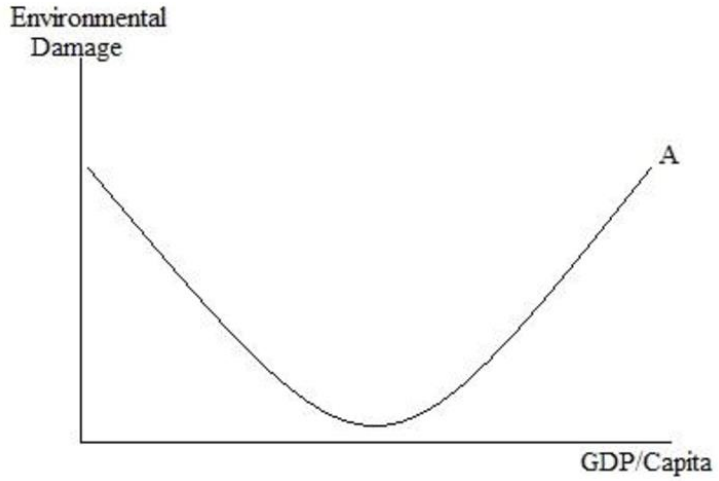

Figure 4.4. Brundtland Curve

(Source: Cederborg et al, 2016)

4.3.3 Pollution Haven Hypothesis

One well known trade theory, Comparative Advantage theory by David Ricardo gives the idea that a country should produce and export goods and services in which it has a comparative advantage which means the goods and services it can produce more efficiently than the other country. The theory claims that if all the countries produce what they have a comparative advantage, all the countries become better off with the help of free trade (Ricardo, 1817).

Pollution haven hypothesis on the other hand claims that firms seek to avoid the costs of environmental regulations by choosing to produce goods where these regulations are not strict. Thus, developed countries put environmental regulations into action to improve their environmental quality and on the other hand they move their pollutants into another country, which is a less developed country. Thus, pollution haven hypothesis claims that free trade and openness results in environmental degradation for poor countries while it helps to increase environmental quality for rich countries (Copeland and Taylor, 1994). According to the hypothesis, developed countries import dirty industry goods from developing countries and developing

countries import clean industry goods from developed countries. This makes developing countries a pollution haven for developed countries.

There are several works which criticize EKC hypothesis, claiming that EKC hypothesis graph is obtained not by solely technological improvements or the increased consciousness by people. It is obtained by the relocation of dirty industries from developed countries to developing or poor countries which is the main idea expressed with Pollution Haven Hypothesis. These studies claim that the EKC is the result of Pollution Haven Hypothesis. Selden and Song claim that the EKC is the result of the relocating of dirty manufacturing industries from rich countries to developing and poor countries where environmental regulations are loose. They also state that these loose regulations in developing countries make them have a comparative advantage in dirty industries (Selden and Song, 1994).

4.4 History of Environmental Agreements

Environmental degradation is one of the greatest challenges of our time. Even if environmental degradation is in its nature originates from a national level, problems expanded and created regional, international, and global problems which became a threat for all the livings on the planets including human beings.

All the living organizations and non-living organizations are interconnected globally and cannot be separated from each other. Thus, the problem of environmental degradation cannot be solved by individual initiatives of countries. As an example, India is only responsible for 7% of total greenhouse gas emissions in the world (Boden et al, 2017). Thus, individual action done by India to reduce environmental degradation is limited. For the case of air pollution, this is even more obvious since there are no borders for atmosphere. India's individual actions can be easily ineffective by greenhouse gas emissions done by other countries. In addition, environmental degradation is a problem caused by all the countries and threatens living and non-living organizations in all the countries. Thus, necessary actions need to be discussed at a global level and all the countries must be responsible accordingly.

To limit environmental degradation, there have been discussions going on for years. As the awareness regarding environmental issues increased, countries started to gather to discuss and limit environmental degradation by making collective agreements.

On the 5th of June 1972, The United Nations Conference on the Human Environment is held in Stockholm. This conference is better known as Stockholm Conference. Stockholm Conference was the first major conference where countries discussed global environmental issues and projects to overcome environmental problems. As a result of the conference, several principles are determined to protect the environment and raise awareness among people. However, after the conference countries did not attach too much importance to these principles and they continued to determine their growth and development plans without considering environmental problems.

It is also important that the idea of "Sustainable Development" is presented and discussed during this conference. Before the Stockholm Conference, a group consisting of academics, NGO members and government officials gathered in Foamex, Switzerland to discuss environmental issues with respect to economic development. Founex Report put the idea that environmental protectionism and economic development and growth could be established at the same time. This report established a basis for the term Sustainable Development as well. (Founex Report, 1971) From 1974 on, the 5th of June, which is the day Stockholm Conference was held, is being celebrated as World Environment Day every year.

The United Nations Conference on Environment and Development (UNCED), which is also known as Rio de Janeiro Earth Summit is an important UN conference held in Rio de Janeiro from 3 to 14 June in 1992 (United Nations, 1992). The conference brought together academics, political leaders, government officials, NGOs, media members from 179 countries to focus on the impact of human socio-economic activities on the environment (United Nations, 1992).

One of the major results of the Earth Summit was the Agenda 21, which was a roadmap for international cooperative action to achieve green growth and development for the 21st century. Agenda 21 starts with the sentence "Humanity stands at a defining

moment in history." to define the importance of the issue and emphasize the necessity of the required actions on Agenda 21 (United Nations, 1992).

Kyoto protocol aimed to reduce greenhouse gas emissions in accordance with individual targets of countries. The protocol was signed in 1997 but came into effect in 2005 since the necessary condition for the protocol to be valid is to cover at least 55% global greenhouse gas emissions of 1990 by the accepting parties of the protocol. This was possible when Russia accepted the protocol in 2005. The USA, as one of the most air pollutant countries signed the protocol, but it was not accepted at the senate.

The protocol put a heavy burden on developed countries since they were mostly responsible for the global greenhouse gas emissions because of their heavy industrial activities. Countries in the protocol were separated into two groups as Annex I and Non-Annex I. Developed countries are categorized under Annex I and emission limits and targets are only given to them. There were no emission limits for Non-Annex I group which consisted of developing countries.

Kyoto Protocol is important in emission targets since it presented the concept of ETS. Article 17 of Kyoto Protocol allows countries that have emission units which are permitted but not used to sell to countries which used all their permitted emission units (United Nations, 1997). As a result of Kyoto targets, Emission trading has been created as a new commodity and emission rights are traded in the market as any other product and this market is called carbon market since most greenhouse gases emitted are carbon.

According to the World Bank, Kyoto Protocol had only a slight effect on limiting global emissions growth (World Bank, 2010). Their claim is based on the statistics showing energy related greenhouse gas emissions increased by 24% compared to 1997 levels where Kyoto Protocol was negotiated (World Bank, 2010). In addition to this, the World Bank stated that the treaty had provided limited financial support to developing countries to help them reduce their emissions (World Bank, 2010).

Even if most of the developed countries signed Kyoto Protocol, huge emitters such as China, India, Indonesia, and Brazil did not have any emission reduction target. The USA initially signed the protocol, but it was not accepted at the senate, and it became obsolete. Canada and Russia left the protocol afterwards. Thus, the

effectiveness of the protocol stayed limited. The protocol is extended until 2020 in Doha, Katar.

The Paris Agreement is one of the most recent and comprehensive legally binding international treaties on climate change. It was adopted by 196 Parties in Paris, on December 2015 and entered into force on November 2016 (UNFCCC, 2015). The Paris Agreement is a milestone for global climate change since it is the first international agreement which covers almost all the emissions permitted globally. Before Paris Agreement, Kyoto Protocol came into existence with countries emitting only 55% of total global greenhouse gas emissions as The USA was not in the protocol and other huge emitters such as China, India and Brazil did not have emission reduction targets. Several countries such as Canada and Russia left the protocol afterwards as well. After all of these, Kyoto Protocol covered just countries which make approximately 14% of global greenhouse gas emissions (Karakaya, 2016). On the other hand, almost 98% of the global population and almost 99% of global greenhouse gas emissions are covered under the Paris Agreement. In this manner, the Paris Agreement is the first legally binding agreement about the environment which is accepted by most of the countries.

The main goal of the Paris Agreement is to limit global warming to below 2 degrees, ideally 1,5 degrees Celsius compared to pre-industrialized period. For this, responsibilities are given to all countries. Since developed countries are the primary source of greenhouse gas emissions now, developed countries have strictly defined and heavier targets where developing countries have less targets based on their current emission and financial conditions. By 2050, it is desired that developed countries become carbon neutral, which means do not have any additional emissions.

As an outcome of the Paris Agreement, a 100 billion USD financial support by developed countries to developing countries is guaranteed by 2020 to be used for climate action. This amount will be increased in 2025. In addition to financial support, developed countries have the obligation to guide and consult developing countries to limit emissions.

4.5 Economical Interpretation of Environmental Degradation

A specific branch of economics, basically called “Environmental Economics” studies financial and economic impacts of environmental policies. Environmental Economics is especially important for the implementation of efficient environmental policies.

In terms of environmental economics, environmental degradation is considered as a market failure. Market failure arises when the distribution of goods and services does not function optimally in terms of efficiency. In theory, competitive markets provide necessary conditions for economic efficiency in production, consumption, and exchange (Phang, 2013). This situation is called “Pareto Optimality.” Pareto optimality can be described as the optimally allocated point where the market is not able to make someone better off without making someone else worse off (Mock, 2011). Thus, in a pareto optimal market, all costs and benefits are included in consumption or production decisions of households. If pareto optimality condition is not satisfied, overproduction or underproduction problem can occur (Helbling, 2012). This results in a market failure and the social well-being cannot be maximized.

A market failure type, externalities are important in terms of environmental degradation. Externality occurs when the production or consumption activities of households have an impact on any third parties. In other words, externalities occur whenever the utility or production function of one economic agent is affected by the unintended or incidental by-products of the activity of another economic agent (Coase, 1960; Buchanan and Stubblebine 1962). If the pareto optimality does not prevail due to externalities, production and consumption related costs and benefits of households are not completely reflected on economic activities.

An externality can be a negative or positive. A positive externality is the benefit incurred to a group which is not the producer of that benefit. R&D activities of a company are a type of positive externality since the company benefits from these activities and society benefits from these activities since the general knowledge improves. A negative externality is an external cost incurred to a specific group which is not the producer of that externality (Kara and Kone, 2009). Environmental degradation

is a type of negative externality. A company can invest in projects without considering the environment. This increases the level of greenhouse gases they emit since they do not pay for clean energy technologies such as filters for pipelines or more efficient equipment. As a result, the negative externality resulting from environmental degradation is received by the society.

The way to overcome externality problem is internalizing the externalities which means making producers of the externality to pay for their externality (Armagan, 2003). If goods and services which produces positive externality, are produced less than the necessary amount or goods and services which produce negative externality, are produced more than the necessary level; social welfare is negatively affected, and externalities are internalized either by government or by the market itself.

Imposing a tax on negative externality is one of the solutions. The government could impose a tax on producing any kind of negative externality. This type of taxes is described as Pigouvian Tax which is suggested by the British economist Arthur Cecile Pigou in 1920s. This can be the taxation of environmental pollution, congestion, or the production of harmful goods such as alcohol or tobacco. Application of ETS in European Union is type of a Pigouvian tax.

In his book, called "The Economics of Welfare," Pigou suggested the idea of taxes on environmental pollution (Pigou, 1924). He claimed that industries were only interested in their private net product of their operations, not the social product (Pigou, 1924). Thus, an intervention by the government is considered necessary to produce at socially efficient level. According to Pigou, with a negative externality, market produces more than socially efficient level, which is Q1 in the graph. At Q1, social marginal benefit is equal to personal marginal costs, and it is lower than social marginal cost. By imposing a Pigouvian Tax, production decreases until the socially efficient level which is Q2 in the graph. As a result, the new market equilibrium point would be P2 which is a socially efficient equilibrium.

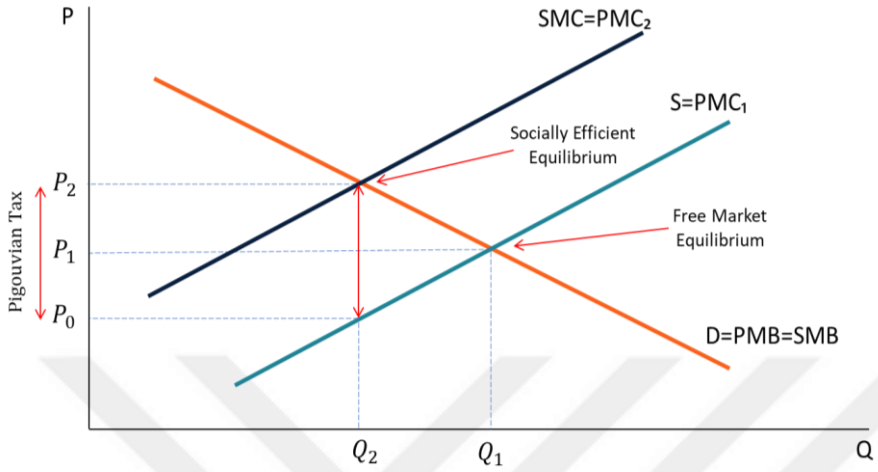

Figure 4.5. Graphical Representation of Pigouvian Tax

(Source: Corporate Finance Institute, 2023)

Main purpose of a Pigouvian tax is to limit environmental pollution in the first place. However, it has an additional benefit as well. By way of imposing taxes, governments have another income source which can be used to improve environmental quality by investing in modern technologies to reduce pollution.

5. DATA

Without mathematical notations, regressions are formed as following equation:

Environmental Degradation Indicator = Informal Economy + GDP per capita + energy intensity + Industrial performance index

In terms of environmental degradation, which is our dependent variable in this study, several variables are to be used such as Share of deaths by outdoor air pollution, CO_2 emissions per unit of energy, CO_2 emissions per capita and NO_2 emissions per capita. As explained, CO_2 emissions per capita is the most widely used environmental degradation indicator in related literature and it will be used in this study as well. Other environmental degradation variables will be examined in this study additionally.

CO_2 emissions per unit of energy, CO_2 emissions per capita and NO_2 emissions per capita comes from Ourworldindata CO_2 and Greenhouse Gas Emissions database which is prepared by Hannah Ritchie, Max Roser and Pablo Rosado. Detailed breakdown of GHG emissions related data is available in this study (Ritchie, Roser and Rosado, 2020).

CO_2 emissions per unit of energy represent Annual total production-based CO_2 emissions measured in kgs per kw/hour of primary energy consumption. CO_2 emissions per capita represent the annual total production-based CO_2 emissions measured in tons per capita. NO_2 per capita represents total NO_2 emissions including land use change and forestry which is measured in tons of NO_2 equivalents per capita.

The share of deaths by outdoor air pollution is derived from Ourworldindata Outdoor air pollution database which is prepared by Hannah Ritchie and Max Roser (Ritchie and Roser, 2019). The data represents the percentage of deaths occurred by outdoor air pollution each year.

For Informal Economy Share “Dynamic general equilibrium model based (DGE)” has been used which is derived from the cross-country Informal Economy database created by Elgin, Kose, Ohnsorge and Yu (Elgin et al, 2021). DGE estimate is available between the periods 1950 to 2009 for 161 countries. Dataset consists of different informal economy estimates including model-based estimates and survey-

based estimates. Since DGE method is less subject to measurement errors as this method does not use proxy variables for the estimation and has better economic reasoning, only this measurement from their study is taken. This is the most accepted method to measure the share of informality in most of the related literature as well. In addition, The World Bank represents this dataset as an official data set available for informal economy estimates. This dataset is also available on the world bank website. Because of these reasons, this data set is used in this study.

As control variables, Industrial Performance index and Energy intensity are used since these variables are some of the most crucial factors which have an impact on the level of environmental pollution. Additionally, Real GDP per capita measured in 2015 constant USD is used as control variable since it has an impact on environmental degradation, and it is one of the most used variables in the literature.

Countries are also classified based on their GDP levels as Low Income, Lower Middle Income, Upper Middle Income and High-Income countries. This classification will be useful for differentiating relations of the variables for different income levels.

Based on these data, the model is represented as follows by including the most suitable variables in overall dataset:

Overall dataset is an annual cross-country dataset covering between 1940 and 2020 for 204 countries. Since some of the variables are not available for specific countries for specific years, data imputation is applied with the median value of that variable for the same country. If there is no available data, median value of countries in the same income level has been used. In addition, several outliers have been eliminated to have a robust regression. These outliers have potential to have a negative impact on the accuracy and validity of a regression model unless they are eliminated.

Before running necessary regressions, several plausibility checks are applied for the dataset.

Box plots for all variables are derived to check for significant outliers in the dataset.

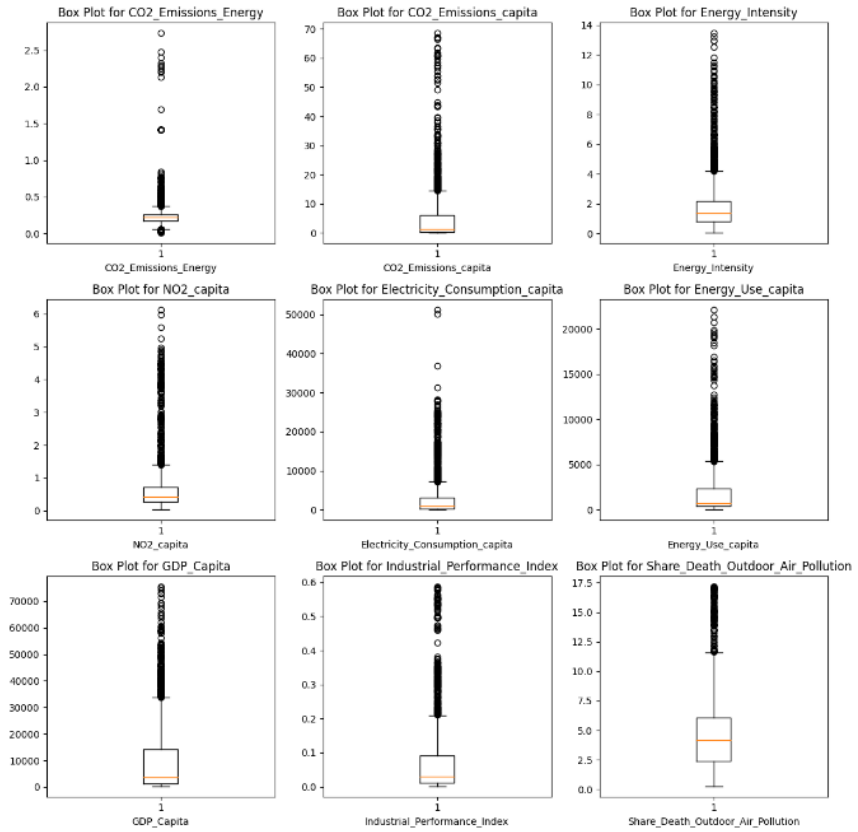

Figure 5.1. Boxplots of the variables

(Source: Own Tabulations)

Since variables do not seem to be distributed normally, log transformation method is used. After the transformation, variables seem distributed mostly normally.

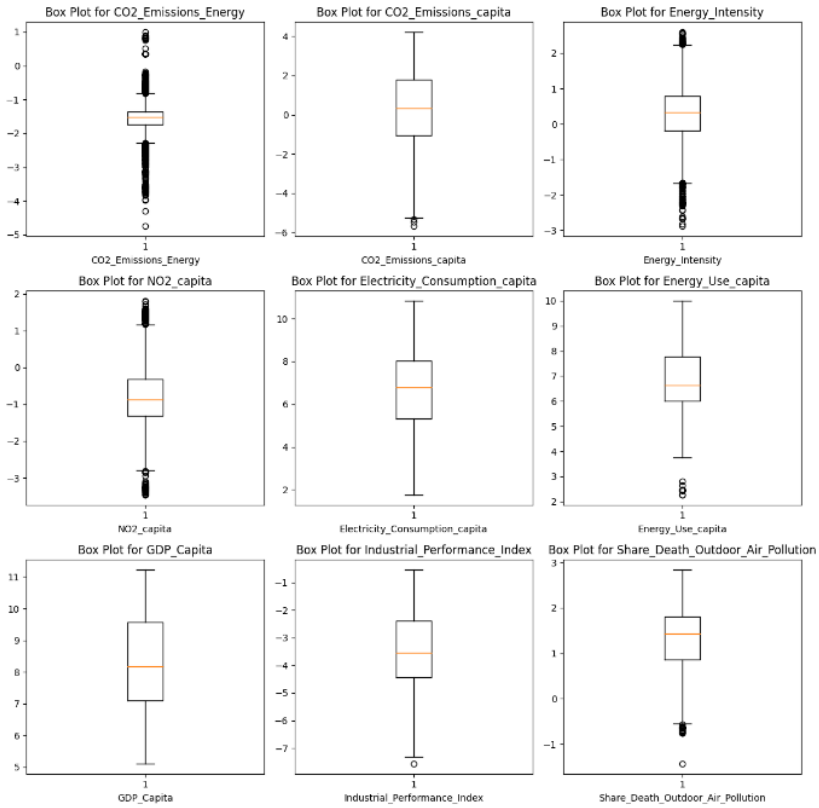

Figure 5.2. Boxplots of the variables with log transformation

(Source: Own Tabulations)

To identify patterns and relationships of the variables, Correlation Coefficient Heatmap is derived. For environmental degradation variables, the heatmap mostly represents a negative relationship with Informal Economy Share except CO_2 emissions per unit of energy which has significantly low positive relationship.

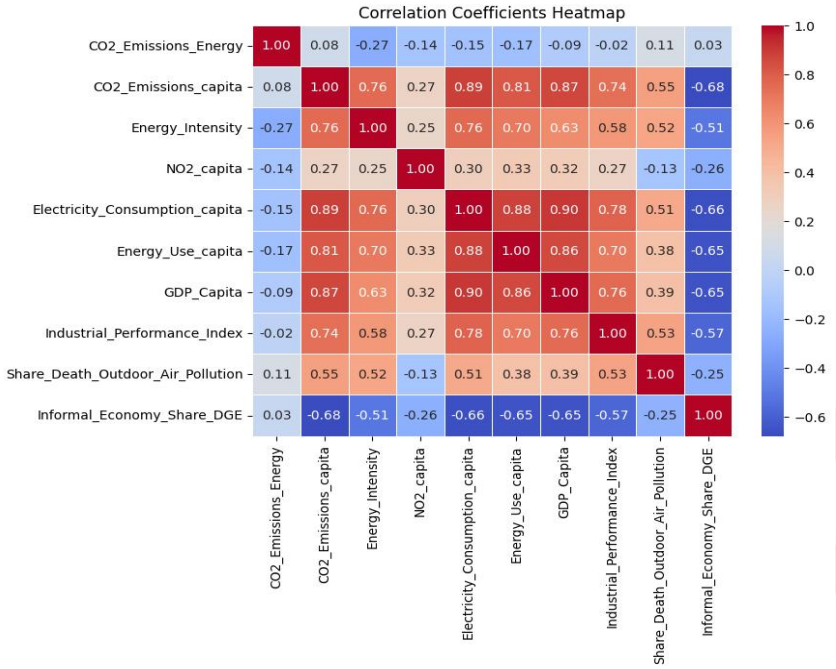

Figure 5.3. Correlation Coefficient Heatmap for the variables

(Source: Own Tabulations)

The variables are transformed into logarithmic scales to have a normally distributed dataset and interpret the results with coefficients of the regression and analyze the effect of changes in independent variables on dependent variable.

Variables represent mostly a linear relationship, which is reflected on the scatterplots.

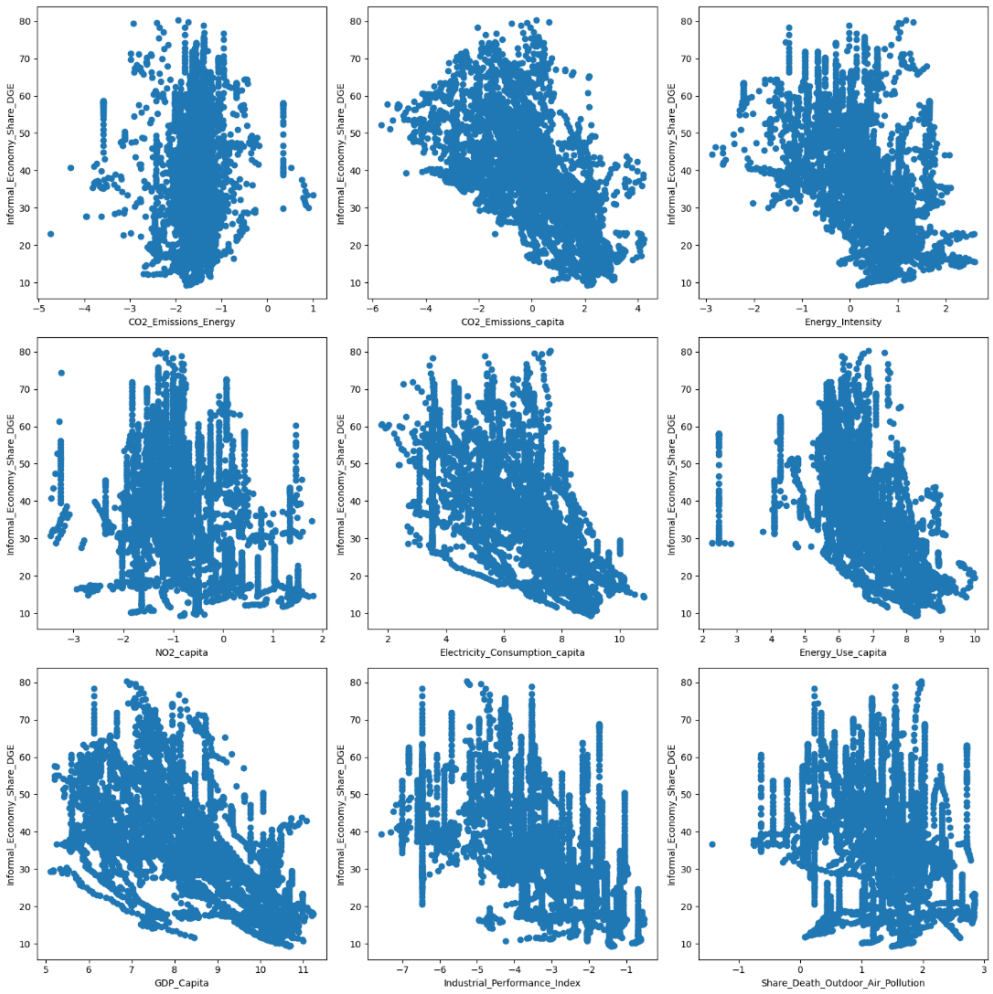

Figure 5.4. Scatterplot of the variables

(Source: Own Tabulations)

Quantile-Quantile (QQ) plot is also derived to statistically analyze and assess the similarity between the distribution of observed data and a specified theoretical distribution. In a QQ plot, a diagonal line represents perfect agreement between observed and expected quantiles. Deviations from the line indicate moving away from the theoretical distribution. QQ plots are useful for assessing normality of data, demonstrating outliers, comparing different distributional assumptions, and ensuring the completeness of statistical models. Based on the QQ plot analysis of the dataset, it can be observed that the data predominantly adheres to a normal distribution, with no notable presence of outliers.

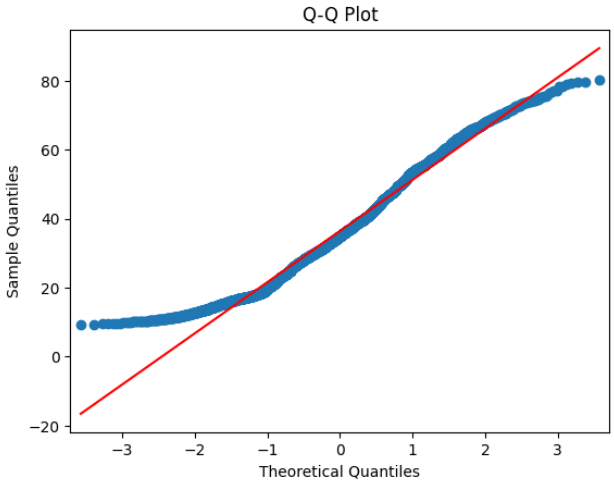

Figure 5.5. Q-Q plot Analysis

(Source: Own Tabulations)

QQ plots are also generated separately for distinct income categories to assess the normality of data distribution within various income classifications. A similar distribution pattern is available for different income groups.

Figure 5.6. Q-Q Plot Analysis for Upper Middle-Income Level

(Source: Own Tabulations)

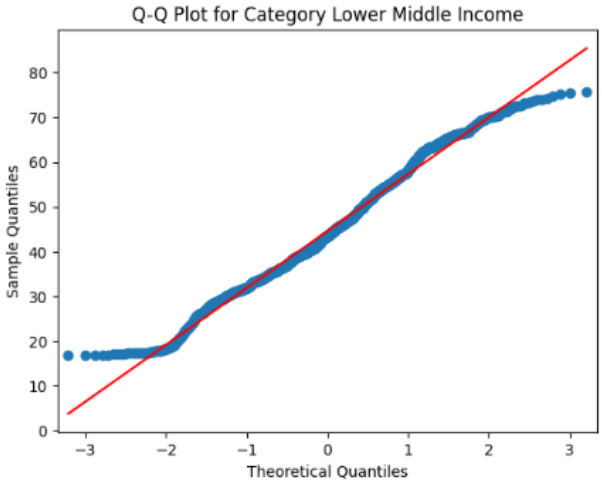

Figure 5.7. Q-Q Plot Analysis for Lower Middle-Income Level

(Source: Own Tabulations)

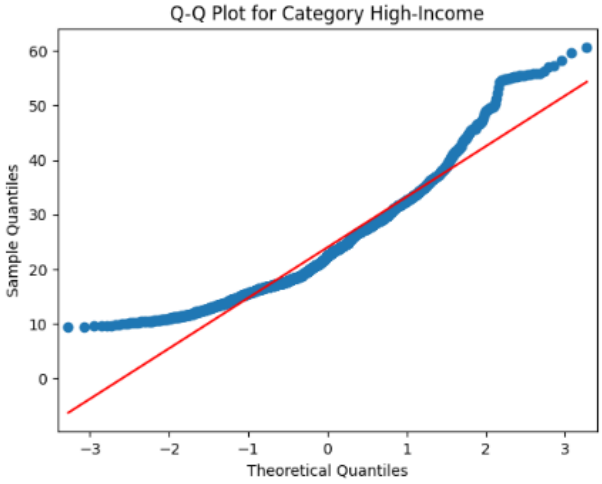

Figure 5.8. Q-Q Plot Analysis for High Income Level

(Source: Own Tabulations)

In addition, QQ Plot for residuals represents mostly a normal distribution as well.

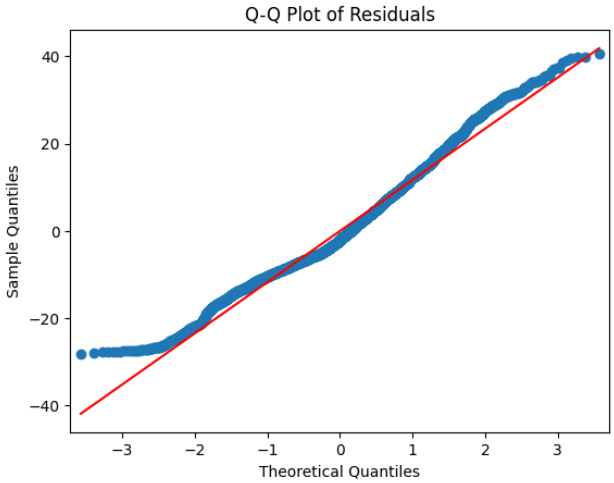

Figure 5.9. Q-Q Plot Analysis for Residuals

(Source: Own Tabulations)

To check means for different income levels, Tukey's Honestly Significant Difference (HSD) test is applied for the level of Informal Economy Share. Main purpose of this test is to identify which pairs of classifications have different means and which have remarkably similar means. So, it is observed that Low Income countries have similar Informal Economy Shares with Lower Middle-Income countries. Thus, the results of these two income levels can be combined and analysis can be made for these jointly. There is no additional similarity for other income levels.

Tukey's HSD Post-hoc Test:

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
High-Income	Low Income	21.4247	0.0	20.0888	22.7606	True
High-Income	Lower Middle Income	20.6198	0.0	19.5798	21.6598	True
High-Income	Upper Middle Income	15.7425	0.0	14.7111	16.774	True
Low Income	Lower Middle Income	-0.8049	0.4388	-2.1857	0.576	False
Low Income	Upper Middle Income	-5.6822	0.0	-7.0565	-4.3078	True
Lower Middle Income	Upper Middle Income	-4.8773	0.0	-5.9663	-3.7883	True

Table 5.1. Tukey's HSD Post-hoc Test Results

To check for the means of Informal Economy shares for different income levels, below bar plot is derived. It is observed that high income countries have relatively lower informal economy shares compared to other income levels. As explained in Tukey's Honestly Significant Difference (HSD) test, Low Income and Lower Middle-Income group have almost the same means. Upper Middle-Income countries have relatively lower Informal Economy shares than Low Income group, and a higher share than high income group. As a summary, it is observed that as the GDP per capita increases, the share of informal economy decreases. However, there can be several cases at country level in which this assumption does not hold.

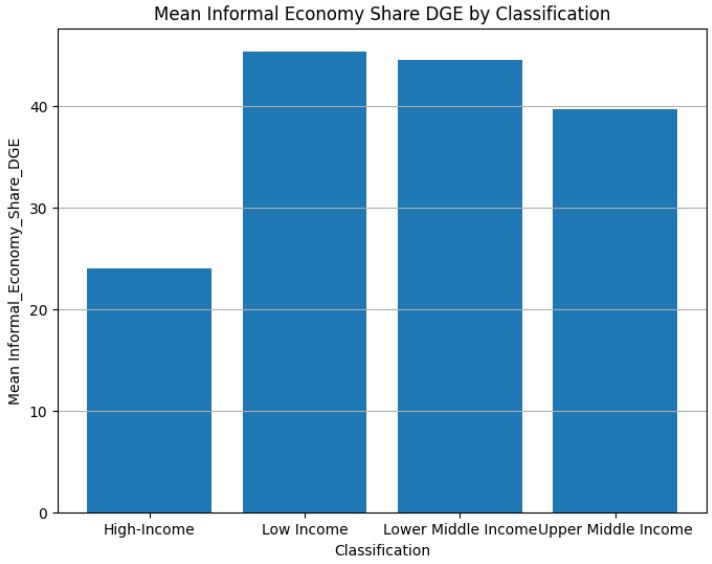

Figure 5.10. Mean Informal Economy Share by Income Classification

(Source: Own Tabulations)

To check the distribution of Informal Economy Share for different income levels and visualize it, Kernel Density Estimate plots are derived. According to this graph, it is observed that constant variance assumption (Also known as homoscedasticity) is not violated. In other words, the variance of the residuals remains relatively consistent across various levels of the Informal Economy Share.

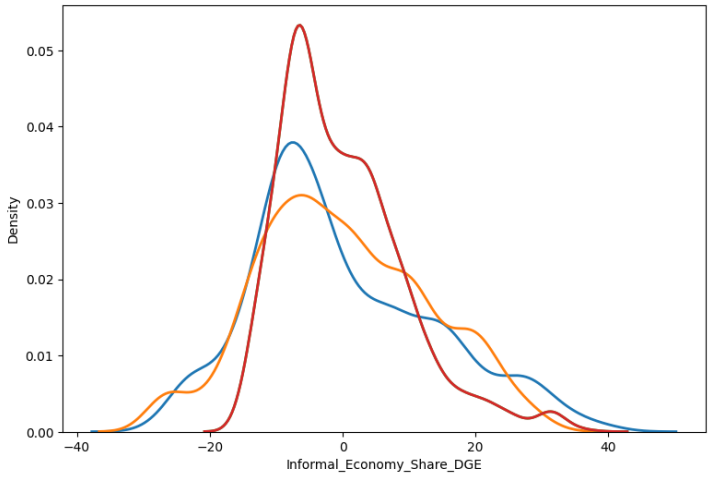

Figure 5.11. Kernel Density Estimate for Informal Economy Share

(Source: Own Tabulations)

Below boxplot is also useful to visualize the distribution and central tendency for different income levels.

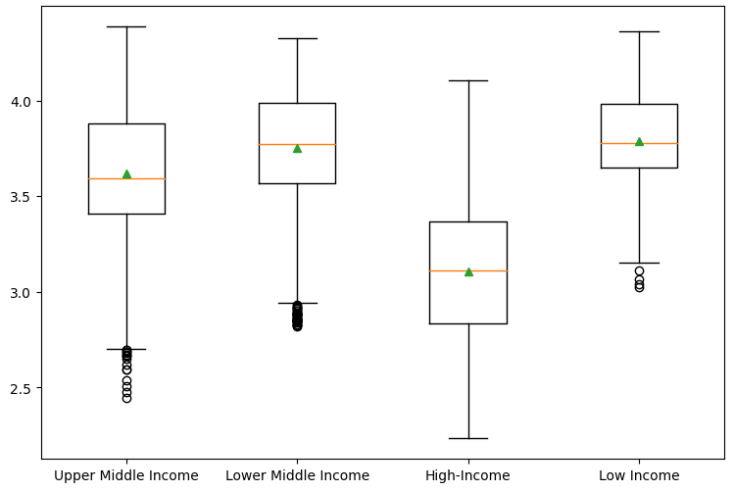

Figure 5.12. Distribution of Income Levels

(Source: Own Tabulations)

To check for multicollinearity, VIF values are derived.

VIF values for all potential independent variables in the dataset is as follows:

	Variable	VIF
0	Energy_Intensity	3.514028
1	NO2_capita	1.436994
2	Informal_Economy_Share_DGE	4.765348
3	GDP_Capita	7.312825
4	Industrial_Performance_Index	1.938183
5	CO2_Emissions_Energy	6.484768
6	Electricity_Consumption_capita	7.684948
7	Energy_Use_capita	8.633844

Table 5.2. VIF Value Table for all potential independent variables

Normally, it is expected to have VIF values less than 10 and even for some cases less than 5 to meet multicollinearity assumption. To meet this, the variables below will be used as independent variables in regressions as all independent variables below have VIF values lower than three if independent variables.

	Variable	VIF
0	Energy_Intensity	2.477147
1	Informal_Economy_Share_DGE	1.795181
2	GDP_Capita	2.601293
3	Industrial_Performance_Index	1.835945

Table 5.3. VIF Value Table for selected independent variables

So, it can be concluded that there is no multicollinearity between selected independent variables.

As explained, the analysis will be based on three different regression sections which accept environmental degradation variable as CO2 Per Capita, NO2 Per Capita and the one formed by PCA method. Thus, in the following parts of this section, plausibility checks for these regressions will be made and the characteristics of the data will be explained.

5.1 Data Description – Regression with respect to CO_2 Per Capita

The aim of this regression is to understand the effect of informal economy and other control variables on CO_2 emissions per capita level.

Mean Absolute Error (MAE) which measures the average absolute difference between the actual values and the predicted values is 0,192. Therefore, on average, the model's predictions deviate from the true values by approximately 0,192 units.

Mean Squared Error (MSE) which measures the mean of the squared difference between the actual and predicted values, with a greater emphasis on larger errors. MSE result of 0,063 in the regression suggests that, on average, the squared errors between predictions and the actual values amount to 0,063.

Feature Importance data frame for the variables with respect to CO_2 Per Capita is as follows

	Feature Importance	
3	Energy_Use_capita	0.574063
6	Classification_Low Income	0.398213
7	Classification_Lower Middle Income	0.210523
8	Classification_Upper Middle Income	0.148107
4	GDP_Capita	0.106399
1	Informal_Economy_Share_DGE	0.084581
0	Energy_Intensity	0.061062
2	Electricity_Consumption_capita	0.034485
5	Industrial_Performance_Index	0.007547

Table 5.4. Feature Importance Data Frame with respect to CO_2 Per Capita

(Source: Own Tabulations)

Positive importance suggests that the feature positively contributes to predicting the dependent variable, while negative importance suggests the opposite. Higher scores represent a more significant impact on the dependent variable.

Graphical representation of the Feature Importance is as follows:

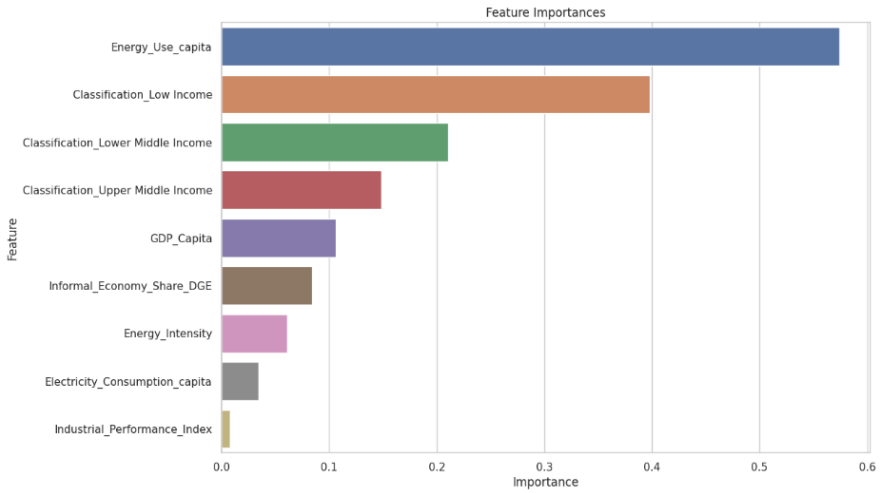

Figure 5.13. Graphical Representation of Feature Importance with respect to CO_2 Per Capita

(Source: Own Tabulations)

In this context, all the variables have a positive feature importance. Energy_Use_per_capita has the highest importance score (approximately 0.5741),

indicating that it is the most influential feature in predicting the target variable. However, to meet multicollinearity assumption and have a stronger model, this variable is excluded from the model as it is correlated with other independent variables.

Classification_Low Income: The feature "Classification_Low Income" has the second-highest importance score (approximately 0.3982), making it one of the top contributors to the model's predictions.

Classification_Lower Middle Income and Classification_Upper Middle Income: These two features also have positive importance scores, suggesting that they contribute to the model's predictive power, though to a lesser extent than the previous two features.

GDP_Capita, Informal_Economy_Share_DGE, Energy_Intensity, Electricity_Consumption_per_capita and Industrial_Performance_Index have importance scores ranging from 0.0075 to 0.1064.

Since scatterplot of True Values vs Predicted Values forms almost a diagonal line, the regression represents almost a perfect regression. In other words, it indicates that the model's predictions are in good agreement with the actual values.

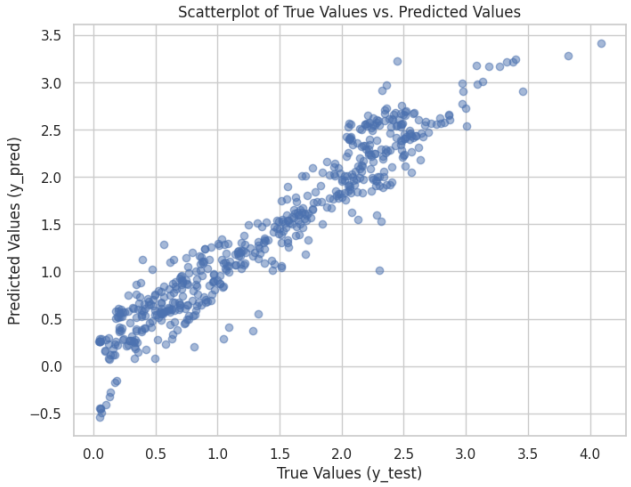

Figure 5.14. Scatterplot of True Values vs Predicted Values

(Source: Own Tabulations)

The scatter plot of the residuals is randomly distributed around horizontal line y=0, which represents that model's predictions are unbiased and there is no systematic error.

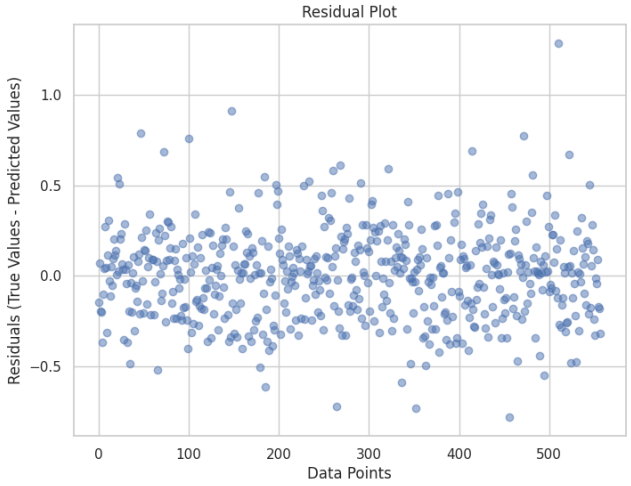

Figure 5.15. Scatterplot of Residuals

(Source: Own Tabulations)

The autocorrelation plot shows no significant autocorrelation, as most of the correlation values remain close to zero, indicating little to no linear relationship between the time series and its lagged values.

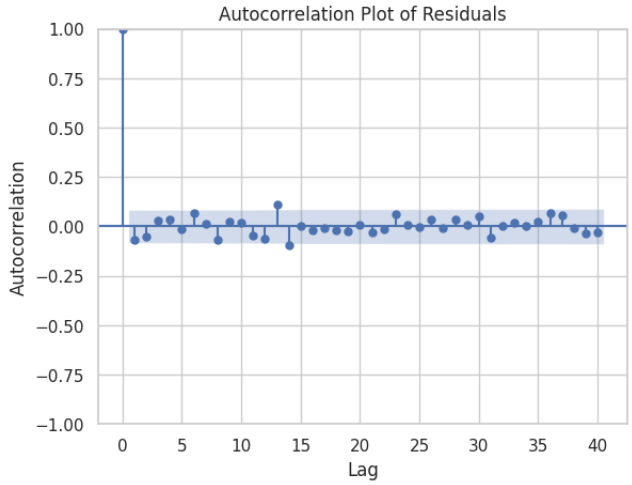

Figure 5.16. Autocorrelation plot of residuals
(Source: Own Tabulations)

In addition, The Durbin-Watson statistic for the dataset is 2.13, indicating there is no significant level of autocorrelation in the residuals, and consecutive observations appear to be independent.

The Hausman test is also used to determine whether the fixed effects (FE) model or the random effects (RE) model is more appropriate for panel data analysis. At 5% significance level, we fail to reject the null hypothesis since the Chi-square statistic is less than the critical value. This implies that coefficients do not differ significantly between the fixed effects and random effects models. Based on these findings, Random Effects Model seems more appropriate for the application of panel data regression.

Hausman Test:

Model Comparison

	FE	RE
Dep. Variable	log_CO2_Emissions_capita	log_CO2_Emissions_capita
Estimator	PanelOLS	RandomEffects
No. Observations	2788	2788
Cov. Est.	Unadjusted	Unadjusted
R-squared	0.5292	0.6532
R-Squared (Within)	0.5292	0.5281
R-Squared (Between)	0.8156	0.9483
R-Squared (Overall)	0.8095	0.9534
F-statistic	752.56	1311.0
P-value (F-stat)	0.0000	0.0000

Fail to reject the null hypothesis. Coefficients do not differ significantly between FE and RE models.
Chi-square statistic: -4.986183308688764e-05
Critical value: 9.487729036781154

Table 5.5. Hausman Test – CO_2 Per Capita

(Source: Own Tabulations)

The histogram of residuals closely resembles a normal distribution, suggesting that the residuals follow a Gaussian pattern, which is a positive characteristic for the validity of the regression model. The QQ plot of residuals forms an almost diagonal line as well, indicating that the distribution of residuals closely approximates a normal distribution. This suggests that the model's assumptions about the normality of residuals are largely met.

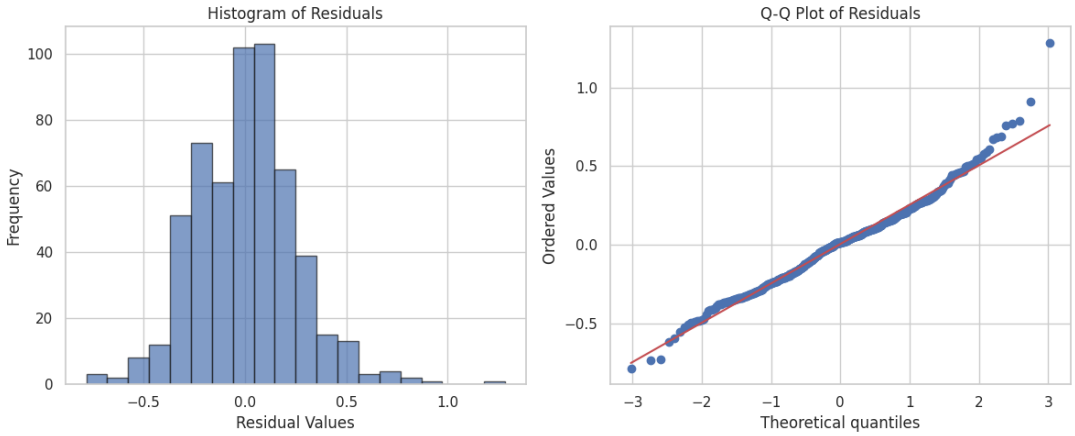

Figure 5.17. Histogram of Residuals & Q-Q Plot of Residuals

(Source: Own Tabulations)

The mean of the residuals is remarkably close to zero with the value of 0,0058, implying that, on average, the model's predictions are unbiased, with minimal systematic overestimation or underestimation of the target variable.

The scatter plot of residuals vs predicted values displays a random scatter of data points around the horizontal line at y=0. This suggests that the model's predictions are unbiased, and there is no systematic error.

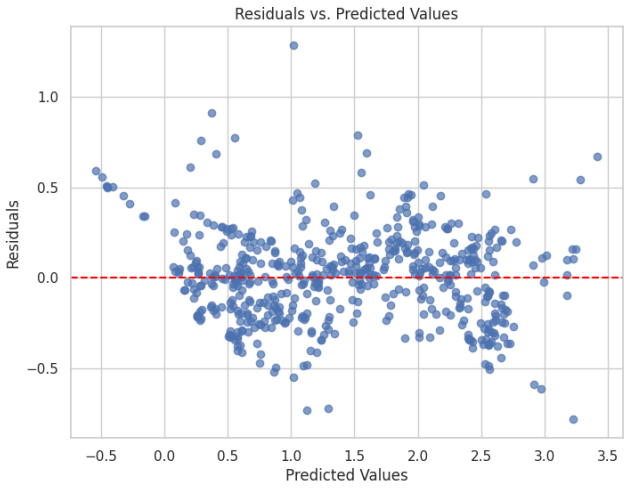

Figure 5.18. Residuals vs Predicted Values

(Source: Own Tabulations)

Scatter plot of residuals vs independent variables display a random scatter of distribution around the horizontal line at y=0. This also suggests that the model's variables are unbiased, and there is no systematic error. Independent variable of Industrial Performance Index should be considered specifically since the scatter plots are not distributed randomly.

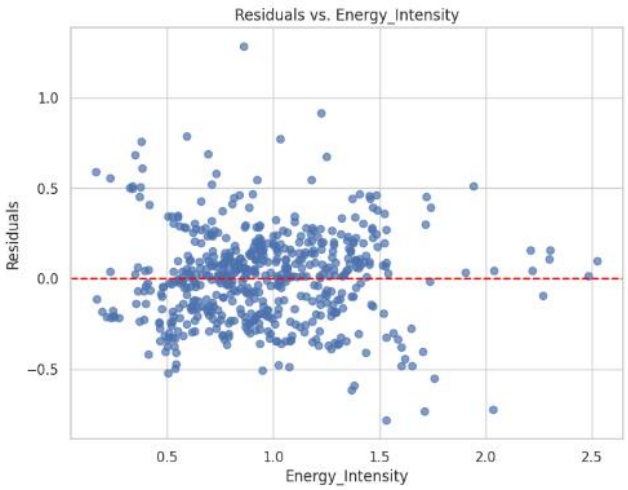

Figure 5.19. Residuals vs Energy Intensity

(Source: Own Tabulations)

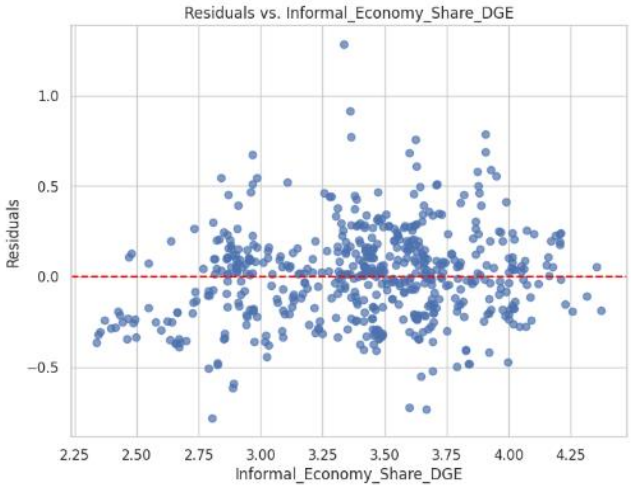

Figure 5.20. Residuals vs Informal Economy Share

(Source: Own Tabulations)

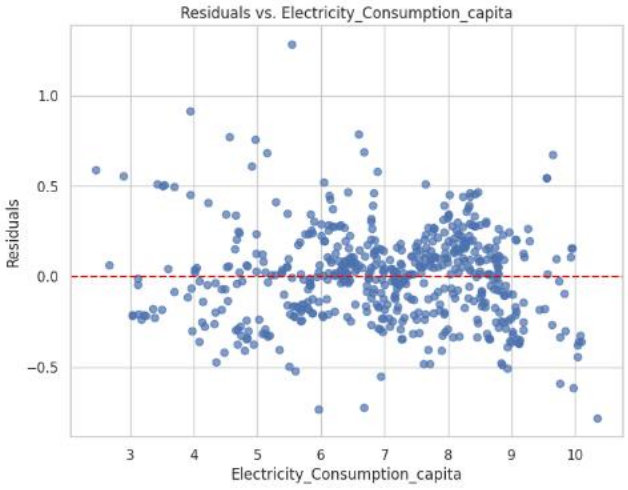

Figure 5.21. Residuals vs Electricity Consumption Per Capita

(Source: Own Tabulations)

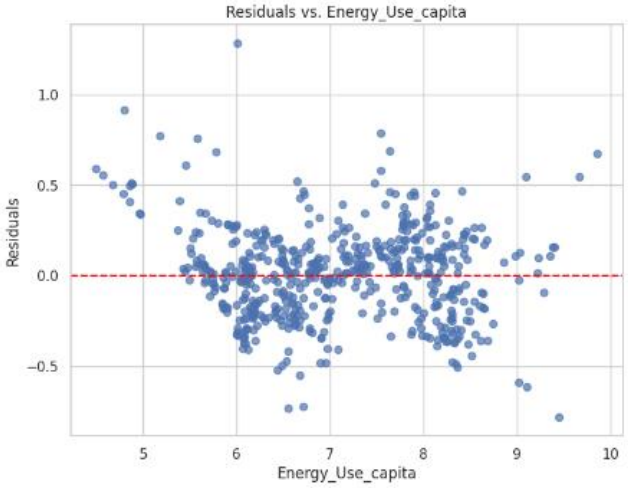

Figure 5.22. Residuals vs Energy Use Per Capita

(Source: Own Tabulations)

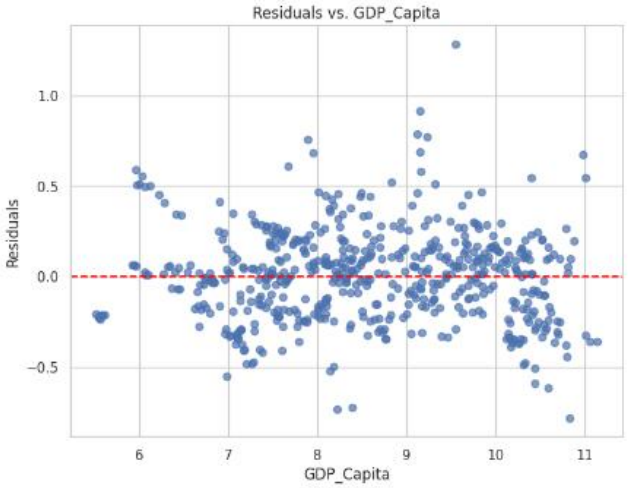

Figure 5.23. Residuals vs GDP Per Capita

(Source: Own Tabulations)

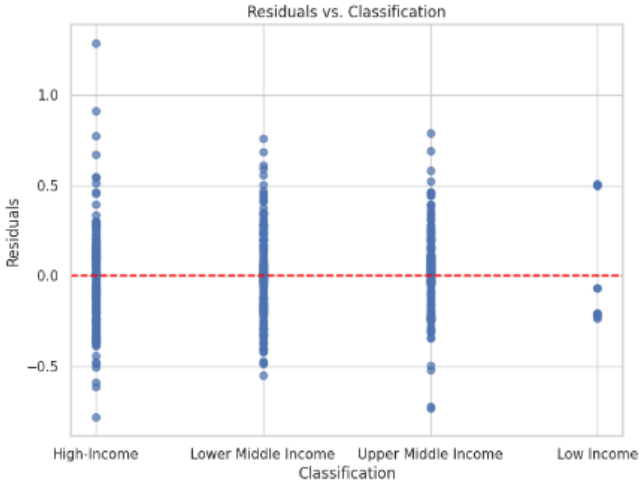

Figure 5.24. Residuals vs Classification

(Source: Own Tabulations)

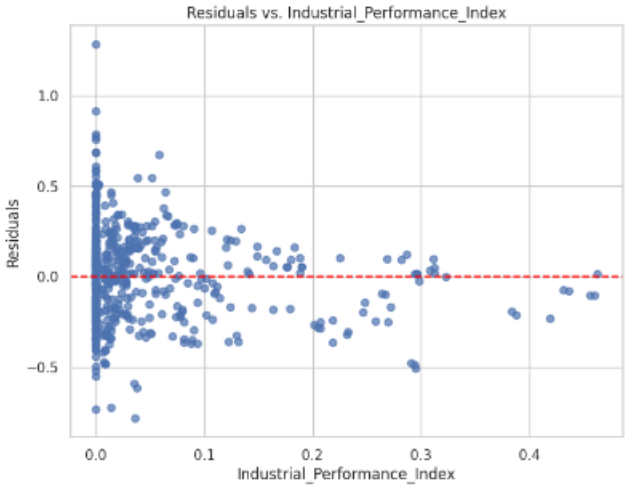

Figure 5.25. Residuals vs Industrial Performance Index

(Source: Own Tabulations)

5.2 Data Description – Regression with respect to NO_2 Per Capita

The aim of this regression is to understand the effect of informal economy and other control variables on NO2 emissions per capita level.

Mean Absolute Error (MAE) which measures the average absolute difference between the actual values and the predicted values is 0,224. Therefore, on average, the model's predictions deviate from the true values by approximately 0,224 units.

Mean Squared Error (MSE) which measures the mean of the squared difference between the actual and predicted values, with a greater emphasis on larger errors. MSE result of 0,121 in the regression suggests that, on average, the squared errors between predictions and the actual values amount to 0,121.

Feature Importance data frame for our variables is as follows:

	Feature Importance	
3	Energy_Use_capita	0.189714
2	Electricity_Consumption_capita	0.140634
4	GDP_Capita	0.116072
7	Classification_Lower Middle Income	0.102205
8	Classification_Upper Middle Income	0.076212
5	Industrial_Performance_Index	0.056661
1	Informal_Economy_Share_DGE	0.052392
0	Energy Intensity	0.042705
6	Classification Low Income	0.009746

Table 5.6. Feature Importance Data Frame with respect to NO_2 Per Capita

Graphical representation of the Feature Importance is as follows:

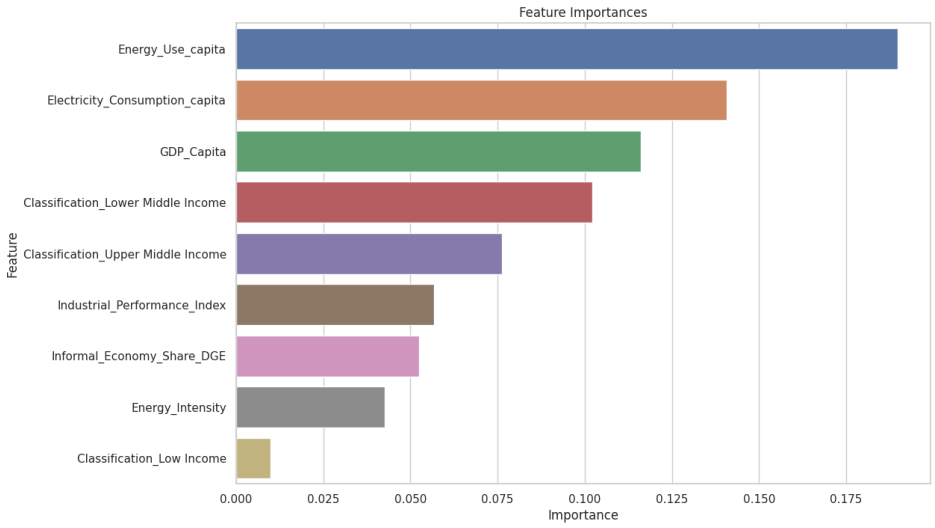

Figure 5.26. Feature Importance with respect to NO_2 Per Capita

(Source: Own Tabulations)

In this context, all the variables have a positive feature importance. Energy_Use_per_capita has the highest importance score (approximately 0.1879), indicating that it is the most influential feature in predicting the target variable.

However, to meet multicollinearity assumption and have a stronger model, this variable is excluded from the model as it is correlated with other independent variables.

The feature " Electricity_Consumption_per_capita " has the second-highest importance score (approximately 0.1406), making it one of the top contributors to the model's predictions. This variable is also excluded from the model.

GDP per capita has an importance score of 0,1160.

Classification_Lower Middle Income and Classification_Upper Middle Income: These two features also have positive importance scores, suggesting that they contribute to the model's predictive power, though to a lesser extent than the previous three features.

Informal_Economy_Share_DGE, Energy_Intensity and Industrial_Performance_Index have importance scores ranging from 0.056 to 0.009, indicating their respective contributions to the model's predictions are less.

Scatterplot of True Values vs Predicted Values does not form a diagonal line and there are several outliers in the regression.

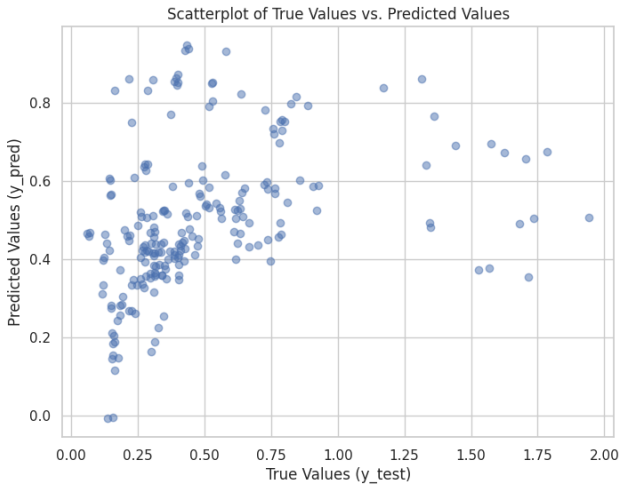

Figure 5.27. Scatterplot of True Values vs. Predicted Values

(Source: Own Tabulations)

The scatter plot of the residuals is mostly randomly distributed around horizontal line y=0, which represents that model's predictions are unbiased and there is no systematic error. It is important to keep in mind that there are still outliers.

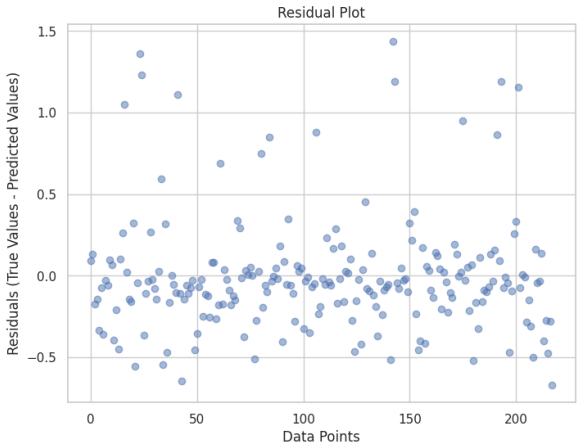

Figure 5.28. Scatterplot of Residuals

(Source: Own Tabulations)

The autocorrelation plot shows no significant autocorrelation, as most of the correlation values remain close to zero, indicating little to no linear relationship between the time series and its lagged values.

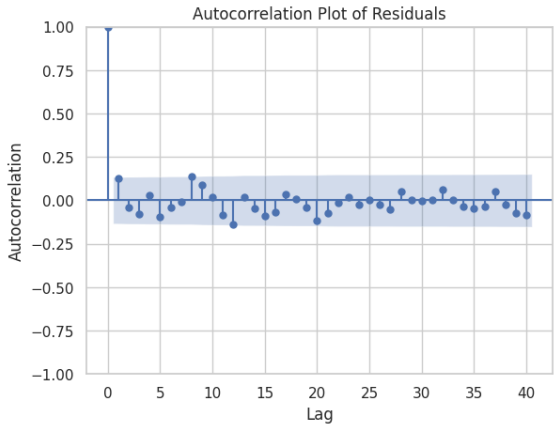

Figure 5.29. Autocorrelation Plot

(Source: Own Tabulations)

In addition, The Durbin-Watson statistic for the dataset is 1.72, indicating that there is some degree of positive autocorrelation, but it is not extremely strong. This means that there may be a mild tendency for adjacent residuals to be positively correlated, but it is not a severe violation of the independence assumption.

The Hausman test is also used to determine whether the fixed effects (FE) model or the random effects (RE) model is more appropriate for panel data analysis. At 5% significance level, we fail to reject the null hypothesis since the Chi-square statistic is less than the critical value. This implies that coefficients do not differ significantly between the fixed effects and random effects models. Based on these findings, Random Effects Model seems more appropriate for the application of panel data regression.

Hausman Test:

Model Comparison

	FE	RE
Dep. Variable	log_NO2_capita	log_NO2_capita
Estimator	PanelOLS	RandomEffects
No. Observations	2788	2788
Cov. Est.	Unadjusted	Unadjusted
R-squared	0.3342	0.3363
R-Squared (Within)	0.3342	0.3289
R-Squared (Between)	-7.9609	0.4517
R-Squared (Overall)	-5.0712	0.3799
F-statistic	336.06	352.66
P-value (F-stat)	0.0000	0.0000

Fail to reject the null hypothesis. Coefficients do not differ significantly between FE and RE models.
Chi-square statistic: 0.020419083561516973
Critical value: 9.487729036781154

Table 5.7. Hausman Test – NO_2 Per Capita

The histogram of residuals closely resembles a normal distribution but not 100% normal. This finding indicates that most of the data points in our dataset are distributed in a manner that resembles the classic bell-shaped curve characteristic of a normal distribution. However, it is important to note that while the histogram closely resembles a normal distribution, it does not guarantee that the data is perfectly normal. The presence of outliers or deviations from the normal pattern should be carefully considered and addressed in the analysis. Outliers in the model is represented in The QQ plot of residuals as well which does not show a perfect diagonal line form.

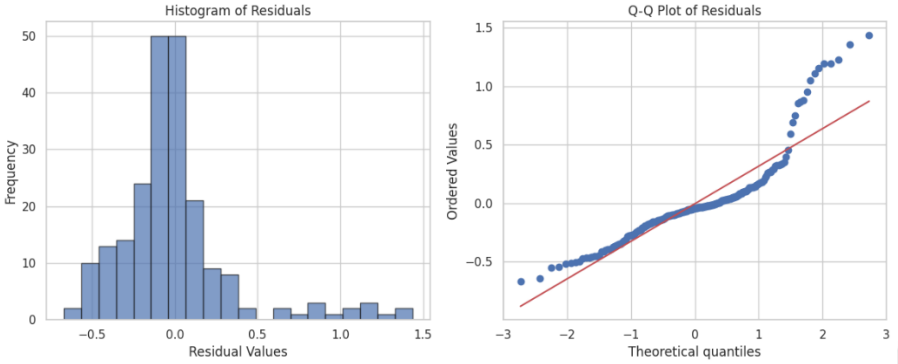

Figure 5.30. Histogram of Residuals & Q-Q Plot of Residuals

(Source: Own Tabulations)

The mean of the residuals is remarkably close to zero with the value of -0,0054, implying that, on average, the model's predictions are unbiased, with minimal systematic overestimation or underestimation of the target variable.

The scatter plot of residuals vs predicted values displays a random scatter of data points around the horizontal line at y=0 with several outliers. This suggests that the model's predictions are unbiased, and there is no systematic error.

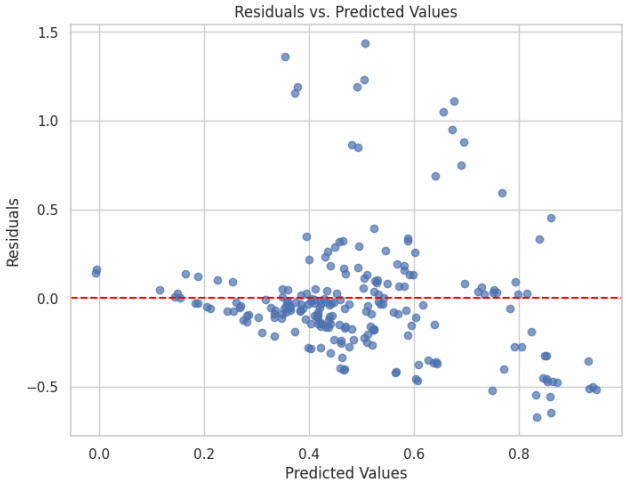

Figure 5.31. Residuals vs Predicted Values

(Source: Own Tabulations)

Scatter plot of residuals vs independent variables display a random scatter of distribution around the horizontal line at y=0. This also suggests that the model's variables are unbiased, and there is no systematic error. Independent variable of Industrial Performance Index should be considered specifically since the scatter plots are not distributed randomly.

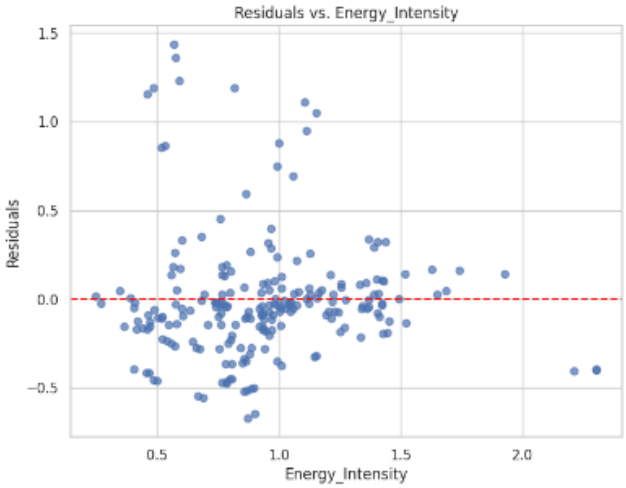

Figure 5.32. Residuals vs Energy Intensity

(Source: Own Tabulations)

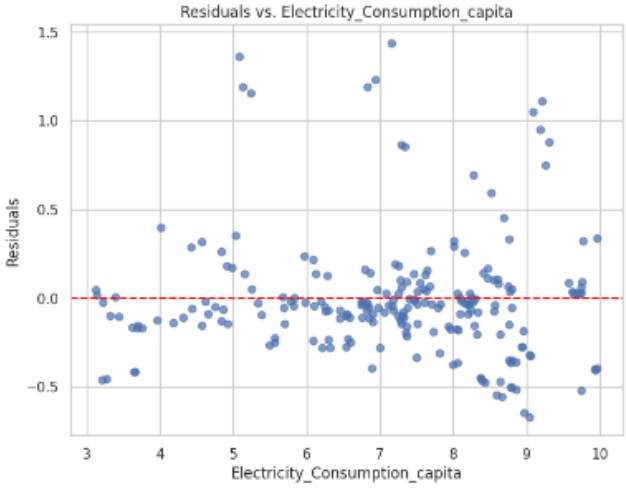

Figure 5.33. Residuals vs Energy Consumption Per Capita

(Source: Own Tabulations)

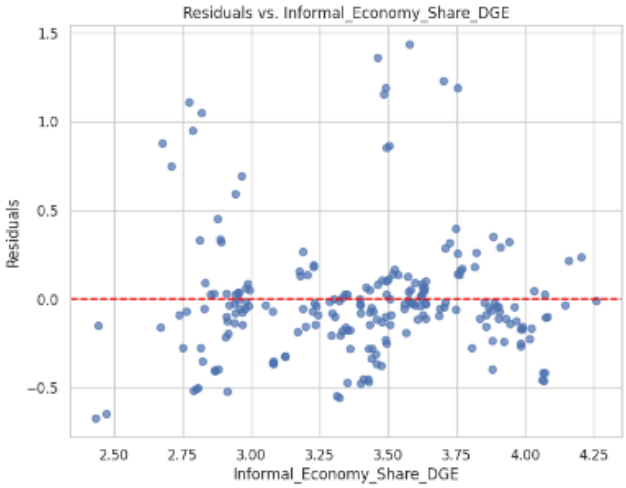

Figure 5.34. Residuals vs Informal Economy Share

(Source: Own Tabulations)

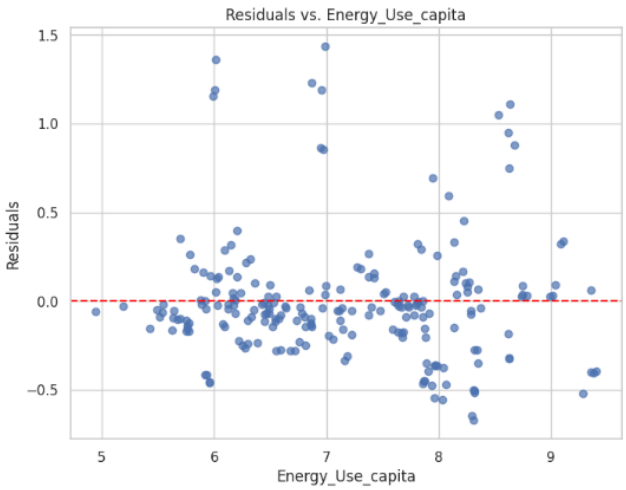

Figure 5.35. Residuals vs Energy Use Per Capita

(Source: Own Tabulations)

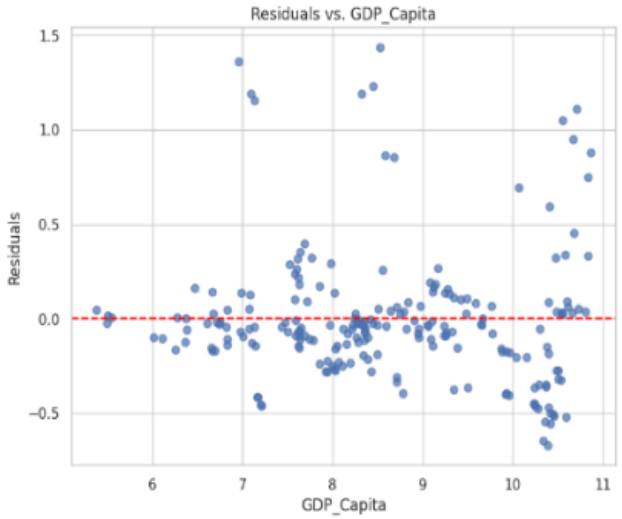

Figure 5.36. Residuals vs GDP Per Capita

(Source: Own Tabulations)

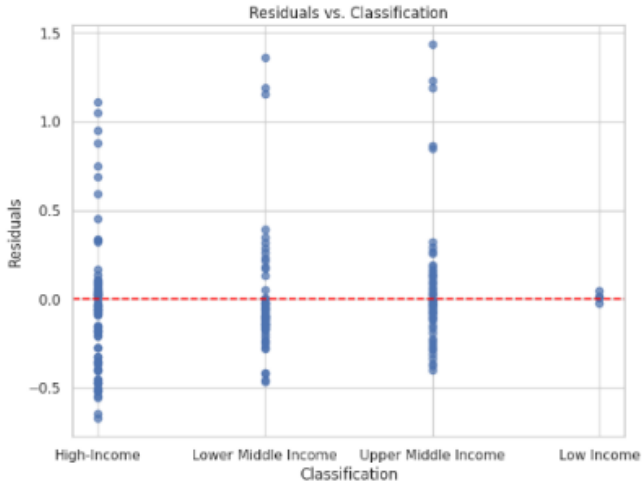

Figure 5.37. Residuals vs Classification

(Source: Own Tabulations)

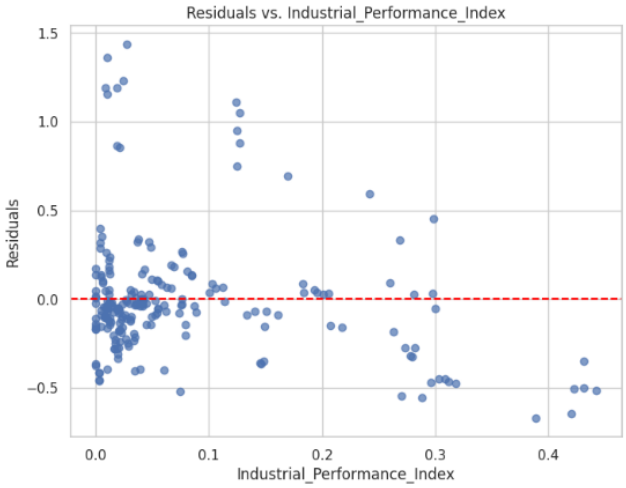

Figure 5.38. Residuals vs Industrial Performance Index

(Source: Own Tabulations)

5.3 Data Description – Regression with respect to PCA

The aim of this regression is to understand the effect of informal economy and other control variables on the environmental degradation variable which is obtained by PCA method.

To identify patterns and relationships of the variables, Correlation coefficient heatmap is derived. For our dependent variable "scores" which is formed in PCA model, the heatmap mostly represents a positive relationship between variables except Informal Economy Share.

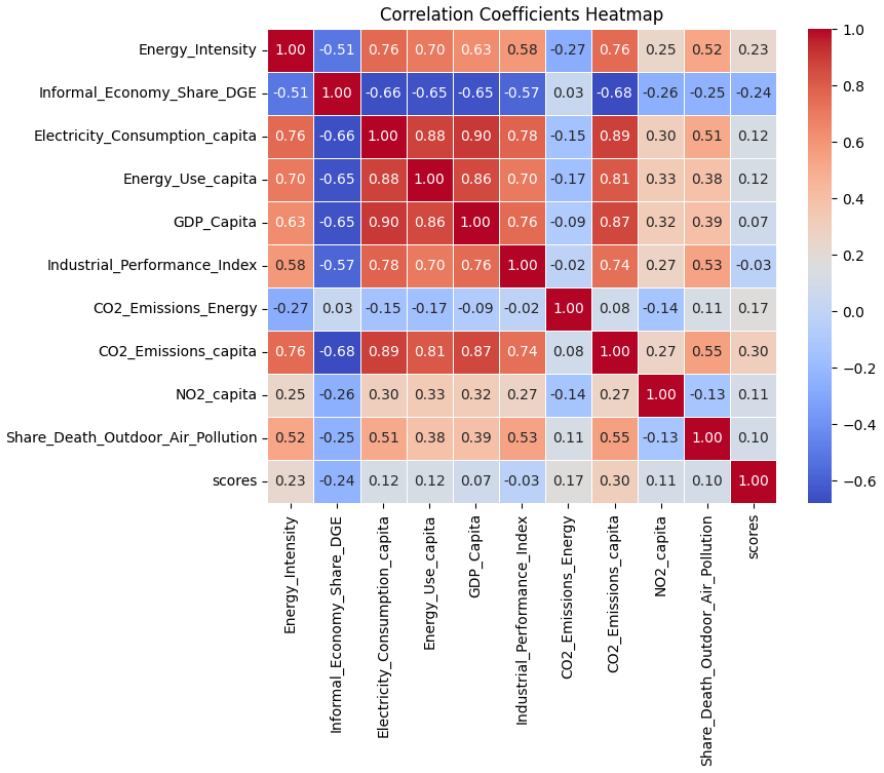

Figure 5.39. Correlation Coefficients Heatmap

(Source: Own Tabulations)

Mean Absolute Error (MAE) which measures the average absolute difference between the actual values and the predicted values is 0,46. Therefore, on average, the model's predictions deviate from the true values by approximately 0,46 units.

Mean Squared Error (MSE) which measures the mean of the squared difference between the actual and predicted values, with a greater emphasis on larger errors. MSE

result of 0,50 in the regression suggests that, on average, the squared errors between predictions and the actual values amount to 0,50.

Feature Importance data frame for our variables is as follows.

	Feature Importance	
6	Classification_Low Income	0.438954
3	Energy_Use_capita	0.438159
1	Informal_Economy_Share_DGE	0.178151
7	Classification_Lower Middle Income	0.126620
4	GDP_Capita	0.060119
0	Energy_Intensity	0.029949
5	Industrial_Performance_Index	0.025155
2	Electricity_Consumption_capita	0.014815
8	Classification_Upper Middle Income	0.013188

Table 5.8. Feature Importance Data Frame with respect to PCA Analysis

Graphical representation of the Feature Importance is as follows:

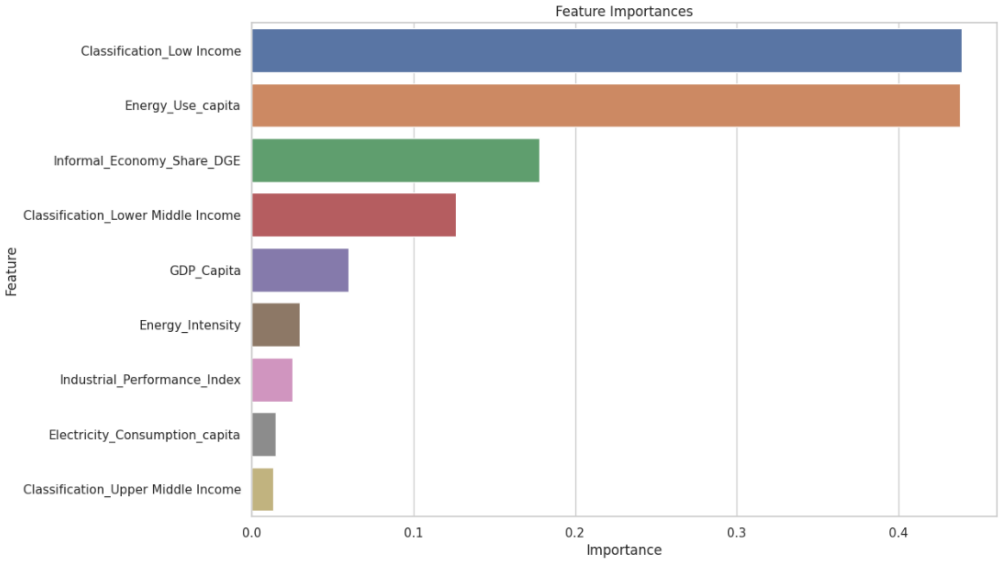

Figure 5.40. Feature Importance with respect to PCA Analysis

(Source: Own Tabulations)

Since scatterplot of True Values vs Predicted Values does not form almost a diagonal line as in the regression of CO_2 Emissions, we can conclude that the accuracy of the regression is weaker compared to the one with CO_2 emissions. However, it is still close to a diagonal line.

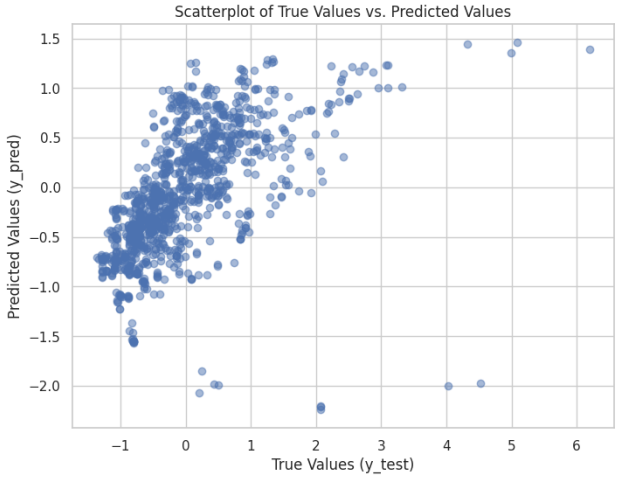

Figure 5.41. Scatterplot of True Values vs Predicted Values

(Source: Own Tabulations)

The scatter plot of the residuals is mostly randomly distributed around horizontal line y=0, which represents that model's predictions are unbiased and there is no systematic error.

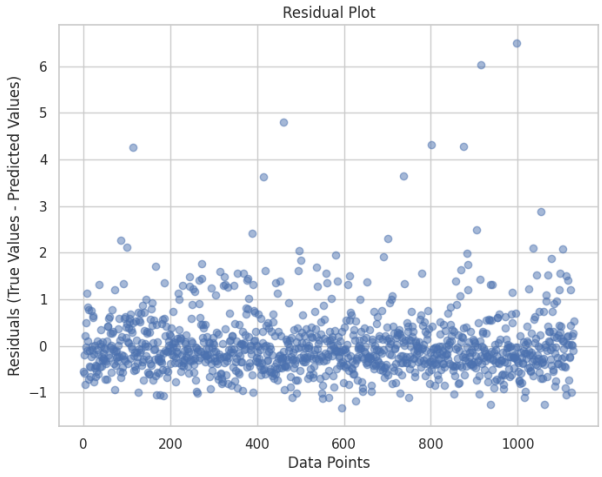

Figure 5.42. Scatterplot of Residuals

(Source: Own Tabulations)

The autocorrelation plot shows no significant autocorrelation, as most of the correlation values remain close to zero, indicating little to no linear relationship between the time series and its lagged values.

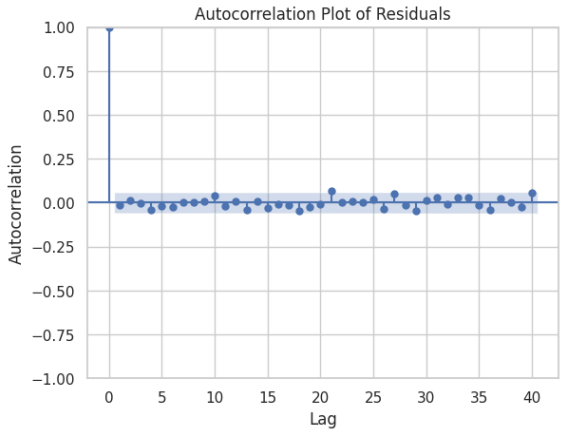

Figure 5.43. Autocorrelation Plot
(Source: Own Tabulations)

In addition, The Durbin-Watson statistic for the dataset is 2.02, indicating there is no autocorrelation in the residuals, and consecutive observations are independent.

The Hausman test is also used to determine whether the fixed effects (FE) model or the random effects (RE) model is more appropriate. At 5% significance level, we reject the null hypothesis since the Chi-square statistic exceeds the critical value. This implies that coefficients differ significantly between the fixed effects and random effects models. Based on these findings, Fixed Effects Model (FE) seems more appropriate for the application of panel data regression.

Hausman Test:

Model Comparison

	FE	RE
Dep. Variable	log_PCA_result	log_PCA_result
Estimator	PanelOLS	RandomEffects
No. Observations	2146	2146
Cov. Est.	Unadjusted	Unadjusted
R-squared	0.3218	0.2993
R-Squared (Within)	0.3218	0.3125
R-Squared (Between)	-5.8390	0.0214
R-Squared (Overall)	-3.3535	-0.0455
F-statistic	242.72	228.72
P-value (F-stat)	0.0000	0.0000

Reject the null hypothesis. Coefficients differ significantly between FE and RE models.
Chi-square statistic: 59.6447888079666
Critical value: 9.487729036781154

Table 5.9. Hausman Test – PCA

The histogram of residuals mostly resembles a normal distribution, suggesting that the residuals follow a nearly Gaussian pattern, which is a positive characteristic for the validity of the regression model. The QQ plot of residuals forms an almost diagonal line as well although there are outliers, indicating that the distribution of residuals closely approximates a normal distribution. This suggests that the model's assumptions about the normality of residuals are largely met.

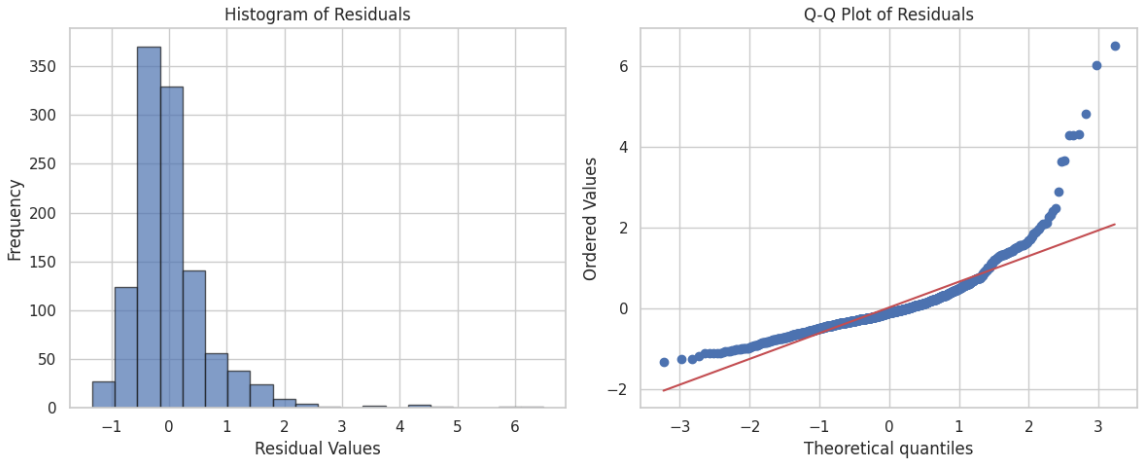

Figure 5.44. Histogram of Residuals & Q-Q Plot of Residuals

(Source: Own Tabulations)

The mean of the residuals is close to zero with the value of 0.021, implying that, on average, the model's predictions are unbiased, with minimal systematic overestimation or underestimation of the target variable.

The scatter plot of residuals vs predicted values displays a random scatter of data points around the horizontal line at y=0. This suggests that the model's predictions are unbiased, and there is no systematic error.

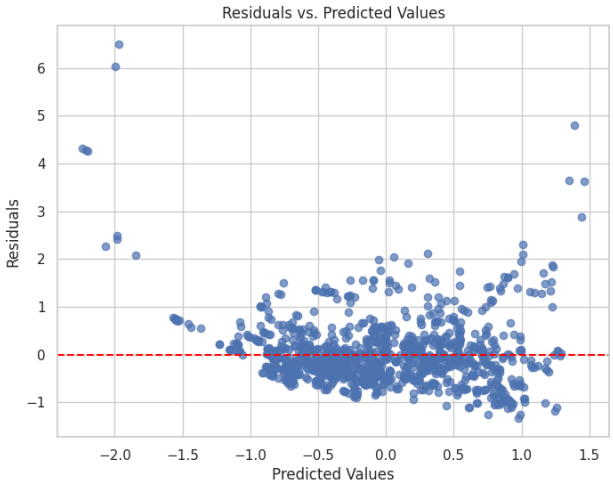

Figure 5.45. Residuals vs Predicted Values

(Source: Own Tabulations)

Scatter plot of residuals vs independent variables display a random scatter of distribution around the horizontal line at y=0. This also suggests that the model's variables are unbiased, and there is no systematic error. Special consideration should be considered for the independent variable of Industrial Performance Index since the scatter plots are not distributed randomly.

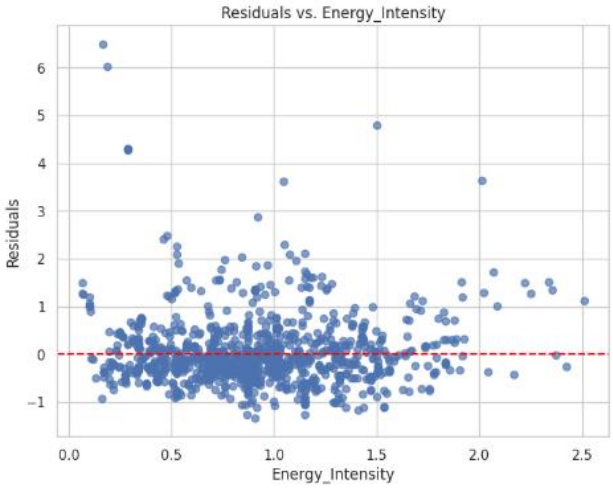

Figure 5.46. Residuals vs Energy Intensity

(Source: Own Tabulations)

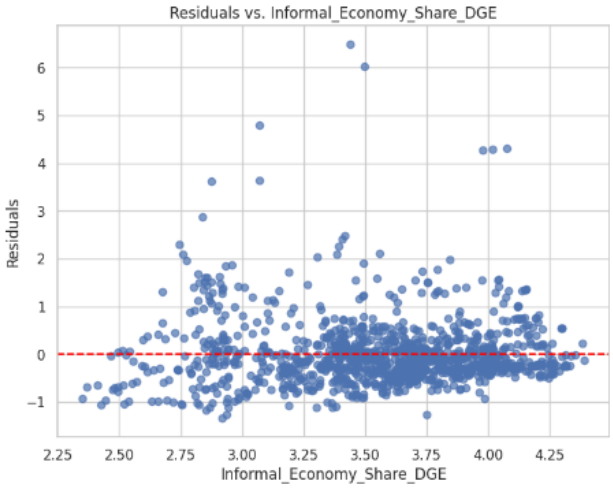

Figure 5.47. Residuals vs Informal Economy Share

(Source: Own Tabulations)

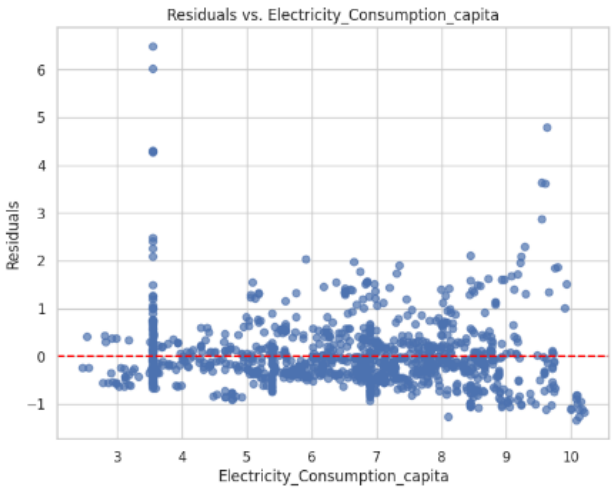

Figure 5.48. Residuals vs Electricity Consumption Per Capita

(Source: Own Tabulations)

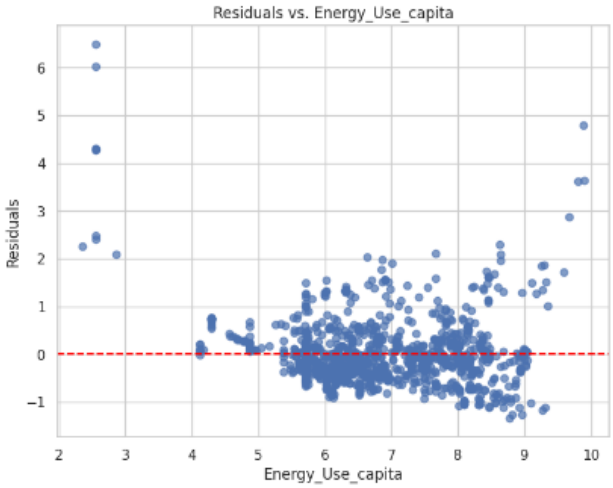

Figure 5.49. Residuals vs Energy Use Per Capita

(Source: Own Tabulations)

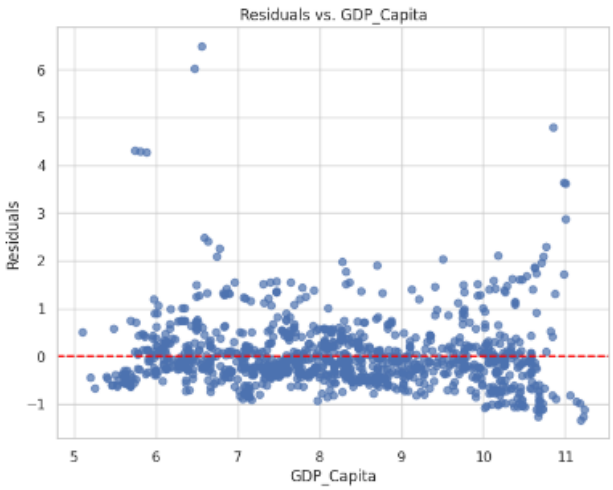

Figure 5.50. Residuals vs GDP Per Capita

(Source: Own Tabulations)

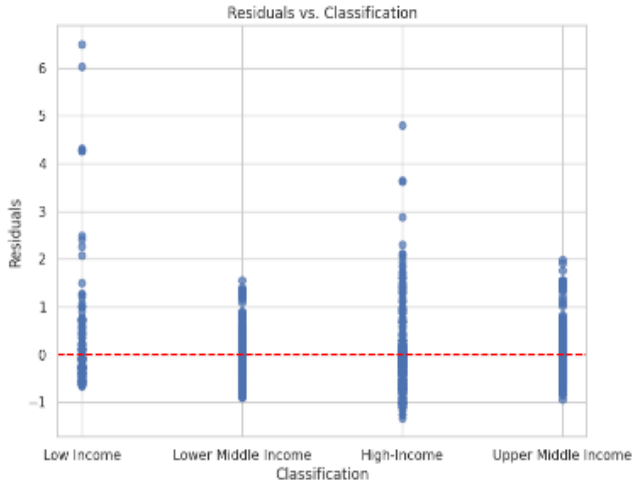

Figure 5.51. Residuals vs Classification

(Source: Own Tabulations)

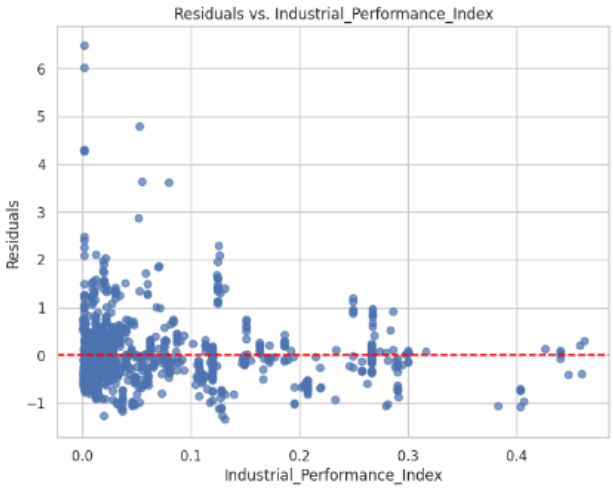

Figure 5.52. Residuals vs Industrial Performance Index

(Source: Own Tabulations)

6 EMPIRICAL STUDIES

In this sections, three different regressions will be run by using Fixed Effect and Random Effect Panel OLS Models to compare the effect of Informal economy on the level of different environmental degradation variables including CO_2 Per Capita, NO_2 Per Capita and the one formed by PCA method.

6.1 Analysis with CO_2 Per Capita

For the first regression; CO_2 emission per capita is considered as environmental degradation variable which is our dependent variable in the model. Other variables include energy intensity, Share of Informal Economy measured by DGE method, Real GDP per capita measured in 2015 constant USD and Industrial Performance Index. Variables are regressed in logarithmic forms.

Model is represented as per below:

$$CO_2 = \beta_0 + \beta_1 * IE + \beta_2 * GDPPC + \beta_3 * IP + \beta_4 * EI + \varepsilon$$

β_1 to β_4 represents intercepts of the regression, CO_2 represents CO_2 Emissions Per Capita as our Environmental Degradation variable, IE represents Informal Economy Share, GDPPC represents Real GDP per capita measured in 2015 constant USD, IP represents Industrial Performance Index, EI represents Energy Intensity and e represents the error term for our regression.

In logarithmic forms, regression is formed as follows:

$$\ln CO_2 = \beta_0 + \beta_1 * \ln IE + \beta_2 * \ln GDPPC + \beta_3 * \ln IP + \beta_4 * \ln EI + \varepsilon$$

Overall, summary table for the regression is as follows:

	Panel - CO_2					
	Random Effects			Fixed Effects		
	Coeff/Std Error	T-Stat	P-Value	Coeff/Std Error	T-Stat	P-Value
Informal Economy Share	-0.5286 (0.014)	-35.96	0.000***	-0.4173 (0.0483)	-8.64	0.000***
Energy Intensity	0.073 (0.003)	19.63	0.000***	0.0737 (0.004)	18.26	0.000***
GDP Per Capita	0.3665 (0.005)	62.11	0.000***	0.3916 (0.0179)	21.82	0.000***
Industrial Performance Index	-0.272 (0.037)	-7.32	0.000***	-0.255 (0.0375)	-6.81	0.000***
R-squared	0.6532			0.5292		
F-Stat	1311			752.56		

Note: Standard Errors are in brackets and p*<0.1; p**<0.05; p***<0.01.

Table 6.1. Summary Table for Regression with CO_2 Per Capita

For RE regression, "Informal_Economy_Share_DGE" has a negative coefficient of approximately -0.52, indicating that an increase in the informal economy share is associated with a decrease in CO_2 emissions per capita. This means that for each one-unit increase in the "Informal_Economy_Share," we expect a decrease of approximately 0.52 units in CO_2 emissions per capita. For FE regression, the coefficient is in the same direction with -0,4173.

For RE regression, "Energy_Intensity" has a positive coefficient of approximately 0.073, suggesting that an increase in energy intensity is associated with higher CO_2 emissions per capita. For FE regression, is almost the same with small decimal difference.

For RE regression, "GDP_Capita" has a positive coefficient of approximately 0.3665, indicating that higher GDP per capita is associated with higher CO_2 emissions per capita. For FE regression, the coefficient is in the same direction with 0.3916.

For RE regression, "Industrial_Performance_Index" has a negative coefficient of approximately -0.272. This variable has a moderate negative effect on CO_2 emissions per capita. For FE regression, the coefficient is in the same direction with a lower absolute value of -0.255.

All the coefficients are statistically significant with p-values less than 0.05 which suggests that at least one of the independent variables is making a significant contribution to explaining the variability in the dependent variable. In addition, a high F-statistic indicates that the explained variation in the dependent variable (due to the independent variables in the model) is much greater than the unexplained variation. In other words, the independent variables together have a strong relationship with the dependent variable.

If categorical variable "Classification" is represented as binary dummy variables, each of these categorical variables have a negative coefficient, meaning they are associated with lower CO_2 emissions per capita compared to the reference category which is “High Income.” and the model still becomes significant.

"Low Income" has a coefficient of approximately -0.36.
"Lower Middle Income" has a coefficient of approximately -0.45.
"Upper Middle Income" has a coefficient of approximately -0.23.

6.2 Analysis with NO_2 Per Capita

In the second regression, NO_2 per capita has been used as environmental degradation variable, in other words dependent variable in the regression. CO_2 per capita is one of the most widely used variables measuring environmental impact. However, NO_2 per capita is another important measurement which should be checked and addressed when designing environmental policies and needed importance did not attached to it within existing literature. Thus, it has been included in a separate regression.

Model is represented as per below:

$$NO_2 = \beta_0 + \beta_1 * IE + \beta_2 * GDPPC + \beta_3 * IP + \beta_4 * EI + \varepsilon$$

β_1 to β_4 represents intercepts of the regression, NO_2 represents NO_2 Emissions Per Capita as our Environmental Degradation variable, IE represents Informal Economy Share, GDPPC represents Real GDP per capita measured in 2015 constant USD, IP

represents Industrial Performance Index, EI represents Energy Intensity and e represents the error term for our regression.

In logarithmic forms, regression is formed as follows:

$$\ln NO_2 = \beta_0 + \ln\beta_1 * \ln IE + \beta_2 * \ln GDPPC + \beta_3 * \ln IP + \beta_4 * \ln EI + \varepsilon$$

Overall, summary table for the regression is as follows:

	Panel - NO_2					
	Random Effects			**Fixed Effects**		
	Coeff/Std Error	**T-Stat**	**P-Value**	**Coeff/Std Error**	**T-Stat**	**P-Value**
Informal Economy Share	-0.0915 (0.021)	-4.36	0.000***	-0.3761 (0.093)	-4.02	0.0001***
Energy Intensity	-0.0187 (0.0068)	-2.72	0.006***	-0.021 (0.0078)	-2.8	0.0051***
GDP Per Capita	0.065 (0.0086)	7.55	0.000***	0.05 (0.0347)	1.447	0.1479
Industrial Performance Index	1.816 (0.0693)	26.2	0.000***	1.694 (0.0725)	23.39	0.000***
R-squared	0.3363			0.3342		
F-Stat	352.66			336.06		

Note: Standard Errors are in brackets and p*<0.1; p**<0.05; p***<0.01.

Table 6.2. Summary Table for the regression with respect to NO_2 Per Capita

For RE regression, "Informal_Economy_Share_DGE" has a negative coefficient of approximately -0.0915, indicating that an increase in the informal economy share is associated with a decrease in NO_2 emissions per capita. This means that for each one-unit increase in the "Informal_Economy_Share," we expect a decrease of approximately 0.0915 units in NO_2 emissions per capita. For FE regression, the coefficient is in the same direction with -0,3761.

For RE regression, "Energy_Intensity" has a slightly negative coefficient of approximately -0.0187, suggesting that an increase in energy intensity is associated with lower NO_2 emissions per capita. For FE regression, the coefficient is in the negative direction with -0.021.

For RE regression, "GDP_Capita" has a positive coefficient of approximately 0.065, indicating that higher GDP per capita is associated with higher NO_2 emissions per capita. For FE regression, the coefficient is in the same direction with 0.05.

For RE regression, "Industrial_Performance_Index" has a positive coefficient of approximately 1.816. For FE regression, the coefficient is in the same direction with a lower absolute value of 1.694.

All the coefficients are statistically significant with p-values less than 0.05 except Energy Instensity which has a p-value of 0.92 for FE regression and 0.80 for RE regression.

All the coefficients are statistically significant with p-values less than 0.05 except GDP per capita in FE regression which suggests that at least one of the independent variables is making a significant contribution to explaining the variability in the dependent variable. In addition, a high F-statistic indicates that the explained variation in the dependent variable (due to the independent variables in the model) is much greater than the unexplained variation. In other words, the independent variables together have a strong relationship with the dependent variable.

If the categorical variable "Classification" is added using binary dummy variables, the updated findings indicate that Lower Income exhibits a higher correlation with "NO_2 per capita" in contrast to the reference group of "High Income Countries".

6.3 Principle Component Analysis (PCA)

PCA is the acronym for Principal Component Analysis, and it is a good technique to reduce complexity for high-dimensional analysis. Main benefit it offers is to reduce dimensionality of the dataset. In other words, PCA is a technique to identify the most important directions of variance in a dataset and project the data onto those directions and in the end, form new variables called principal components. PCA simplifies data analysis by applying less dimensions into model which makes it easier to classify results and make analysis accordingly. It aims to protect the most important aspects of the dataset while simplifying data analysis.

PCA (Principal Component Analysis) model is used to reduce dimensionality of the dataset and analyze four different environmental variables at the same time as

dependent variables which are NO_2 per capita, CO_2 per capita, Share of Death by Outdoor Air Pollution and CO_2 emissions per energy. In most of the studies, environmental degradation is analyzed through only an indicator which is most of the time Carbon Footprint, CO_2 Emissions Per Capita or Ecological Footprint. This study can be one of a kind by including a PCA Analysis to analyze the relationship with a wider scope.

Model is represented as per below:

$$PCA = \beta_0 + \beta_1 * IE + \beta_2 * GDPPC + \beta_3 * IP + \beta_4 * EI + \varepsilon$$

β_1 to β_4 represents intercepts of the regression, PCA represents Dependent Variable derived by PCA method which is actually the reduced form of four environmental degradation variables including CO_2 emissions per energy, CO_2 emissions per capita, NO_2 per capita and Share of death by outdoor air pollution; IE represents Informal Economy Share, GDPPC represents Real GDP per capita measured in 2015 constant USD, IP represents Industrial Performance Index, EI represents Energy Intensity and e represents the error term for our regression.

In logarithmic forms, regression is formed as follows:

$$lnPCA = \beta_0 + \beta_1 * lnIE + \beta_2 * lnGDPPC + \beta_3 * lnIP + \beta_4 * lnEI + \varepsilon$$

Overall, summary table for the regression is as follows:

	Panel - PCA					
	Random Effects			**Fixed Effects**		
	Coeff/Std Error	**T-Stat**	**P-Value**	**Coeff/Std Error**	**T-Stat**	**P-Value**
Informal Economy Share	-0.874 (0.072)	-11.98	0.000***	-1.76 (0.355)	-4.95	0.000***
Energy Intensity	-0.0624 (0.0203)	-3.07	0.002***	-0.0511 (0.0239)	-2.13	0.032**
GDP Per Capita	0.326 (0.0285)	11.43	0.000***	0.438 (0.1249)	3.5	0.0005***
Industrial Performance Index	3.23 (0.192)	16.83	0.000***	2.709 (0.2047)	13.23	0.000***
R-squared	0.2993			0.3218		
F-Stat	228.72			242.72		

Note: Standard Errors are in brackets and p*<0.1; p**<0.05; p***<0.01.

Table 6.3. Summary Table for the regression with respect to PCA

For RE regression, "Informal_Economy_Share_DGE" has a negative coefficient of approximately -0.874, indicating that an increase in the informal economy share is associated with a decrease in environmental degradation. For FE regression, the relationship is in the same direction with coefficient a coefficient of -1.76.

For RE regression, "Energy_Intensity" has a slightly negative coefficient of approximately -0.0624, suggesting that an increase in energy intensity is associated with lower environmental degradation. For FE regression, the coefficient is in the negative direction with -0.0511.

For RE regression, "GDP_Capita" has a positive coefficient of approximately 0.326, indicating that higher GDP per capita is associated with higher environmental degradation. For FE regression, the coefficient is in the same direction with 0.438.

For RE regression, "Industrial_Performance_Index" has a positive coefficient of approximately 3.23. For FE regression, the coefficient is in the same direction with a lower absolute value of 2.709.

All the coefficients are statistically significant with p-values less than 0.05 which suggests that at least one of the independent variables is making a significant contribution to explaining the variability in the dependent variable. In addition, a high F-statistic indicates that the explained variation in the dependent variable (due to the independent variables in the model) is much greater than the unexplained variation. In other words, the independent variables together have a strong relationship with the dependent variable.

If the categorical variable "Classification" is added using binary dummy variables, the updated findings indicate that Lower Income exhibits a higher correlation with "PCA" in contrast to the reference group of "High Income Countries".

7 CONCLUSION

The impact of informal economic activity has been recognized as a significant and frequently disregarded part of environmental degradation in this thesis. While the traditional focus has been on how formal economic activities affect the environment, this research shows that the informal economy is also a significant factor in affecting the state of our environment.

Identifying the effects of the informal economy on the environment is essential to create environmental policies that work. The results of this study highlight the significance of inclusive and comprehensive strategies for addressing environmental issues. When forming environmental policies, considering both official and informal economic activity allows us to create solutions that support sustainability and lessen the negative impacts of unregulated behaviors.

In an era where the informal economy continues to thrive in various regions, it becomes imperative to acknowledge its environmental footprint. Therefore, this research underscores the need for considering the environmental impact of the informal economy and integrating it into broader strategies for conservation and regulation. This recognition represents a significant step toward achieving a more equitable and sustainable balance between economic activities and environmental preservation.

Given the limited body of literature on informality and the increasing attention it warrants, this study aims to enrich existing knowledge by providing insights into the historical context, the various dimensions of informality including the informal economy, informal sector, and informal employment, the factors contributing to informality, its repercussions, and methodologies for its measurement. By addressing these, this thesis aims to make a substantial contribution to the literature on the informal economy, from a wide range of perspectives.

In the context of Informal Economy and Environmental Degradation relationship, the relationship was analyzed with several different environmental indicators such as NO_2 per capita and CO_2 per capita. Additionally, by including Share of Death by Outdoor Air Pollution and CO_2 emissions per energy on top of existing two environmental degradation indicators, a PCA Analysis has been implemented to check for an overall impact of these variables.

Based on the last 2 years of average Informal Economy Shares of countries, Low Income Countries have around 37% informal economy share, Lower Middle-Income Countries have around 35% informal economy share, Upper Middle-Income Countries have around 32% informal economy share, and High-Income Countries have around 19% informal economy share. Thus, it can be concluded that as the income level increases, the share of informal economy decreases. However, there can be several cases at country level in which this assumption does not hold. The highest informal economy share belongs to Bolivia with around 60% and the lowest share belongs to Austria with around 9% informal economy share. Another important aspect is the important level of informal economies even for high income countries.

As CO_2 Per Capita being the environmental degradation variable, the analysis represents a positive relationship between income level and CO_2 Per Capita, meaning higher income level is associated with higher CO_2 Per Capita. Additionally, there is a significant negative relationship between informal economy and the CO_2 Per Capita.

For the case of NO_2, the findings similarly suggest that informal economy share has a negative relationship with " NO_2 per capita.", meaning higher informal economy size is associated with lower NO_2 per capita.

The results obtained through the PCA Analysis are in parallel with the results obtained from CO_2 Per Capita and NO_2 Per Capita analysis, implying a negative relationship with informal economy size and environmental degradation.

The findings are similar to the findings of Goel et al. (2013) who found the negative relationship between informal sector and carbon emissions. They also claim that effective environmental regulations have a direct decreasing impact on carbon emissions. Their final prediction states that strict and effective environmental regulations can be a reason for lower formal environmental degradation, on the other hand it can be a reason for a higher informal environmental degradation. This is probably because informal sector is less capital intensive compared to the formal counter parts, so the net effect becomes less as the informality increases.

Moreover, the outcomes of this study align with those of Baloch et al. (2022). Although their methodology was to apply an ARDL bound testing procedure which is different compared to this study, they found a strict co-integration between informal economy and environmental degradation. According to them, the effect of informal

sector is not only limited to CO_2 emissions, but instead it is co-integrated with most of the variables related to environmental degradation.

Conversely, the results of this study diverge from several previous studies in the field.

Chaudhuri (2005) develops a three-sector general equilibrium model and highlights that informal manufacturing entities produce significantly higher pollution compared to formal counterparts. He notes that informal sector entities often act as subcontractors for formal entities, increasing environmental degradation.

Biswas et al. (2012) emphasize the negative environmental impact of a large informal sector, attributing it to weak enforcement of laws and regulations, allowing informal entities to evade compliance more easily. They suggest that combating corruption could mitigate the informal sector's adverse effects on the environment.

Blackman and Banister (1998) characterized the informal sector as comprising low-tech, unlicensed microenterprises, significant sources of pollution. They suggest that despite the costliness, the adoption of clean technology tools in this sector could be increased with support from local organizations and communities.

To sum up, high informal economy harms the effectiveness of policies whether it is an environmental policy, fiscal policy, tax policy and so on and so forth. Thus, it is extremely important to calculate the actual levels of informal economy and act accordingly to combat informal economy and in the end, have a situation where the policies are applicable and effective.

For predictability and accountability purposes, the level of informal economy needs to be decreased for countries to better form policies, eliminate externalities, and create a fair environment on behalf of the public. In line with the aim of this thesis, further studies can be done to assess what is needed to decrease informal economy and country specific informal economy reasons can be examined as well to focus on specific reasons at country level.

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