The Impact of Renewable Energy, Globalization, and The Rule of Law on Japan’s Ecological Imprint and Its Implications.

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Economics

Eastern Mediterranean University
September 2024
Gazimağusa, North Cyprus

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ABSTRACT

The implementation of environmental rules often lags behind practice, and there is currently a lack of data to help understand and bridge this gap. It is in this context, this thesis explores the impact of renewable energy, globalization and the rule of law on Japan's ecological imprint and its implications. Chapter three examined the effect of globalization, economic growth, and energy consumption on Japan's ecological imprint using annual time series data from 1990 to 2021. The research used Granger causality tests, autoregressive distributed lag (ARDL), and dynamic ordinary least squares (DOLS). Empirical data shows globalization and non-renewable energy consumption positively impact Japan's ecological imprint, whereas long-run renewable energy usage and gross domestic product (GDP) have inverse effects. The short-run outcome reveals a direct correlation between GDP and ecological imprint but a negative correlation between globalization, renewable energy usage and non-renewable energy usage on the ecological imprint. Chapter four explored the ecological footprint in Japan, and it lacks substantial research on its ecological footprint, which illustrates the environmental impact of its adherence to the rule of law, regulatory quality, globalization, research and development and trade openness. To this end, the study examined the relationship between rule of law, regulatory quality, research and development, globalization and trade openness in Japan using dataset spanning between 1990–2021. The study employed the Autoregressive Distributed Lag and Granger causality and diagnostics tests to test the stability of the variables. Based on the outcomes of the Autoregressive Distributed Lag method (i) the rule of law and trade openness dampens ecological footprint (ii) Regulatory quality and globalization upsurges ecological footprint in the long run. (iii) Research and development improved the quality of ecological footprint in the short-run. The Granger Causality test shows that there is unidirectional relationship between rule of law, regulatory quality, globalization, trade openness and ecological footprint which means that ecological footprint granger causes all the explanatory variables investigated. The results emphasize how crucial it is for decision-makers to execute policies in a well-coordinated manner in order to halt Japan's notable environmental degradation.

Keywords: Ecological Imprint, Energy Consumption, Globalization and Rule of Law

ÖZ

Çevresel kuralların uygulanması sıklıkla uygulamanın gerisinde kalıyor ve şu anda bu boşluğun anlaşılmasına ve kapatılmasına yardımcı olacak veri eksikliği mevcut. Bu bağlamda bu tez, yenilenebilir enerjinin, küreselleşmenin ve hukukun üstünlüğünün Japonya'nın ekolojik damgası üzerindeki etkisini ve bunun sonuçlarını araştırıyor. Üçüncü bölüm, 1990'dan 2021'e kadar yıllık zaman serisi verilerini kullanarak küreselleşmenin, ekonomik büyümenin ve enerji tüketiminin Japonya'nın ekolojik etkisi üzerindeki etkisini inceledi. Araştırmada Granger nedensellik testleri, otoregresif dağıtılmış gecikme (ARDL) ve dinamik sıradan en küçük kareler (DOLS) kullanıldı. . Ampirik veriler, küreselleşmenin ve yenilenemeyen enerji tüketiminin Japonya'nın ekolojik izini olumlu yönde etkilediğini, uzun vadeli yenilenebilir enerji kullanımı ve gayri safi yurtiçi hasılanın (GSYİH) ise ters etkileri olduğunu gösteriyor. Kısa vadeli sonuç, GSYİH ile ekolojik etki arasında doğrudan bir korelasyon olduğunu ancak küreselleşme, yenilenebilir enerji kullanımı ve yenilenemeyen enerji kullanımı arasında ekolojik baskı üzerinde negatif bir korelasyon olduğunu ortaya koymaktadır. Dördüncü bölümde Japonya'daki ekolojik ayak izi araştırılmıştır ve hukukun üstünlüğüne, düzenleyici kaliteye, küreselleşmeye, araştırma ve geliştirme ve ticari açıklığa bağlılığın çevresel etkisini gösteren ekolojik ayak izine ilişkin önemli bir araştırma bulunmamaktadır. Bu amaçla çalışma, Japonya'da hukukun üstünlüğü, düzenleme kalitesi, araştırma ve geliştirme, küreselleşme ve ticari açıklık arasındaki ilişkiyi 1990-2021 yılları arasındaki veri setini kullanarak inceledi. Çalışmada değişkenlerin stabilitesini test etmek için Otoregresif Dağıtılmış Gecikme ve Granger nedensellik ve teşhis testleri kullanıldı. Otoregresif Dağıtılmış Gecikme yönteminin sonuçlarına göre (i) hukukun üstünlüğü ve ticari açıklık ekolojik ayak izini azaltır (ii)

Düzenleyici kalite ve küreselleşme uzun vadede ekolojik ayak izini artırır. (iii) Araştırma ve geliştirme, kısa vadede ekolojik ayak izinin kalitesini artırdı. Granger Nedensellik testi, hukukun üstünlüğü, düzenleyici kalite, küreselleşme, ticari açıklık ve ekolojik ayak izi arasında tek yönlü bir ilişki olduğunu göstermektedir; bu, ekolojik ayak izinin incelenen tüm açıklayıcı değişkenlere neden olduğu anlamına gelir. Sonuçlar, Japonya'nın kayda değer çevresel bozulmasını durdurmak amacıyla karar vericilerin politikaları iyi koordineli bir şekilde yürütmesinin ne kadar önemli olduğunu vurguluyor.

Anahtar Kelimeler: Ekolojik Baskı, Enerji Tüketimi, Küreselleşme ve Hukukun Üstünlüğü

DEDICATION

I dedicated this thesis to God and my wonderful family

ACKNOWLEDGMENT

I express my sincere gratitude and genuine thanks to my supervisor, Prof. Dr. Hasan Güngör whose support and supervision enabled me to complete this task. In addition, I want to sincerely thank the jury members for their invaluable contributions. I also want to express my appreciation to my friends and family for their constant support and encouragement along this journey.

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag
BP	British Petroleum
BRICS	Brazil, Russia, India, China and South Africa
CO_2	Carbon Emissions
DOLS	Dynamic Ordinary Least Square
ECFP	Ecological Footprint
ECM	Error Correction Model
EKC	Environmental Kuznet Curve
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Square
GDP	Gross Domestic Product
GFN	Global Footprint Network
GHA	Global Hectare per person
GHGs	Greenhouse Gas Emissions
GLO	Globalization
GMM	General Method Moments
IDB	Inter- American Development Bank
KT	Kilotons
Law	Rule of Law
MINT	Mexico, Indonesia, Nigeria and Turkey
NATGAS	Natural Gas Rent

OLS	Ordinary Least Square
PP	Phillip-Peron
RENEW	Renewable Energy
RQ	Regulatory Quality
SEI	Swedish Economic Institute
TRADE	Trade Openness
UN	United Nations
VECM	Vector Error Correction Model
WDI	World Development Indicators

Chapter 1

INTRODUCTION

The most important thing that can be done to prevent the worst effects of global warming is typically to switch to renewable energy when it comes to climate change discussions. This is due to the fact that carbon dioxide and other greenhouse gases that cause global warming are not released by renewable energy sources like wind and solar power. Sustainable energy offers much more benefits than being "green." This expanding industry helps reduce energy costs, boosts access to energy in emerging nations, strengthens the resilience of electric grids, and generates jobs. With solar and wind power generating new heights in electricity production, all of those variables have helped fuel a current revival in renewable energy. Around the last 150 years, humans have become increasingly dependent on fossil fuels like coal, oil, and other fuels to power factories, cars, and lightbulbs. The greenhouse gasses that are emitted during the combustion of fossil fuels have reached previously unheard-of levels since fossil fuels are a part of almost everything we do. Like every energy source, renewables come with trade-offs and related discussions. One of them is on what constitutes renewable energy. In strict terms, renewable energy is exactly what you might expect: endlessly suppliable, or as the US Energy Information Administration describes it, "virtually inexhaustible." Opponents of huge hydropower dams and ethanol derived from corn frequently contend that "renewable" does not always equate to sustainable. It also excludes other resources with low or zero emissions that have their own proponents, such as nuclear power and energy efficiency.

Due to its impact on global warming and ability to sabotage the global carbon cycle, environmental degradation is a serious threat that is becoming more and more apparent on a global scale and is on the radar of governments everywhere. Climate change is one of the most important issues facing humanity today. According to Dong et al. (2018), climate change brought on by greenhouse gas emissions (GHGs), primarily CO_2 pollutions, poses unparalleled hazards to human development and survival. These risks include extreme weather, extinction of species, and food scarcity. Burning fossil fuels, such as coal and natural gas, for energy and transportation is the main human activity that contributes to CO_2 pollution. Nonetheless, some land-use changes and industry operations continue to release CO_2 emissions. According to Lincoln et al. (2021), extreme weather events such as floods, heatwaves, storms, and droughts, sea level rise, disruptions to water systems, and stunted plant growth are only a few of the potential health, physical, and ecological repercussions of climate change and global warming.

A nation's enormous financial burden may result in environmental deterioration that could have negative economic effects due to the high cost of cleaning up landfills and safeguarding endangered species. Thus, environmental protection is one of the contemporary global issues that has been incorporated into the political agendas of many countries. In the hopes that this research would shed light on the macroeconomic elements of climate change, numerous scientific investigations have been conducted to identify the components that contribute to pollution in order to comprehend the economic aspects of environmental degradation Adebayo et al. (2021).

The free flow of people, capital, ideas, and goods within a single global system has led to a growing degree of interdependence and integration among nations, which is known as globalization. "The growing integration of economies and societies around the world" is how the World Bank describes globalization. Additionally, the word suggests that the significantly increasing levels of international trade and cultural interchange have led to changes in societies and the global economy. Globalization was recently compared to the song "Imagine there are no countries" by John Lennon by the British publication The Economist. It is simple to complete. Globalization undoubtedly has diverse meanings for various individuals. Today, money is seen to be circulating freely throughout the globe. International and national boundaries are being crossed by global networks created by internet technology. Cultural factors are influencing people both domestically and outside Mukherjee, (2008).

Why Japan? Global environmental consciousness has prompted intergovernmental organizations to organize international efforts, such as the Paris Agreement and the Kyoto Protocol. Maintaining less than a global temperature increased by 2 °C over pre-industrial levels and pushing it toward 1.5 °C is the fundamental objective of the historic Paris Accord IEA (2018). In terms of coal and petroleum product imports worldwide, Japan is the world's fourth-largest importer of liquefied natural gas. Japan has limited domestic energy resources, which since 2012 have made up less than 10% of the nation's total annual primary energy consumption. Japan has the third-largest GDP in the world, behind China, with a GDP of $US4.872 trillion in 2018 World Bank, (2020). It is also the seventh-largest emitter of GHGs. It moved away from nuclear power and increased its use of fossil fuels as a result of the Fukushima nuclear accident in 2011, which delayed its decarbonization ambitions. Right now, the Japanese government is getting ready to increase nuclear and renewable energy use.

However, it also intends to build a sizable number of new coal-fired power plants. By 2030, Japan wants to reduce GHG emissions by 26% from 2013 levels.

Japan's achievements in the economy are the reason it was also chosen as a case study. But instead of just looking at its economic performance in terms of GDP doubling in the 1960s and then doubling again in 1970s and 1990s, a similar indicator of overall environmental performance is given. Over time, new technologies or management strategies may make it possible to support higher economic activity while having less of an adverse effect on the environment and increasing the productivity of environmental resources. The World Commission on Environment and Development's sustainable development goals, as well as Japan's Basic Environment Law and Basic Environment Plan JEA (1996); Rees (1992) and WCED (1987), have not been met, according to recent ecological footprint studies that shed light on current consumption levels. The environmental demands of the lifestyles and "advanced" technologies of the 1990s, however, are not compared to those of previous eras in the ecological footprint assessments that are currently conducted.

The Japanese government significantly increased its emissions objectives for 2030 in April 2021, establishing a new goal to reduce greenhouse gas emissions by 46% by 2030 relative to 2013 levels. October 2021 saw the Japanese government update its strategic energy strategy to take the new aims into account. According to the plan, 20–22% of electricity generation will come from nuclear energy by 2030, with the remaining 36–38% coming from renewable sources. Moreover, the percentages for coal, liquefied natural gas, oil, and hydrogen and ammonia will all be lowered to 19%, 20%, and 1%, respectively. This makes it rather evident that the administration wants to make renewable energy a significant source of electricity.

After Russia invaded Ukraine in February 2023, the Japanese government unveiled a core program to address the demand for a steady energy supply and to establish a decarbonized society. With the aim of restarting nuclear power facilities that have been put on hold, the core strategy fundamentally alters the prior nuclear policy of the Japanese government. In addition, by removing shutdown times from operating periods, the Japanese government hopes to encourage the building of next-generation reactors and extend the operational life of current nuclear power facilities beyond their 60-year lifespan. Close observation will be required to see how this policy change affects the growth of renewable energy sources that aren't nuclear. The ecological footprint of Japan is shown in Figure 1 from 1961 to 2022. It also demonstrates a structural break between 1979 and 1981. The ecological footprint reached its high in 1995 and began to drop as a result of investments made by the Japanese government in renewable energy and the implementation of stringent environmental legislation.

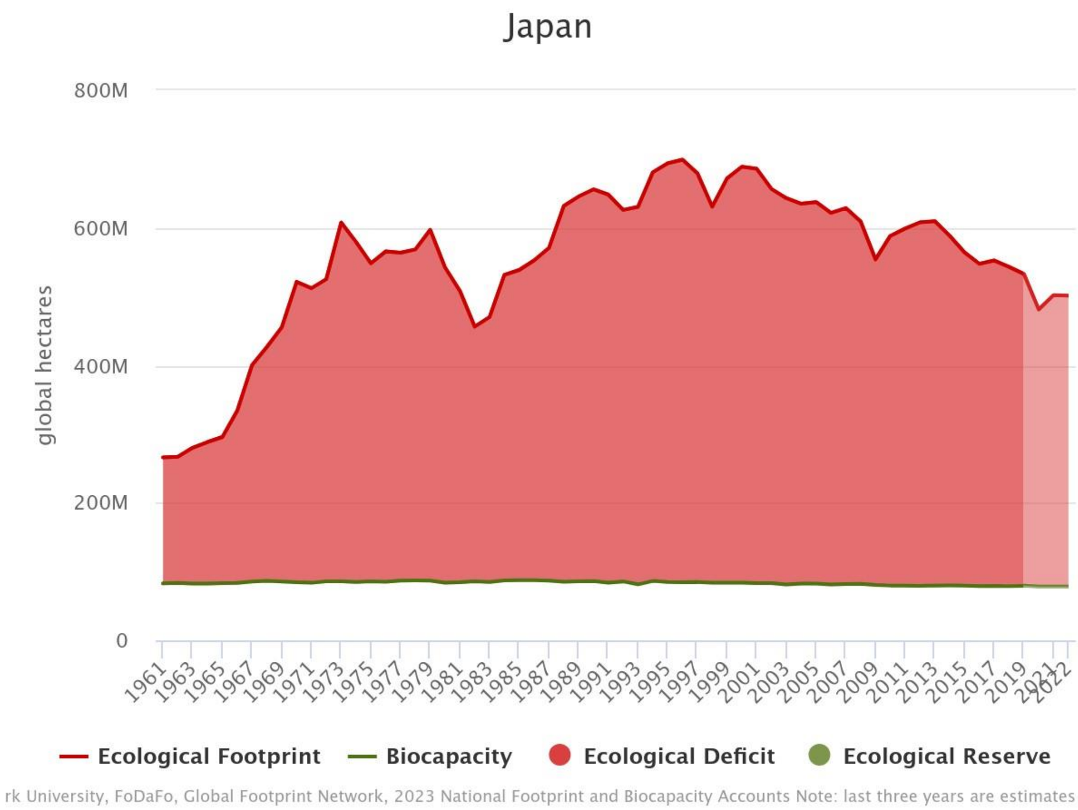

Figure 1: Ecological Footprint

This research contributes key points to the body of literature. The primary goal of this study is to answer the following crucial question. Given the significant threats that ecological imprint poses to environmental sustainability in Japan, how much can be done to reduce ecological footprint through the rule of law, regulatory quality, renewable energy consumption, economic growth, research and development, globalization and trade openness? Second, this research presents an extensive analysis in order to gain a deeper comprehension of the connections between ecological footprint, rule of law, economic growth, renewable energy, research and development, globalization and trade openness. Third, it also offers fresh data by investigating the dynamic relationship between dependent and explanatory variables. This is done by applying the Granger Causality Test, and ARDL technique to show how the relationship between these variables has changed over time. Through this, the impact of rule of law, economic growth, renewable energy consumption, regulatory quality, research and development, globalization and trade openness are evaluated in order to provide an empirical response to the research question. Fourth, although the environmental effects of ecological footprint have been studied in the energy literature to date, there is still a dearth of knowledge on the subjects of rule of law, regulatory quality, research and development and trade openness all of which need for more research in the case of Japan. Finally, policymakers must have a thorough grasp of how these explanatory variables affect ecological footprint in order to develop environmental policies that will effectively battle climate change. Therefore, this analysis provides strong evidence about how important it is to achieve climate change targets through the rule of law, research and development and trade openness.

The current body of research on the topic is outlined in the literature review section, which is followed by chapter 3 of this thesis, and chapter 3 focuses on globalization and energy consumption's effect on Japan's ecological imprint: The research performs an empirical examination of how energy usage affects Japan's environmental degradation. And chapter 4, explore the impact of Rule of Law, Regulatory Quality and R&D on Japan's environmental sustainability. The study uses the ARDL model to investigate how Japan's environmental imprint is affected by globalization, the rule of law, and the use of renewable energy. This has not been the subject of any prior research in the area. The concluding insight are presented in chapter 5.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This section presents the literature studies on the relationships of rule of law, economic growth, renewable energy consumption, regulatory quality, R&D, globalization and trade openness on ecological imprint. It seeks to offer a succinct overview of the numerous disputes pertaining to the nexus.

2.2 Renewable Energy and Ecological Imprint

The ecological imprint is one approach to measure how dependent humans are on natural resources. The quantity of environmental resources required to sustain a specific industry or way of life is measured. Recent studies, including those by Apergis & Ozturk (2015), Dogan & Seker (2016), with others have looked at the relationship between using renewable energy, GDP and environmental imprint, and they have discovered that renewable energy provides a positive link with both, but an inverse relationship with environmental degradation. In a (2019) study, Zafar et al. research was done on the effects of renewable energy utilization on carbon emissions in G-7 nations. The outcome demonstrated that the long-term elasticities of gross capital formation and GDP are both significant and advantageous. Additionally, they discovered that capital market operations result in lower carbon dioxide emissions in N-11 nations but higher emissions in G-7 nations. The researchers, came to the further conclusion that the environmental quality was improved by the usage of clean energy which reduce the intensity of carbon emissions into the atmosphere. Ben Jebli el al.,

(2019) demonstrated that while GDP and nonrenewable energy increase the amount of CO_2 in Tunisia, the consumption of clean energy only slightly reduces carbon emissions in that nation. In (2017) Zoundi studies the impact of renewable energy usage on carbon emissions to assess the reliability of the EKC across 25 African nations. Hence, the findings show clean energy significantly lowered carbon emissions, however the EKC claim was not true nationwide. However, Ben Jebli and BenYoussef (2017) asserted that renewable energy really causes a rise in carbon emissions in five Middle Eastern and Northern African nations (MENA). The cause of the disparate outcomes is that trash and flammable materials are used in the production of renewable energy. Usman et al. (2020) found out that while economic expansion as shown by real GDP benefits the environment, the degree of environmental quality in the USA is significantly higher when renewable energy is used. Similar evidence showing the adoption of renewable energy has an inverse influence on environmental degradation in G7 countries was shown by Ike et al. (2020) at panel and country-specific levels.

2.3 Economic Growth, Energy Consumption and Ecological Imprint

Several researches have also looked into the connection among energy use with economic expansion. Using data from 1971 to 2006, Odhiambo (2009) examined the relationship between energy use and GDP in Tanzania and he found a direct correlation between the two. Gozgor et al. (2018) examined the link between energy use and real economic growth in 29 OECD nations using the ARDL technique. To establish this connection, the researchers used a dataset spanning the years 1990 & 2013. The empirical findings demonstrated that Tanzania's GDP is accelerated by energy use. Magazzino (2012) used annual data from 1883 to 2009 to conduct cointegration analysis and Granger causality tests to investigate the link between disaggregate energy production and real aggregate income in Italy. With the exception of nuclear-thermoelectric energy, the long-run causality study demonstrates a bi-directional flow between each energy source and GDP in the period 1946–2009. Shabaz et al. (2018) examined the connection among economic expansion and energy use, using quarterly data from 1960 to 2018 and using the top 10 energy-consuming nations as an example. Quantile-on-quantile was utilized by the authors to establish the relationship. The findings show that energy use and GDP interact favorably. Using data for the years 1971 to 2016 and wavelet coherence, Odugbesan and Adebayo (2020) discovered a favorable correlation between South Africa's GDP and CO_2 emissions. According to Khan et al.'s (2020) analysis of the G7 nations, economic expansion has a beneficial effect on environmental degradation. Saidi and Hammami (2015) also looked at the relationship between environmental sustainability and actual growth in the economies of the Caribbean, Europe, North and South America, and North Africa between 1990 and 2012. The researchers used GMM, and the results showed that energy use promotes economic growth. In contrast, Ahmed et al. (2020) found no significant correlation between CO_2 and real growth for Myanmar from 1975 to 2015 using the ADRL and bootstrap-corrected causality tests. Economic expansion and the use of non-renewable energy caused a rise in environmental damage, according to findings by Ahmed et al. (2017) on the relationship among CO_2, GDP and trade liberalization in Southeast Asian Countries (ASEAN). Akadiri & others (2019) used data of 1972 to 2017 to examine the effect of energy use on Iraq's GDP using ARDL and T-Y causality methods. The study's findings provided no proof that real growth and energy use are related causally. Eweade et al. (2022) investigate the relationship between economic growth, trade openness, natural gas consumption, gross fixed capital formation and CO_2 in Japan from 1980 to 2020, using Toda and Yamamoto approach to causality.

The outcome revealed bidirectional causality between economic growth and CO_2 and unidirectional causality between economic growth and natural gas usage. Using data from 1971 and 2017, Ha and Ngoc (2020) looked at how energy usage in Vietnam affected economic growth. The researchers used Granger causality and NARDL. Empirical findings indicated a causal association among GDP and energy usage. Rafindadi & Ozturk (2016) in Japan, found that economic expansion and financial sector development have a beneficial effect on energy usage, using the Cobb-Douglas production function.

When Dogan & Turkekul (2016) explores the relationship among carbon emissions, energy usage, economic expansion (GDP), the squared of economic growth (GDP2), trade liberalization, urbanization, and financial market in USA for the period of 1960–2010, they discovered a significant relationship exists between energy usage, carbon emissions, and economic growth. Researchers again demonstrated that, expansion of urbanization in tandem with an effective energy policy has the capacity to reduce CO_2 emissions in the short and medium terms while preserving output. Magazzino (2016) investigates the connection between Turkey's real GDP, carbon emissions, and energy usage in the South Caucasus countries between 1992 and 2013. The causality findings demonstrate that, in the case of Armenia, the "conservation hypothesis" is accurate, but we reached mixed conclusions for Azerbaijan and Georgia because both the "feedback hypothesis" and the "growth hypothesis" were supported by empirical data. And there is no proof of a causal relationship for Turkey, supporting the "neutrality hypothesis". Mountinho et al., (2018) carried extensive research on 23 top nations, other regions of the entire world, and the factors affecting CO_2 emissions using 26 years of data. They determined six criteria in order to recognize, measure, and clarify the real causes of change in the total energy-related carbon dioxide emissions in those nations. Their research findings make it abundantly clear that the major causes of overall and negative changes in carbon emissions are the effectiveness of clean energy sources, as well as effect of financial market on the production of renewable power as a proportion of GDP. Additionally, Dogan & others (2019) examined the correlation between the ecological imprint, economic growth, fossil fuel, renewable resources, trade openness, urbanization, and financial market for Mexico, Indonesia, Nigeria, and Turkey using autoregressive distributed lag (ARDL) model. The outcomes indicated that financial sector development had a detrimental effect on ecological imprint in Mexico, Indonesia, Nigeria, and Turkey. While exports facilitated the deterioration of the environment in MINT countries. In MINT countries, urbanization and the usage of fossil fuels both have a substantial impact on the deterioration of the environment. The EKC hypothesis was recently studied for European countries between 1980 and 2014 in the context of economic structure by Dogan and Inglesi-Lotz (2020). Because economic growth has an effect on carbon emissions, an inverted U-shaped correlation among these factors was discovered in a study nation group. Although, when industrial share was utilized as a stand-in for economic structure, the EKC theory was not supported by the U-shaped relationship among economic expansion and CO_2 emissions.

The analyzed empirical research make it evident that a number of studies have looked into the connections between CO_2, GDP, globalization, and renewable energy consumption. However, using the ARDL method, no preceding study has thoroughly examined the causal relationship between GDP, globalization, renewable energy consumption, and natural gas use, which serves as a proxy for nonrenewable energy in the case of Japan. ARDL has the benefit of being able to capture the causality and connections between series at various orders of cointegration. As a result, the current study closes a gap in the body of knowledge.

2.4 Rule of law, Regulatory quality and Ecological Imprint

Regulations are the rules and laws that the government adopts, and violators face fines or other penalties Coglinanese, (2012). The state uses regulation as a tool to accomplish its objectives, one of which is to promote environmental sustainability. The efficacy of a rule can be evaluated based on its capacity to accomplish its objectives. The state's environmental performance is determined by the regulatory quality, which is linked to environmental sustainability Esty and Porter, (2001). According to Scruggs (1999), strict regulations encourage adaptable cooperation between the state and business in order to improve environmental performance. Three metrics are mentioned by OCED (2008) to assess the quality of regulations: 1) transparency, 2) nondiscrimination, and 3) efficiency. Good and exceptional regulations assist the state in achieving goals of public policy, such as safety, public health, and environmental sustainability (Treasury Board of Canada Secretariat, 2011). Laws are necessary for social welfare, economic development, and environmental preservation. One of the best ways for governments to encourage trade, investment, and economic development is through regulatory reform and regulatory management Tracey & Anne (2008). Global Bank clarifies. Regulatory quality is the perception of the government's ability to enact and enforce reasonable laws and regulations that permit and promote the expansion of the private sector. The way regulations are formulated and created has a significant effect on the standard of a country's regulatory framework. Governments want to make sure that the rules they enact promote social welfare, economic growth, and environmental standards Malyshev (2008). Adequate regulation can offer substantial assistance in addressing these obstacles. On the other hand, inefficient regulation will impede growth, hinder recovery, sabotage attempts to handle complicated problems like climate change, and increase public mistrust of the government OECD (2010).

We also need to acknowledge regulatory quality in order to attain environmental sustainability. According to Dannbach & Mintz (2011), environmental legislation is crucial to attaining sustainability because it offers the organizations and instruments needed for sustainable governance. We will need to create and put into place rules and legal structures that either do not already exist or exist in a very different form if we are to make any kind of progress toward a sustainable society, let alone achieve sustainability Dernbach and Mintz (2011).

2.5 R&D and Ecological Imprint

Technological innovation as a means of tackling climate change challenges and attaining sustainable development has received a lot of attention in the economic literature in recent years, particularly in the energy sector Costa Campi et al. (2015) and Sayegh et al. (2017). A few contributions (Stevanović, et al., 2016) have examined the technological transformation process. Others research the best energy technologies to use to satisfy the need for power while accounting for environmental and economic factors for the case of China; see Koltsaklis et al., 2014, 2015, and Georgiadis, (2015) for the Greek case. Refer to Delarue et al. (2009) for Belgium. Christodoulakis et al. (2000) concentrate more intently on the Community Support Framework's program effects regarding CO_2 emissions and energy use, as well as the introduction of natural gas into Greece's energy mix.

Innovation's drivers and obstacles have also received a lot of attention. Two opposing strategies—one technological, one economic—are the subject of the discussion. The first contends that only market failures—such as incomplete information, public policy ought to handle R&D spillover effects, often known as agent-principal issues Sutherland, (1991); Jaffe and Stavins (1994). Whether or not these market failures occur, the technical approach contends that public policy must handle all the challenges, as per the findings of Trianni and Cagno (2012), Brown (2001), Hirst and Brown (1990), and restricted rationality and uncertainty. The need of enacting policies targeted at lowering and/or getting rid of all barriers and market failures is highlighted in the most recent literature Backlund et al., (2012). As a result, numerous studies have examined the various causes of the failure of numerous industries to implement innovations Jaffe et al. (2004); Horbach et al., (2012).

According to certain empirical research Jakobsen & Clausen, (2016); Leiponen & Helfat, (2010), environmental goals should be adopted by businesses because they both directly and indirectly influence the process of innovation. Costa Campi et al. (2015) investigated the extent to which inventive companies make energy efficiency advancements a priority in their research. Their findings for industrial companies in Spain demonstrate the significance of enterprise scale for energy efficiency innovation. Furthermore, they discovered that businesses are more inclined to innovate for the purpose of improving energy efficiency if their goal is to reduce environmental impacts.

Recent research has shown a particular interest in studies that have attempted to establish an empirical relationship between GHG emissions and economic agents' inventive activities as assessed by R&D. Ruiz (2010) conducted an analysis of the correlation between the energy intensity levels observed in the EU-15 member states between 1974 and 2007 and the public funds allotted to energy research. In order to achieve this, he specified a model error correction and performed a Granger causality study. The findings demonstrate that, while there is a two-way causal relationship between energy intensity and public R&D in energy over the long run. Public funding for energy research contributes to a reduction in the intensity of energy consumption in the near term. Using panel data for 13 advanced nations from 1980 to 2004, Garrone and Grilli (2010) investigated the relationship between public R&D in energy and CO_2 emissions per unit of GDP and its two components, energy intensity and carbonization factor. The findings support the notion that increasing public spending on R&D alone will not suffice to enhance the innovation process. Public investment for energy research and development has helped increase the country's energy efficiency, but it has had no impact on emission intensity or the carbonization factor. Using the Environmental Kuznets Curve model, Cantos and Balsalobre (2013) demonstrate that public investment on the amount of energy-related R&D and innovation projects is inversely correlated with Spain's emissions of greenhouse gases.

The various forms of energy consumption and energy research and development's short- and long-term elasticities were estimated by Wong et al. (2013) to Chow (2013) provides an overview of Chinese environmental policy. variations in the 20 OECD countries' income and oil prices between 1980 and 2010. They discovered that the demand for coal had a negative income elasticity, whereas the demand for oil and gas had a positive income elasticity, indicating the significance of economic expansion in promoting the adoption of greener energy sources. They discovered that the consumption of fossil fuels stimulates the research and development of fossil fuels, which in turn promotes fossil fuel use due to the dynamic interactions between R&D and energy consumption. Lee and Min (2015) found a positive link between green R&D and firm-level financial success, but a negative correlation between carbon emissions and green R&D using a sample of Japanese manufacturing enterprises from 2001 to 2010.

2.6 Globalization and Ecological Imprint

Globalization has a good and bad effects on pollution emissions, according to numerous academics who have investigated the linear relationship between globalization and CO_2 emissions Doytch & Uctum, (2016); Khan et al., (2019). Ecological footprint has become a more important instrument in environmental research in recent years to help comprehend anthropogenic environmental stresses and their effects. By applying panel regression techniques to a dataset of 171 nations and utilizing the Maastricht Index as a globalization indicator, Figge et al. (2017) started a discussion about the possible impact of globalization on footprint. Their paper's conclusions imply that globalization increases a country's footprint, but the index's breakdown into its three parts reveals that the sole factor reducing footprint is the political one. Interestingly, the results of a comparable study by Rudolph and Figge (2017), which used the same KOF index to examine the short-run effect of globalization on footprint in a panel of 146 countries from 1981 to 2009, were very different. They came to the conclusion that the main cause of ecological footprints is economic globalization, but the sole factor that negatively affects footprints is social globalization. Globalization in politics, however, has little bearing on the environmental stresses brought about by human activity. However, these studies only looked at the association in the short term, which may not hold true over the long term.

Sabir and Gorus (2019) investigated the effects of globalization on footprints in Asian nations after this research. They contend that, regardless of the globalization proxy employed, human activity increases environmental stressors and footprints. Their work is not without flaws, though; for example, they employed panel ARDL in the face of cross-sectional dependence (CD). Notably, figures may be skewed due to PMG's incapacity to counter CD. Comparable to this research, Saud et al. (2020) examined, from 1990 to 2014, the relationship between footprints in 49 Belt and Road nations and globalization. They claimed that globalization reduces environmental deterioration by lowering footprints and other important environmental indices, in contradiction to Sabir and Gorus's (2019) findings. Nevertheless, the outcomes of the analyses that were done for each country showed that the results varied.

Moving on to time-series research, Ahmed et al. (2019) proposed that as variables like globalization can have both positive and negative effects on the environment, and because their relationships may vary between nations, the examination of time series is more helpful in determining the precise impact of these variables. Nevertheless, their examination of Malaysia from 1971 to 2014 did not show that the footprint was significantly impacted by globalization. The results were not noteworthy even after breaking down globalization into its three constituent parts. It's interesting to note that Suki et al. (2020) used the ARDL approach and data conversion to explore this relationship in Malaysia at the quarterly frequency. They come to the conclusion that whereas the other two components decreased footprint, economy and globalization as a whole raised footprint. On the other hand, Ibrahiem and Shaimaa (2020) report that, between 1971 and 2014, globalization decreased Egypt's footprint using DOLS and FMOLS.

2.7 Trade Openness and Ecological Imprint

Sun et al. (2020) looked into how trade openness affected ecological harm in Sub-Saharan African countries between 1990 and 2014. The study used FMOLS and DOLS to ascertain the long-term equilibrium linkage of the series. The analysis supported the EKC hypothesis, which suggested that, once commerce reached a certain threshold, it would eventually contribute to a reduction in environmental pollution in this region. Furthermore, You et al. (2021) examined the relationship between environmental impact and trade openness in the United States from 1990Q1 to 2018Q4. The long-run connection between the covariates was investigated using correlated component regression, FMOLS, and DOLS techniques. The research conclusions show that trade openness has a long-term negative impact on environmental sustainability. This indicates that increased trade openness has caused the United States' carbon emissions to rise.

Additionally, from 1970 to 2019, Dong et al. (2021) looked into the potential effects and internal mechanisms of trade openness on ecological harm in China, Japan, and South Korea. The research examined the connection between these countries' environmental and trade openness using panel regression techniques. The assessment indicates that trade openness is becoming more and more influential in causing environmental destruction, but that the signing of the Regional Comprehensive Economic Partnership trade agreement by these countries may lessen the impact of trade openness on ecosystem destruction. Once more, the results showed that exports significantly reduce a country's environmental damage while imports cause increasing environmental harm. Additionally, it was demonstrated that increasing trade openness has three main effects that have an effect on carbon emissions that is both direct and indirect (i.e., structure effect, technological effect, and scale effect). Finally, the study found that trade openness and environmental degradation are causally related.

Furthermore, Chen et al. (2021) used panel data from BRICS nations between 2001 and 2019 to investigate the relationship between trade openness and ecological degradation. In the investigation, the panel quantile regression technique was applied to explore at the connections between the factors. The empirical findings demonstrate a strong positive relationship between trade openness and the reduction of ecological degradation. This suggests that environmental concerns are made worse by growing trade openness. Furthermore, it was discovered that trade openness had a negative indirect effect on environmental degradation but a favorable indirect influence through the economic effect through the substitution of energy and the technology effect.

Additionally, Wang et al. (2023) looked into the relationship between 208 countries' carbon emissions and trade openness. The study used the FMOLS and GMM estimators to evaluate data from 1990 to 2018. The study's conclusions demonstrated that trade openness has a significant effect on lowering carbon emissions, but only in nations that show a modest decoupling upon approaching the turning points of the EKC. In a similar vein, Li et al. (2021) examined the connection between trade openness and carbon emissions across 147 countries using data from 1990 to 2015. Trade openness is linked to a decrease in environmental deterioration, according to research that used the FMOLS regression and Granger causality approaches. Furthermore, the outcomes confirmed that there is the result of a one-way causal link between carbon emissions and trade liberalization. Similarly, from 1996 to 2015, Osei-Assibey et al. (2022) investigated the relationship link environmental quality and trade openness in 134 different nations. Using the model of threshold regression, the study found that increased trade openness increases environmental pressure.

Additionally, Wang et al. (2023) utilized data from 56 countries and the threshold panel model to analyze how trade openness affects emissions of carbon. The investigation's findings showed that trade encourages rise in carbon emissions. Last but not least, from 2000 to 2018, Wang et al. (2023) carried out an extensive investigation analyzes the relationship between trade liberalization and carbon emissions in 124 countries. The structural threshold model and the Tapio decoupling model were applied in the investigation. The findings showed that inadequate decoupling was the main condition of the connection between carbon emissions and trade openness. Once more, the analysis found two thresholds for the relationship between trade openness and carbon emissions. Contrary to what trade protectionists assert, trade openness reduces carbon emissions once certain structural breakpoints are reached and helps achieve global carbon neutrality. Trade openness at the subregional level encourages carbon neutrality in wealthy nations but not in less developed nations.

In conclusion, there is significant disagreement in the previous studies on this subject. The rule of law, economic growth, renewable energy use, regulatory quality, R&D, globalization, and trade openness have all been found to have differing effects on ecological footprint in earlier research, most of which employed panel data. Additionally, the review of the literature suggests that when analyzing the environmental effects of the regressors, most researchers have substituted CO_2 emissions for ecological footprint. In the context of Japan, the third-largest economy in the world, very few empirical studies have examined the relationship between trade openness, globalization, R&D, regulatory quality, and the rule of law and its impact on the environment. Therefore, this paper aims to fill the gap identified in the literature.

Chapter 3

GLOBALIZATION AND ENERGY CONSUMPTION'S EFFECT ON JAPAN'S ECOLOGICAL IMPRINT: IMPLICATIONS FOR ENVIRONMENTAL SUSTAINABILITY

3.1 Introduction

Japan was among the nations that took part in Paris Conference of December 2015 which determine ways to halt climate change and reduce greenhouse gases (GHGs). The historic Paris Accord's main goal is to continue reducing global warming up to 1.50°C while keeping it below 20°C over pre-industrial levels (IEA, 2018). The fourth-largest importer of coal, petroleum products, and liquefied natural gas in the world is Japan. Since 2012, the nation's primary annual energy consumption has been met by less than 10% of its domestic energy resources, which are insufficient. With a GDP of $US4.872 trillion, Japan ranked third in terms of economy in the world after China. Also, the seventh-largest generator of greenhouse emissions globally. It delayed its clean air efforts after the Fukushima nuclear incident of 2011, that caused it to give up nuclear power and raise its reliance on fossil fuels. Increasing the green nuclear power is something the Japanese government is currently planning to do.

It is crucial to address climate change and the environment's impact, and Japan has declared that its goal is to become carbon neutral. To achieve net-zero greenhouse gas emissions is to be carbon neutral. In 2019, 1.210 billion tons of GHG were released in Japan, of which CO_2 from energy sources accounted for 85%. (Emitted from fuel combustion activities). Therefore, reducing GHGs associated with energy will be a major problem in the future. Making efforts to achieve carbon neutrality is crucial for the entire globe, not just Japan (IEA, " CO_2 Emissions from Fuel Combustion Highlights 2020"). In recent years, there has been an exponential increase in interest in sustainability, along with strong scientific evidence that human activity affects the global climate. The mild Japanese climate is becoming progressively warmer due to global warming, which is anticipated to have a considerable influence on energy use and associated CO_2 emissions (JMOE). In 2002, the Japanese government accepted the Kyoto Protocol and started making efforts to build a society with minimal carbon emissions. As a result, in 2008, the Japanese Prime Minister unveiled a new vision dubbed "Towards a Low-Carbon Society," which involves setting a long-term goal to cut CO_2 emissions by 60 to 80 percent by 2050 compared to the level in 1990 "2050 Japan Low-Carbon Society" scenario team (2008).

Global warming, which is characterized by global climate variation, is one of the most important environmental turbulences of recent decades. Increased human activity is largely to blame for the expansion of the global economy with the assistance of factors of production and other production inputs Owusu, P. A., & Asumadu (2016). Although, natural resources competition between creatures, particularly humans, have been connected to environmental damage. The primary factor contributing to the environment's declining is still carbon emissions. According to studies, CO_2 emissions have raised by almost 46% over the previous 130 years Lin et al. (2018). Along with the release of CO_2 from plants, animals, and other sources, carbon emissions have primarily been related with the usage of energy sources. Sadly, CO_2 continue to be harmful to the ecosystem and are a significant debating point in the international discussion of global warming. Lowering carbon emissions, which are majority of anthropogenic GHGs about 81% of GHG, has thus gradually become important for the global affluent countries Owusu & Asumadu-Sarkodie (2016). This is due to carbon emissions continuing to be the most serious concern that the natural environment and human beings have ever encountered. Anthropogenic carbon dioxide, which also increase the earth's temperature, heat the atmosphere. Based on a report from the Intergovernmental Panel on Climate Change, gaseous emissions increased to 34649.4 million tons in 2011 compared to 943.4 million tons in 1961,5th Assessment Report, (2014).

The British Petroleum Statistics Assessment of Global Energy British Petroleum; (2018) made the following observation: CO_2 emissions was 33,444.0 million tons in 2017, from 29,714.2 million tons in 2009.Notwithstanding the 2015 Paris Agreement and member nations' robust efforts to cut carbon emissions, the BP analysis shows that between 2006 and 2017, world’s carbon dioxide emissions climbed by 1.61%. It's significant to note that between the aforementioned times, the European region's CO_2 emission growth rate, which trails only the Middle Eastern countries, was 2.55 percent British Petroleum, (2018). As a result, the continent has continuously led the fight against climate change. Even after seeing that its commitment was fulfilled during the first phase of Kyoto Protocol (2008–2012). Other objectives were set to account for a change in the region's carbon emission decomposition factors. Existing literature has highlighted the dynamics that change the amount of energy-related CO_2 emissions and economic expansion, non-renewable energy component, component of clean energy and other important elements are a few of these driving forces (Apergis et al. 2010; Al-mulali,(2012); Asumudu & Owusu, (2016); Inglesi-lotz & Dogan, (2018); Nguyen & Kakinaka, (2019). The entire amount of revenue made from the resource's extraction, is specifically expected to impact the EU-28's economic growth and carbon reduction policies.

Many researchers across globe investigates the connections among controversy that surrounded the environment, GDP, and energy usage during the recent decades. It has gained widespread acceptance, that energy serves as an important element in making all factors of production work effectively and efficiently. Energy is crucial for the growth and prosperity of the economy Shahbaz et al. (2019) and Udemba et al. (2020). Energy is important for economic expansion, but it also harms the environment which includes greenhouse gas pollution and global warming Ouyang et al., (2019); Al-mulali el al., (2021). The 2015 Millennium Development Goals Report states that between 1990 and 2015, global CO_2 emissions grew by more than 50%. Clean air and a stable favorable weather are by far the most crucial indices needed for life, carbon dioxide is regarded to be the biggest hazard and obstacle for all governments worldwide. Though, a number of experts recently discovered that a nation's economic expansion is boosted by environmental degradation Shahbaz et al. (2018); Udemba el al., (2020). According to this, a nation's exposure to CO_2 emissions would increase as its economy became more industrialized.

The fact that Japan has stated its intention to attain net-zero greenhouse gas emissions by 2050 and that its total GHG emissions as of (2019) were 1.21 billion tons, 85% of which were related to energy, served as the motivation for this study.

The purpose of this research is to examine the effects of economic expansion, globalization, and energy use on Japan's ecological imprint and their implications for long-term environmental sustainability. Additionally, in order to suggest practical solutions, such as investing in green manufacturing technology that could lower CO_2 emissions was suggested for Japan. By proposing a control variable and a prospective methodology that is better suitable for a country like Japan, this work is expected to add new knowledge to the body of existing literature on energy consumption research. Secondly, plans for environmental sustainability should be developed and put into action by researchers and policymakers. Thirdly, this study raises awareness of the need to save the ecosystem and sustain it in the face of the threat posed by climate change. This essay's major aim is to look into how Japan's ecological imprint is affected by globalization, GDP, and energy use. Within the framework of this primary goal, the following questions are addressed.

1) What are the effects of globalization, GDP and energy consumption on Japan's ecological imprint?
2) Is there any significant effect of globalization, GDP and energy consumption on Japan's ecological imprint?

3.2 Methodology

3.2.1 Data and Methodology

This research work makes use of time series data ranging from the period 1990 through 2021. Ecological imprint which is a proxy for carbon dioxide (CO_2), is expressed in kilotons (kt), renewable energy usage, which is measure as a proportion of total final energy usage, and natural gas rent, which serves as a stand-in for nonrenewable energy consumption. As a stand-in for actual output, the GDP per capita in constant US (2015) dollars is used. The globalization is lastly determined by taking into account the economic, social, and political dimension. Political, social, and economic globalization, each account for 26%, 38%, and 36% of the total. This assessment follows Dreher (2006), and the data were obtained from World Development Indicators (WDI), and KOF Swiss Economic Institute (SEI).

3.2.2 Model Specification

We derive this empirical model from Al-mulali el al. (2015), and Destek & Sinha (2020).

CO_2 = f (GDP, GLO, RENEW, NATGAS). (1)

Where GDP represents real output, GLO measures globalization, CO2 represents ecological imprint, and NATGAS represents natural gas rent. To reduce data inconsistency and make it easier to evaluate the findings, all variables are translated into their log forms.

$$LNCO_{2t} = \alpha_0 + \beta_1 LNGDP_t + \beta_2 LNGLO_t + \beta_3 LNRENEW_t + \beta_4 LNNATGAS_t + \mu_t \qquad (2)$$

Where; LN represents natural log, α_0 indicates intercept, $\beta_1 - \beta_4$ denotes the slope of the parameters; μ_t= stochastic variable or disturbance variable and the a priori expectations are expected to be $\beta_1 > 0$ - $\beta_4 > 0$. From the equation (1), $LNCO_2$ represents the carbon dioxide emission, LNGDP represent GDP per capita, LNGLO represents the global index of economic, social, and political dimension of Japan, LNRENEW denotes renewable energy consumption of Japan and, LNNATGAS depicts the total natural gas rent of Japan.

3.2.3 Descriptive Statistics and Plots of the Variables

Table 1: Descriptive Statistics of the Variables

	$LNCO_2$	LNGDP	LNGLO	LNRENEW	LNNATGAS
Mean	13.968	10.387	4.232	1.556	-5.930
Median	13.971	10.395	4.244	1.490	-5.684
Maximum	14.048	10.494	4.360	2.039	-4.885
Minimum	13.893	10.254	4.014	1.252	-7.255
Std. Dev.	0.041	0.068	0.102	0.233	0.775
Skewness	-0.032	-0.143	-0.559	0.848	-0.409
Kurtosis	2.136	1.972	2.193	2.494	1.658
Jarque-Bera	0.999	1.517	2.536	4.180	3.295
Probability	0.606	0.468	0.281	0.123	0.192
Observations	32	32	32	32	32

Descriptive statistics were used over the course of the study period to acquire deeper acknowledge of the distribution and dispersion of the data used for the analysis as shown in Table 1. It displays the variables in their logarithmic form, with the natural log of CO_2 having a min. and max value of 13.893 and 14.048, the log of GDP having a min. and max values of 10.254 and 10.494, the globalization index having a min & max. value of 4.014 & 4.360. The min and maximum values for the log of natural gas rent are -7.255 and -5.684, while the values for the log of renewable energy are 1.252 and 2.039. Similar to the natural log of economic growth has a mean and median of 10.387 and 10.396, the natural log of the globalization index has a mean and median of 4.231 and 4.244, the natural log of natural gas has a mean and median of -5.930 and -5.684, and the natural log of renewable energy has a mean and median of 1.557 and 1.490. The natural log of CO_2 has a mean and median of 13.968 and 13.972 respectively. Additional findings display the variables' Standard deviation, skewness, and kurtosis.

Considering their probabilities are more than 5% level of significance, the Jaque-Bera likelihood demonstrates that $LNCO_2$, LNGDP, LNGLO, LNRENEW, and LNNATGAS are normally distributed variables. While NLRENEWABLE exhibits a positive trend, $LNCO_2$, LNGDP, LNGLO, and LNNATGAS are all negatively skewed variables. Additionally, the variables' low standard deviations imply that none of the variables are particularly volatile.

The plots of the series shown in the figure 1 below shows that while CO_2, natural gas rent, and renewable energy show variations because of structural breaks, GDP and the globalization index are heading upward. Over the sample period, the variable globalization shows no signs of a break in its increasing trend.

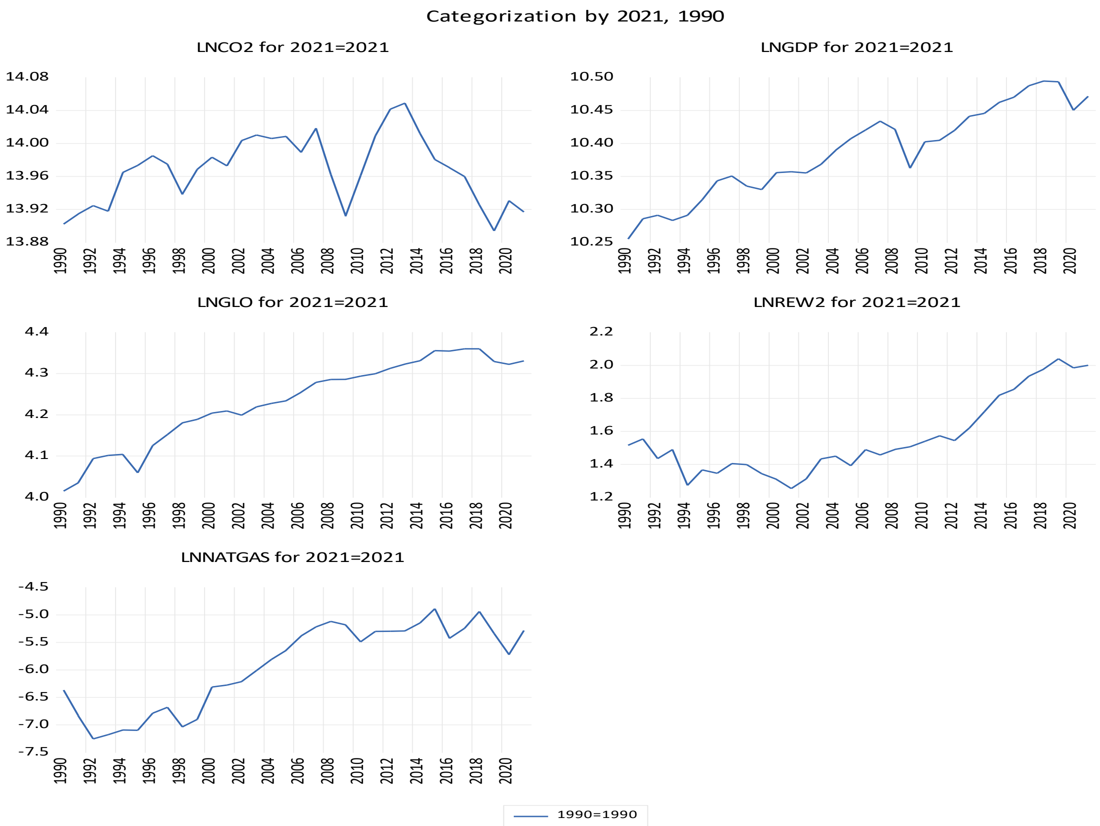

Figure 2: Graphical Illustration showing the Trend of the Variables

We used a correlation matrix to determine how the model's variables interacted with one another. The correlation matrix's signs and values reveal the direction and degree of relationship between the variables. The correlation is higher the closer it is to 1 and weaker the closer it is to 0 in the Pearson correlation estimate. The signs of the correlation suggest a direct relationship when it is positive and an inverse relationship when it is negative.

Estimates of the variables' Pearson correlation coefficients are shown in table 2. It demonstrates a slight but positive association between natural gas rent and CO_2, GDP, and the globalization index. However, there is weak and inverse link among CO_2 emissions and renewable energy usage.

Table 2: Pearson Correlation Estimates

Probability	LNCO2	LNGDP	LNGLO	LNRENEW	LNNATGAS
LNCO2	1.000000				

LNGDP	0.203559				
t-Statistic	1.138781	1.000000			
p value	0.2638	-----			
LNGLO	0.252500				
t-Statistic	1.429312	0.946411	1.000000		
p value	0.1632	16.05037	-----		
		0.0000	-----		
LNRENEW	-0.339368				
t-Statistic	-1.976070	0.753006	0.659768	1.000000	
p value	0.0574	6.267930	4.808844	-----	
		0.0000	0.0000	-----	
LNNATGAS	0.244198				
t-Statistic	1.379283	0.868888	0.887007	0.614037	1.000000
p value	0.1780	9.614171	10.52145	4.261136	-----
		0.0000	0.0000	0.0002	-----

The estimations of the Pearson correlation coefficient between the pairs of variables are shown in the table. The correlation coefficient's significance is shown by the t-statistics, and the marginal probability is shown by the p value.

Based on Dancey & Reidy (2007), the Pearson association estimate reveals that $LNCO_2$ has weak and positive correlations with LNGDP (0.203), LNGLO (0.253), and LNNATGAS (0.244), as well as weak and negative correlations with LNREW (-0.339). Similarly, LNGDP shows a strong and positive correlation with LNGLO (0.946), LNRENEW (0.753), and LNNATGAS (0.869). Once more, there is a significant and high association with LNGLO and LNNATGAS (0.887) and also a positive and moderate correlation with LNRENEW (0.659). Lastly, there is a positive and moderate association between LNRENEW and LNNATGAS (0.614).

3.2.4 Unit Root Tests

Investigating the series stationary features, which are important in is the study's initial objective, the study uses both ADF Augmented Dickey Fuller (1981) founded by Dickey & Fuller and the Philips-Perron (PP) test created through Phillips & Perron in 1988. In order to evaluate the integration order of the series, it is imperative to employ more than one unit root test, according to numerous researchers (Odugbesan & Adebayo 2020). Equations 3 and 4 show how the ADF & PP tests work.

ADF test:

$$\triangle Y_{t}=\beta_{Dt} + {}_{\pi}\triangle Y_{t-1} + \sum_{j=1}^{p} \theta \triangle Y_{t-1} + \varepsilon_t \tag{3}$$

The error variable has no serial correlation and is represented through ε_t, where the deterministic variable is represented by Dt.

PP **test:**

$$\triangle Y_{t}=\beta_{Dt} + {}_{\pi}\triangle Y_{t-1} + \mu_t \tag{4}$$

Table 3: ADF

Variable at Level	Intercept	Probability	Trend & intercept	Probability	Conclusion
$LNCO_2$	-2.5665	0.1109	-2.3587	0.3921	-
LNGDP	-1.5729	0.4841	-3.1625	0.1104	-
LNRENEW	0.2431	0.9711	-2.0088	0.5739	-
LNNATGAS	-2.3889	0.1547	-0.8144	0.9506	-
	First Difference				
$D(LNCO_2)$	-4.7093	0.0007***	-3.7277	0.0390**	I (1)
D(LNGDP)	-5.7548	0.0000***	-5.6658	0.0004***	I (1)
D(LNGLO)	-5.3303	0.0002***	-5.9153	0.0002***	I (1)
D(LNRENEW)	-6.4336	0.0001***	-7.6271	0.0001***	I (1)
D(LNNATGAS)	-3.1531	0.0340**	-1.8023	0.6731	I (1)

Table 4: PP

$LNCO_2$	-2.3614	0.1604	-2.0141	0.5711	-
LNGDP	-1.7331	0.4054	-2.7620	0.2209	-
LNGLO	-5.5309	0.0001***	-1.4323	0.8308	I (0)
LNRENEW	0.3321	0.9763	-1.9983	0.5794	-
LNNATGAS	-0.7800	0.8108	-2.5936	0.2855	-
	First Difference				
$D(LNCO_2)$	-4.6710	0.0008***	-6.5447	0.0000***	I (1)
$D(LNCO_2)$	-4.6710	0.0008***	-6.5447	0.0000***	I (1)
D(LNGDP)	-8.1353	0.0001***	-8.9904	0.0002***	I (1)
D(LNGLO)	-5.3515	0.0001***	-12.0740	0.0001***	I (1)
D(LNRENEW)	-6.3510	0.0000***	-8.5384	0.0000***	I (1)
D(LNNATGAS)	-5.2864	0.0002***	-5.2125	0.0011***	I (1)

Table 3 and 4, indicate the stationarity of the series. ADF and PP tests reveal the existence of a unit root using 5% level of significance. When using the ADF technique, none of the variables are stationary at level I (0). Every variable is stationary at first difference I (1), and at the 5% level of significance, the null hypothesis is rejected.

All of the variables were analyzed using the logarithm form and p-values and t-statistics (intercept and the trend intercept). At 1% and 5% significance levels, the asterisks (***) & (**) in table (3) and (4) denote that the assumption the variables have unit roots has been rejected. The unit root model built to depict the general model form where a pattern is presented in each model started with an intercept parameter, as shown in the table 3 and 4. Evidence from experiments showed that one of the variables of interest, the globalization index (LNGLO), which is stationary at a level and is integrated at order zero I(0) using PP. Additionally, it had been established that every other variable was stable at the initial difference, and that they were variables or first-order integration.

3.2.5 Co-integration Using the ARDL Model and Bounds Test Technique

The limits test technique for co-integration has been used in this investigation to examine the connection between the factors of interest, provided adequate criteria for the dataset and underlying characteristics were met. Numerous distinct benefits of the ARDL technique have been found by Kripfganz and Schneider (2019) including the using co-integration testing due to the ability to incorporate factors at different lags and given that none of the series is I (2).

In order to estimate a long-run relationship, the ARDL bounds testing approach of cointegration basically requires two steps. The first step is to determine whether there is a long-term link between each of the equation's variables. The ARDL model for equation (2) above may follow as:

Short–run Equation:

$$\Delta LNCO2_t = \alpha_0 + \sum_{i=1}^{q_1} \beta_1 \Delta LNGDP_{t-i} + \sum_{i=1}^{q_2} \beta_2 \Delta LNGLO_{t-i} + \sum_{i=1}^{q_3} \beta_3 \Delta LNRENEW_{t-i} + \sum_{i=1}^{q_4} \beta_4 \Delta LNNATGAS_{t-i} \quad (5)$$

Long-run Equation:

$$LNCO2_t = \alpha_0 + \phi_1 LNCO2_{t-1} + \phi_2 LGDP_{t-1} + \phi_3 NGLO_{t-1} + \phi_4 LNRENEW_{t-1} + \phi_5 LNNATGAS_{t-1} + \mu_t \quad (6)$$

LaggedResiduals: $Z_{t-1} = LNCO2_{t-1} - \phi_1 LGDP_{t-1} - \phi_2 LNGLO_{t-1} - \phi_3 LNRENEW_{t-1} - \phi_4 LNNATGAS_{t-1}$ (7)

$$\Delta LNCO2_t = \alpha_0 + \sum_{n=1}^{p} \Delta LNCO2_{t-1} + \sum_{n=1}^{q_1} \beta_2 \Delta LNGDP_{t-1} + \sum_{n=1}^{q_2} \beta_3 \Delta LNGLO_{t-1} + \sum_{n=1}^{q_3} \beta_4 \Delta NRENEW_{t-1} + \sum_{n=1}^{q_4} \beta_5 \Delta LNNATGAS_{t-1} +$$

$$\phi_1 LNCO2_{t-1} + \phi_2 LNGDP_{t-1} + \phi_3 LNGLO_{t-1} + \phi_4 LNRENEW_{t-1} +$$
$$\phi_5 LNNATGAS_{t-1} + \mu t \quad (8)$$

The advantage of equation (8) over Engle and Granger (1987) representation is that we may estimate long and short-term impacts by utilizing the equation. Equation (8) is comparable to Engle and Granger (1987) technique. From (8), α_0 signifies the intercept, whereas β_{1-} $\beta_5$parameters stand for each coefficient in the short-run variables in the model and $\phi_1 - \phi_5$ The error term in the model is denoted by μt whereas parameters are the coefficients for each long-term variable.

According to Pesaran el al. (2001), critical values of the ARDL limits test require that the long-run variables coefficients ($LNCO2_{t-1}$, $LNGDP_{t-1}$, $LNGLO_{t-1}$, $LNRENEW_{t-1}$, and $LNNATGAS_{t-1}$) be constant in order to explore the null hypothesis. A set of equations for error correction model can also be found in equation 9.

ECM:

$$\Delta LNCO2_t = \alpha_0 + \sum_{n=1}^{p} \beta_1 \Delta LNCO2_{t-1} + \sum_{n=1}^{q_1} \beta_2 \Delta LNGDP_{t-1} + \sum_{n=1}^{q_2} \beta_3 \Delta LNGLO_{t-1}$$
$$+ \sum_{n=1}^{q_3} \beta_4 \Delta LNRENEW_{t-1} + \sum_{n=1}^{q_4} \beta_5 \Delta LNNATGAS_{t-1} + \phi Z_{t-1} + \mu_t \quad (9)$$

The ECM, is equation 9, while its coefficient ϕZ_{t-1} represent the long-run equation. It is predicted to be negative and significant since it gauges how quickly our model reaches equilibrium.

Table 5: Results of the Bounds Test for Cointegration

Lags(AIC)	F-statstics	Decision
4	7.46	Co-integration
	Lower limit at 1% = 3.74	Upper limit at 1% = 5.07
	Lower limit at 5% = 2.87	Upper limit at 5% = 4.01
	Lower limit at 10% = 2.45	Upper limit at 10% = 3.53

Authors' Compilation.

The boundaries assessment in table 5 was applied using the F-statistics values for the ARDL bounds method as given by Pesaran et al (2001). The findings of the test demonstrate that the relevant factors have a long-term relationship because the estimated F-statistic is significantly greater than the upper bound critical values for the boundary test at significance thresholds of 1%, 5%, and 10%. The outcome of the long-term ARDL after confirming the long-run connection are displayed in table 6 below:

Table 6: ARDL Long-run Form

	Coefficient	t-stat	Probability
LNGDP	-1.600978	-1.746134	0.1147
LNGLO	1.233901	2.294461	0.0474
LNRENEW	-0.202615	-2.385079	0.0409
LNNATGAS	0.012175	0.511906	0.6210

Source: Authors' Compilation, E-views 12
Note.: The asterisk (***) and (**) signifies statistical rejection level at 1%, and 5% levels of significance correspondingly.

Table 6 above displays the ARDL's long-run coefficients. The finding indicates that real output has a beneficial and has statistically insignificant effect on the environment. When other factors are held constant, ecological imprint will grow by 1.234% for every 1% increase in the globalization, despite the fact that there is a positive and statistically significant association among the two variables. This suggests that as

Japan speeds up the globalization, its ecological footprint grows, ultimately degrading the environment's quality. There is a statistically substantial inverse correlation between using renewable energy and ecological imprint. This implies that, keep other variables constant, a 1% increase in the consumption of renewable energy improves the state of the environmental by 0.20. In addition, the ecological effect on natural gas rent, a proxy for nonrenewable energy usage, have a positive but statistically insignificant relationship.

Table 7: ECM Regression Result

Variable	Coefficient	Std-Error	t-Statistics	Prob.
C	18.14026	2.468597	7.348410	0.0000***
D(LNCO_2 (-1))	0.333888	0.140310	2.379649	0.0413**
D(LNCO_2 (-2))	-0.199912	0.123148	-1.623352	0.1390
D(LNGDP)	0.451932	0.147350	3.067073	0.0134**
D(LNGDP(-1))	1.259700	0.226393	5.564212	0.0003***
D(LNGDP(-2))	1.290608	0.296207	4.357122	0.0018***
D(LNGDP(-3))	0.662733	0.197041	3.363435	0.0083***
D(LNGLO)	-0.081725	0.170276	-0.479952	0.6427
D(LNGLO(-1))	-0.742070	0.174249	-4.258681	0.0021***
D(LNGLO(-2))	-0.917142	0.166381	-5.512284	0.0004***
D(LNRENEW)	-0.281110	0.040667	-6.912425	0.0001***
D(LNRENEW(-1))	0.097882	0.052985	1.847353	0.0978
D(LNNATGAS)	-0.022603	0.012091	-1.869445	0.0944
D(LNNATGAS(-1))	-0.062890	0.012792	-4.916305	0.0008***
ECM(-1)*	-0.704187	0.095895	-7.343347	0.0000***

Note: Variables are significant *** at 0.01 and ** 0.05 levels, respectively.

The table 7 above displays the short-run ARDL's findings. The error correction mechanism (ECM) results specifically show that ECM is -0.70, suggesting that the ecological imprint in Japan reaches long-term equilibrium level at a speed of 70% each year. It follows that a 1% rise in GDP will cause an increase in ecological imprint of 0.45%, which will cause a short-term reduction in environmental quality because the coefficient of GDP is statistically significant and positive. The globalization exhibits an inverse and statistically negligible relationship, whereas the ecological impact and the use of clean energy do have a significant and negative relationship. According to this, using more non-renewable energy has a short-term relationship that is beneficial but insignificant, whereas increasing Japan's renewable energy consumption by 1% is predicted to improve the country's environmental quality by 0.28%.

Table 8 lists the diagnostic tests. The findings demonstrate that the predicted long-run & short-run models are the most suitable for the ARDL criteria. The serial correlation Breusch-Godfrey Lagrange multiplier test and the heteroscedasticity Breusch-Pagan-Godfrey test could not be used to reject the false hypothesis that no serial correlation exists and no evidence of heteroscedasticity. This shows that, at the 5% level of significance, the calculated model is correctly distributed and that neither serial correlation nor heteroscedasticity are present. Ramsey RESET test result demonstrates that the model is defined properly in terms of stability.

Given that the strength of the short-run and long-run computed parameters is confirmed by our estimated model, it is necessary to once again verify their stability using the CUSUM and CUSUMQ statistical tests created by Brown et al. (1975). Compared to other tests, these statistical tests are the most effective Johansen, S. Hansen, H. (1992). The CUSUM and CUSUMQ include the short-run dynamics to the long-run through residuals. Figures 2 and 3 below show their findings. The results showed that all short-run and long-run calculated coefficients are stable when CO_2

emissions is the dependent variable since the coefficients are well under the crucial boundaries of 5% significance.

Table 8: Residual Diagnostic Test

Test	**F-statistic**	**Degrees of Freedom**	**Probability**
Ramsey RESET test	2.136	F(1,5)	0.4570
Breusch–Godfrey serial correlation LM test	4.5559	F(2,)	0.379
Breusch–Pagan–Godfrey heteroskedasticity test	0.09	F(30,6)	0.7916
Jarque-Bera Normality Test	-	-	0.9091

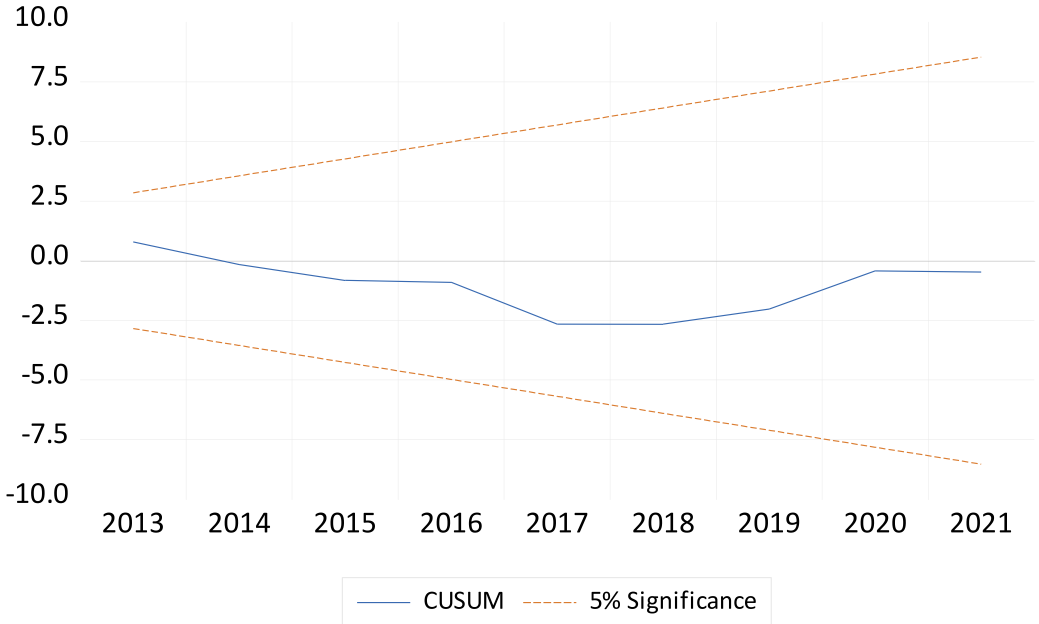

Figure 3: Cusum

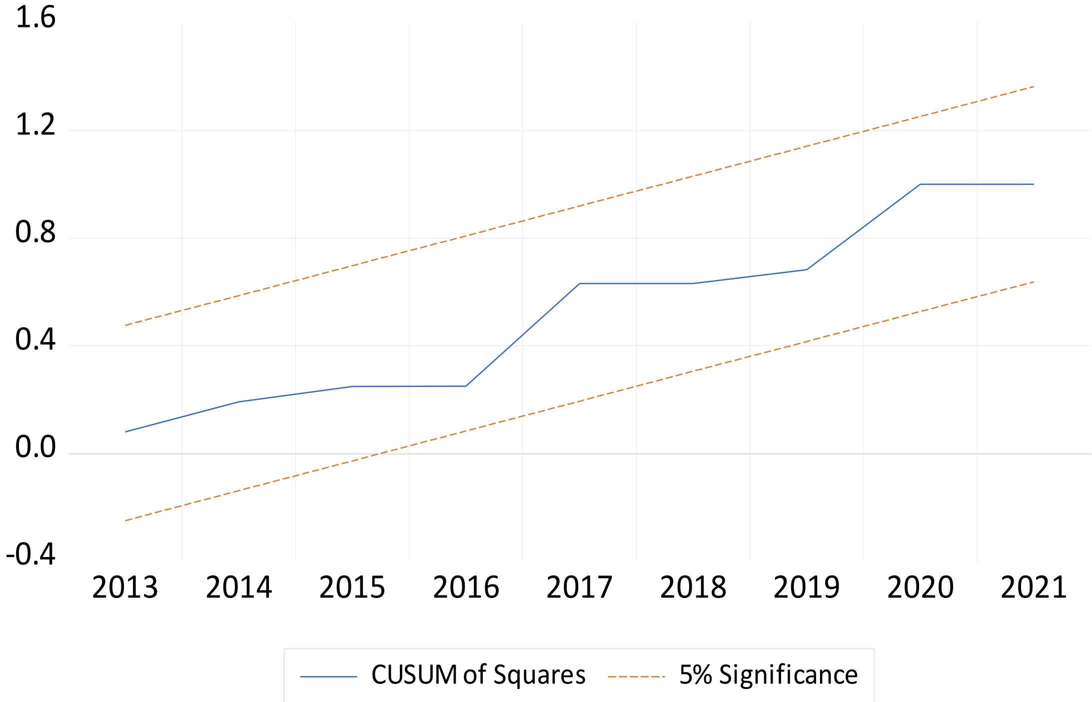

Figure 4: Cusum Square

The study used Dynamic Ordinary Least Square (DOLS), an estimation technique that applies parametric method to eliminate the difficulty inherent in estimation and performs better than the Ordinary Least Square (OLS) & the Fully Modified Ordinary Least Square (FMOLS), especially when the sample size is small, in order to provide the research with a robust result and interpretation.

Table 9: DOLS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	-0.214251	0.759276	-0.282178	0.7826
LNGLO	0.342827	0.318761	1.075501	0.3033
LNRENEW	-0.101965	0.127543	-0.799453	0.4396
LNNATGAS	0.006951	0.025953	0.267831	0.7934
C	14.92437	7.026193	2.124105	0.0551

GDP and renewable energy consumption exhibit negative signs, which are consistent with the long-run boundaries test but are statistically insignificant, according to the

DOLS result in the table 9 above. In keeping with the long-run boundaries test, the globalization index and nonrenewable energy consumption are both positive but not statistically significant.

In ARDL, the selection of the lag duration is crucial since it aids in providing the accurate estimation. That is why the procedure is used in the study. Lag 4 is the ideal lag to utilize, according to the optimal lag choice results, which seeks to discover the best choice criterion for lag period. Akaike information criterion (AIC), is the lowest value among the other criteria, was then chosen.

3.3 Discussion of Findings

Real output (GDP) and ecological imprint have a long-run negative association but a short-run positive one. This suggests that real output, through its effect on ecological imprint, grows in the short run while decreasing environmental degradation in the long-term. The findings are in consistent with Sarkodie & Strezov (2018). The results, however, are inconsistent with those of Ike & others (2020), discovered that Thailand's GDP puts positive relationship on all sources of environmental contamination.

The positive relationship among globalization index and ecological imprint, increases environmental contamination, and is caused by the acceleration of globalization. Although, this judgment concurs with statements made by Dean (2002), and McAusland (2008). Because globalization promotes industrial growth and removes barriers to FDI and commerce, it is therefore expected. Similar to that, it gives markets like Japan the chance to maximize the political, social, and economic advantages of advanced countries. Once more, it enhances the transfer of technology, which eventually spurs the manufacturing sector that has a negative impact on the environment. The research reported here contradicts Shahbaz & others (2017). This study, which revealed an inverse relationship among globalization and environmental impact, whereas Xu & others (2018) study found no conclusive proof to establish the correlation among globalization and environmental damage. Furthermore, Rafindadi, Usman et al. (2019) agrees that there are positive effects of actual productivity in the short -term.

Renewable energy usage has beneficial long and short-run impacts. This reveals that using renewable energy both in short and long-run enhances environmental quality in Japan. This can be understood by the fact that clean energy produces less pollutants. The Tunisia's rate of CO_2 emissions is being slowed by renewable energy, is supported by earlier research by Ben Jebli and BenYoussef (2017). This is to be expected given the growing concern over climate change and the fact that Japan is progressively developing renewable energy as a reliable method of reducing climate change. After the March 2011 Fukushima nuclear disaster and the Great East Japan earthquake, the public mood in Japan has shifted in favor of sustainable, alternative energy sources. In contrast to the European Union (EU), China, and South Korea, the energy revolution has stalled despite a tremendous expansion in renewable energy capacity. Additionally, the consumption of nonrenewable energy is both positive and negative over the short and long-run. The outcome suggests that the use of nonrenewable energy worsens environmental degradation in the long-run in Japan.

Table 10: Granger Causality Tests

Null Hypothesis:	F-Statistic	Prob.	Remark
LNGDP↗LCO$_2$	1.18059	0.3236	
LNCO2↗ LNGDP	3.01041	0.0674	LNGDP ≠ LNCO2
LNGLO↗LNCO2	0.75721	0.4794	
LNCO2↗ LNGLO	1.37767	0.2707	LNGLO ≠ LNCO2
LNREW↗ LNCO2	2.81557	0.0789	
LNCO2↗ LNRENEW	8.08171	0.0020	LNCO2→ LNRENEW
LNNATGAS↗ LNCO2	0.18751	0.8302	
LNCO2↗LNNATGAS	4.03914	0.0302	LNCO2 →LNNATGAS
LNGLO↗LNGDP	2.20819	0.1309	LNGLO ≠ LNGDP
LNGDP↗LNGLO	0.96015	0.3965	
LNREW↗LNGDP	0.01442	0.9857	LNREW →LNGDP
LNGDP↗LNRENEW	6.92405	0.0040	
LNNATGAS↗LNGDP	0.49028	0.6182	LNNATGAS ≠ LNGDP
LNGDP↗LNNATGAS	0.69979	0.5062	
LNREW↗LNGLO	7.43977	0.0029	LNRENEW ↔ LNGLO
LNGLO↗LNRENEW	5.33330	0.0118	
LNNATGAS↗LNGLO	2.11033	0.1423	LNNATGAS ≠ LNGLO
LNGLO↗LNNATGAS	2.49367	0.1029	
LNNATGAS↗LNRENEW	4.77964	0.0175	LNNATGAS→LNRENEW
LNREW↗LNNATGAS	0.27649	0.7607	

Note: ***, **, denotes 1%, and 5% significant level, ↗ denotes does not granger causes, ↔ Denotes bidirectional association, → denotes unidirectional association, ≠ signifies no connection.

When a long-run link in ARDL is confirmed, it means that there is a connection between and among the variables. These connections can be one-way or two-way, and in other cases certain variables may not be connected to one another at all. According to Table 10's Granger causality test, real output (LNGDP) and ecological footprint (LN CO_2) are not causally related; that is, GDP does not granger cause CO_2. Similar to how LNGLO does not directly produce CO_2, which means that, globalization index (LNGLO) also has no causal relationship with LNCO_2. But consumption of nonrenewable energy (LNNATGAS) and CO_2 have a one-way relationship, suggesting that LNNATGAS causes CO_2 but CO_2 does not cause LNNATGAS. There is no causal connection between LNGLO and LNGDP, which means that neither LNGLO nor LNGDP can be said to be the cause of the other. There is also unidirectional relationship between LNRENEW and LNGDP. However, a two-way causal connection exists between the variables for LNRENEW and LNGLO is evident, suggesting that LNRENEW granger causes LNGLO and that LNGLO granger causes LNRENEW. There is no causal connection between LNNATGAS and LNGLO; LNNATGAS does not directly cause LNGLO, and LNGLO does not directly cause LNNATGAS. Finally, a single-way causal relationship exists between LNNATGAS and LNRENEW, meaning that LNNATGAS causes LNRENEW but LNRENEW does not cause LNNATGAS.

3.3.1 Conclusions and Policy Recommendations

This study conducts an investigation into how energy use affects Japan's ecological footprint and environmental sustainability. Time-series data for Japan from 1990 to 2021 were used in the study. Since, in recent years, as a result of climate change, energy has emerged as a distinct formal element of production for expanding the economy.

The outcome of ARDL estimating process show that, in the short and long-run, renewable energy usage has a negative relationship with ecological imprint. This indicates that using renewable energy will improve Japan’s environment both now and in the future. While GDP and ecological imprint have a long-term negative but a short run positive association, this suggests that GDP reduces environmental harm in the long-run and grows it in the short-run. But globalization and natural gas have a long-run positive relationship on Japan's ecological footprint, this equally suggest that, both globalization and natural gas increases environmental degradation in Japan in the long-run. The DOLS outcome is consistent with long-run bounds test result, and the granger causality test shows that globalization and renewable energy are causally related in both directions.

According to the findings of this study, it is crucial to work towards sufficient economic growth and sustainable development in the generation of renewable energy. Therefore, a significant issue that policymakers should consider seriously is how economic expansion may be transformed into rapid growth in renewable energy while lowering CO_2 emissions. While Japan has established and implemented a variety of policies and legislation on clean energy, there are still some difficulties with renewable energy technologies. This article recommends a variety of countermeasures. The development of renewable energy should therefore be actively supported in the future, and policies should be made to increase market competition and provide resources for investment in the renewable energy sector.

The government of Japan should give careful consideration to a number of significant problems that, up until now, have impeded the production of renewable energy, notably wind, hydro, and PV generation. By improving the frameworks for clean energy production and consumption and fostering market systems and policy coordination across sectors and regions, these issues could be effectively resolved. The ultimate goal is to increase the size of the market for renewable energy, enhance the technological capacity of renewable energy companies, and employ R&D expenditures for the Japanese energy industry responsibly. By investing into green technologies, Japan may also temporarily raise environmental standards and increase the efficiency of its energy use. Enhancing the current energy balance and raising the renewable energy percentage will likely come at the expense of economic growth from the standpoint of using green energy. Therefore, it is important for policymakers to strike a balance between economic growth and improved energy usage patterns. The Japanese government should support ongoing CO_2 intensity reductions as called for in the Paris Agreement in order to maintain environmental sustainability.

It is important to note that the study only used globalization, economic growth, renewable energy and natural gas in its assessment of environmental imprint in Japan, and the outcome was robust and trustworthy. However, this study is limited, more macroeconomic variables can be added to expand the research. In addition, future studies can use other proxies for ecological imprint such as environmental quality and fossil fuel for nonrenewable energy consumption.

3.3.2 Suggested Policy

In light of the study's empirical results, Long-term economic goals of Japan place a high premium on cleaner growth and sustainable development. On the other side, environmental deterioration could make it more difficult to achieve the goals of sustainable development. Therefore, in order to reduce pollution, Japan should start public awareness efforts, carry out the required structural adjustments to allow income levels to rise without increasing emissions, and work toward reducing its reliance on fossil fuels. In the end, our research confirms the results of previous investigations and implies that renewable energy sources might be employed as a tool for policy to reduce pollution and environmental damage. Based on the aforementioned factual findings for Japan, we may make some insightful recommendations for a more environmentally friendly and sustainable environment. These policy ramifications might also help

Japan achieve the Sustainable Development Goals of the UN, which include improved energy efficiency and a cleaner, greener environment. The study's conclusions suggest that in order to reduce air pollution, governments should impose strict regulations, encourage investment in renewable energy sources, and discourage the use of fossil fuels. This is because using renewable energy sources enhances people's quality of life. An effective method of lowering CO_2 is to transform additional energy from economic expansion into renewable energy sources, which calls for a technological change. Japan has to invest strategically and pursue more research into the production of renewable energy.

Chapter 4

THE EFFECTS OF RULE OF LAW, REGULATORY QUALITY AND R&D ON JAPAN'S ENVIRONMENTAL SUSTAINABILITY

4.1 Introduction

A number of nations have incorporated the right to a sustainable environment into their constitutions or passed environmental legislation in recognition of the belief that environmental sustainability is essential for humankind. But practice frequently lags behind the enactment of environmental regulations, and there is currently a dearth of information to assist comprehend and close this gap, Inter- American Development Bank (IDB).

As stated by Goodland (1995), the idea of environmental sustainability enhances human welfare by safeguarding the sources of materials used to meet human needs and managing sinks sustainably in a world with finite resources. According to Goodland, environmental sustainability is constrained by four main human activities: waste management, contamination, renewable and non-renewable resource sourcing, and pollution. Holdren & Smith (2000) noted that other specialists who have participated to this initial sustainability study have focused on studying biophysical sustainability and human behavior. Research gathered over time indicates that there is a serious global threat to sustainability of the natural world, or the endowments of biophysical resources Atewamba & Rhodes, (2020). Consequently, technological and natural-based experiments have been the main focus of the search for answers to these environmental issues. Even if the biophysical state of the planet is still declining and there has been a growing need for restrictions recently, many people are advocating for significant changes or viable substitutes to achieve environmental sustainability.

According to the majority of experts, the best way to encourage good environmental practices is to combine state environmental rules with effective monitoring and clear sanctions for non-compliance. Numerous studies conducted recent years have moreover indicated that business environmental practices are impacted by institutional constraints Berrone & Gomez-Mejia, (2009). The degree to which environmental initiatives are shared by highly polluting companies in an economy can also be influenced by institutional quality, as suggested by studies conducted by Delmas & Toffel (2004) and Khanna and Anton (2002). This includes the capacity to enhance adherence to effective ecological management schemes. On the other hand, some scholars contend that institutional measures such as public humiliation, penalties, and external supervision can only produce isomorphic adherence to environmental compliance requirements inside an economy

Generally speaking, the quality of institutions unquestionably has a substantial impact, even though there are many other aspects including ecological, technological, macroeconomic, and other variables that can either support or undermine progressive initiative. They contend that appropriate behavioral coordination is necessary for sustainable economic advancement. Social and economic deficits cannot be addressed in the absence of strong and effective institutions because self-renewing development necessitates the implementation of strategic policies, tactics, and actions, particularly in emerging economies where environmental sustainability concerns are typically perceived as growing Gambetta et al., (2019) and Nechkoska, (2020).

For the majority of the world's economies, maintaining economic growth has been a top priority in recent years. There is no doubt that stabilizing or lowering greenhouse gas (GHG) emissions is necessary to achieve this goal. This means shifting from highly polluting energy-based economic activities to sustainable business ventures founded on consumption and technology that have a smaller environmental effect Foxon, (2011); Stern, (2007). A comprehensive solution to climate change would require a technological transformation that does not impede economic growth. But how can this move be made possible?

Innovation is one of the key strategies to accomplish this alteration in structure. According to Schumpeter (1934), innovation propels economic development. But innovation and technical advancement only started to play a bigger part in the economic literature as factors influencing economic growth after Solow's 1957 paper. Numerous studies in the field of economic growth theory link economic growth to knowledge acquisition through education or research and development (R&D) spending Romer, (1986); Aghion & Howitt (1992); Young (1991); Grossman & Helpman (1991). The endogenous economic growth model states that the R&D sectors use human capital and the corpus of existing knowledge to produce technical innovation Romer, (1986). In actuality, economic theory holds that the development of R&D is critical to economic expansion. However, economic expansion predicated on the use of fossil fuels is strongly linked to environmental deterioration. The Environmental Kuznets Curve (EKC), an inverted U-shaped function, has been employed by most empirical studies during the 1990s to investigate the connection between emissions and economic expansion Grosman and Krueger, (1991). To obtain an exhaustive analysis of the literature pertaining to the EKC theory, consult Dogan and Seker (2016). Nevertheless, empirical findings regarding EKC are equivocal.

According to the endogenous growth theory, production processes can be made more efficient by improving the ability to swap out polluting resources for more environmentally friendly ones has been utilized to illustrate how the development of the interaction between economic growth and environment has been impacted by technical innovation Stokey et al. (1998). These models are based on an environment-conscious society and has the potential to enhance its protection expenditures in tandem with economic growth. Technology will be important if emissions decline as wealth rises, and Hicks' concept of "induced innovation" will be the reason behind the decline in emissions. According to a number of studies Andreoni & Levinson, (1998) and Cantos & Balsalobre, (2013), the EKC's theory of "induced innovation" is implicit, meaning that compliance with it mostly depends on technology.

An issue that is becoming more and more important in trade policy is how trade affects the environment. There has been discussion about the connection between trade liberalization and environmental quality in an increasing number of empirical research for example, Frankel & Romer, (1999); Antweiler et al., (2001); Boulatoff & Jenkins, (2010). This research yields conflicting results; whereas some show a favorable association, others discover a negative one. Evidence and theory both point to the promotion of growth via commerce. For instance, China's incredible ascent was largely fueled by its incorporation into the world trade network. The impacted nations may enact stricter environmental laws if trade stimulates growth, which in turn causes environmental degradation. As a result, we may anticipate that the use of greener

Production methods will improve the environment's quality. Antweiler et al. (2001) discovered that trade openness is connected with lower levels of pollution as assessed by sulphur dioxide concentrations, providing empirical support for this position. Additionally, Baek et al. (2009) demonstrated that trade and money had a good impact on China's and developed nations' environmental quality. Boulatoff and Jenkins (2010) discovered evidence in several income categories of countries indicating a long-term negative correlation between trade and carbon emissions from oil. Le et al. (2016), for instance, demonstrate how increased trade openness worsens environmental quality and increases carbon emissions. On the other hand, Jayanthakumaran and Liu (2012) argue that trade openness plays a vital role in enhancing environmental quality by means of commerce, composition, and technological effects. According to Masson et al. (2021), trade liberalization reduces carbon emissions, albeit this effect varies depending on the level of emissions. They also demonstrate that trade openness positively affects emissions indirectly, but a negative indirect effect as well.

The term "globalization" describes the growing interconnectedness of economies on a social, political, and economic level as a result of international trade, population mobility, investment, technology, and information flows. It is better defined as a transition from historically isolated economies that were governed by laws, cultural disparities and obstacles to interdependent, globally integrated economies Hill, (2007). Globalization can have an impact on environmental sustainability Saud et al. (2020) and economic development Latif et al. (2018) due to its social, political, and economic systems.

Dreher (2006) proposed the KOF index, which combines distinct indices on economic, political, and social globalization with one overall score that covers all three components of globalization. The index of economic globalization is derived from commerce, portfolio investment, foreign direct investment (FDI), and other trade limitations such import tariffs, foreign trade taxes, and import barriers. We must therefore due to the environmental repercussions of economic globalization, consider the ecological effects of foreign investment and commerce. For example, the research by Destek and Okumus (2019) indicates that foreign direct investment (FDI) may result in the creation of pollution havens since wealthy foreign investors tend to transfer technology that is highly polluting to nations with inadequate environmental regulations. Similarly, Doytch (2020) reveal detrimental ecological impacts of foreign direct investment. In a similar way, Shahbaz et al. (2016) proposed that there are multiple environmental impacts of globalization and contend the relocation of production facilities to low-income nations, where they may pay lower workers and benefit from inadequate environmental restrictions that promote ecological damage, is made simpler for multinational businesses by economic globalization. Globalization also increases human activity, and human activity raises pollution levels through increased industrial activities, transportation, and, indirectly, deforestation. Doğan et al. (2019) point out that for all income levels, commerce causes ecological degradation to worsen. However, Ahmed et al. (2019) offers the argument that there are a number of ways in which economic globalization might influence environmental sustainability. First, the utilization of inventive and efficient technology by foreign investors frequently lowers production prices and resource consumption. Even small businesses use similar technology to stay competitive and support environmental sustainability. Second, trade openness can promote the development of a knowledge-based service economy by facilitating structural transformation. Thirdly, aside from composition effects, trade's method effect in developed nations can result in improved environmental laws and green technologies Ahmed and others (2020).

This research examines the effects of trade liberalization, R&D, regulatory quality, and the rule of law using the ARDL model on Japan’s environmental Sustainability. No previous studies have looked into this in the region. The research responds to the following queries:

(1) Is environmental quality correlated with rule of law, R&D, regulatory quality, globalization and trade openness and if so, how?

(2) To evaluate empirically, how does the rule of law, R&D, regulatory quality, globalization and trade openness impact environmental quality?

4.2 Data and Methodology

4.2.1 Data Description

To evaluate the effects of rule of law, R&D, regulatory quality, globalization and trade openness on Japan’s environmental Sustainability covering the period from 1990 to 2021, this research use data from the World Bank's World Development Indicators (WDI) for research and development (R&D), regulatory quality, and the rule of law. While globalization is sourced from Swiss Economic Institute (SEI), the Global Footprint Network (GFN) is the source for the ecological footprint as shown in Table 11 below.

Table 11: Data Sources

Variable	Acronym	Description	Measure	Data source
Ecological Footprint	ECFP	Ecological footprint	GHA	GFN
Rule of Law	Law	Rule of Law	Estimate	WDI
Regulatory Quality	RQ	Regulatory Quality	Estimate	WDI
R& D	RD	R&D Expenditure	% of GDP	WDI
Trade Openness	Trade	Trade	% of GDP	WDI
Globalization	GLOB	Globalization	Index	SEI

4.2.2 Model Specification

This study examined the effect of rule of law, regulatory quality, R&D, trade openness and globalization on Japan's environmental degradation. Time series annual data were utilized from 1990 to 2021. The dependent variable is ecological footprint, which is a stand-in for environmental sustainability, while rule of law, regulatory quality, R&D, trade openness and globalization are independent variables and the equation can be express thus:

ECFT = f (law, RQ, RD, Trade, Glob) (10)

The variables are further transformed into natural log linear econometrics model base on the recommendation of Ozturk and Acaravci,(2013).

$$\text{LNECFT} = \alpha_0 + \gamma_1\text{LNLAW} + \gamma_2\text{LNRQ} + \gamma_3\text{LNRD} + \gamma_4\text{LNTRADE} + \gamma_5\text{LNGLOB} + \varepsilon_t \quad (11)$$

Where LNECFT is the log of ecological footprint, LNLAW is the log of rule of law, LNRQ is the log of regulatory quality, LNRD is the log of R&D, LNTRADE is the log of trade openness and LNGLOB is log of globalization. α_0 is a constant term, γ_1 - γ_5 are coefficient of the variables as well as ε_t is the stochastic error term.

4.2.3 Unit Root Test

The purpose of the unit root test is to ascertain the stationarity of a data series. The augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests are used to investigate the unit root.

$$\triangle Y_{t} = \alpha_0 + \beta_t + \rho Y_{t-1} + \sum_{i=1}^{k} \Upsilon_1 \triangle Y_t + \varepsilon_t \tag{12}$$

$$\triangle Y_{t} = (p-1) Y_{t-1} + \varepsilon_t \tag{13}$$

To verify the stationarity of the data series, the ADF test equation for the unit root is equation 12, and equation 13 is the PP. The symbol $\triangle$ symbolize the first difference operator, and Y_t exhibits a large degree of time-related autocorrelation. Y_{t-1} is the presentation of the independent variables. In equations 12 and 13, the error term is represented by εt.

Table 12: Augmented Dickey Fuller

Variable at level	Constant (t-stat)	Prob.	Constant & Trend (t-stat)	Prob.	Remark
LNECFP	1.2549	0.9977	-2.3640	0.3898	-
LNLAW	-0.5147	0.8748	-2.2422	0.4511	-
LNRQ	-1.5767	0.4818	-3.1081	0.1226	-
LNGLOB	-2.3898	0.1527	-1.8158	0.6726	-
LNRD	-1.1979	0.6626	-1.6104	0.7656	-
LNTRADE	-0.6590	0.8424	-3.1824	0.1064	-
Variable at First Difference					
D(LNECFP)	-5.3951	0.0001***	-4.8374	0.0032***	I (1)
D(LNLAW)	-7.5816	0.0002***	-7.7174	0.0000***	I (1)
D(LNRQ)	-4.4964	0.0018***	-4.0008	0.0197**	I (1)
D(LNGLOB)	-5.3303	0.0001***	-5.9153	0.0002***	I (1)
D(LNRD)	-4.9334	0.0003***	-3.1917	0.1079	I (1)
D(LNTRADE)	-5.4825	0.0001***	-4.5796	0.0053***	I (1)

Table 13: Philips - Perron

Variable at level	Constant (t-stat)	Prob.	Constant & Trend (t-stat)	Prob.	Remark
LNECFP	0.1937	0.9677	-1.7326	0.7122	-
LNLAW	-1.1709	0.6741	-2.0630	0.5452	-
LNRQ	-1.2522	0.6386	-2.3533	0.3950	-
LNGLOB	-5.5309	0.0001***	-1.4323	0.8308	I (1)
LNRD	-1.1314	0.6905	-1.7468	0.7057	-
LNTRADE	-0.3750	0.9016	-3.2206	0.0990	-
Variable at First Difference					
D(LNECFP)	-5.8701	0.0000***	-9.3557	0.0000***	I (1)
D(LNLAW)	-7.6330	0.0000***	-8.6290	0.0000***	I (1)
D(LNRQ)	-4.3045	0.0021***	-4.3475	0.0089***	I (1)
D(LNGLOB)	-5.3515	0.0001***	-12.0740	0.0000***	I (1)
D(LNRD)	-4.9865	0.0003***	-5.0480	0.0016***	I (1)
D(LNTRADE)	-6.0563	0.0000***	-5.9841	0.0002***	I (1)

Establishing the Variable stationarity is a necessary step in the study's empirical analysis as it helps prevent erroneous regression. It is implied by stationarity that the variance of the variable's mean zero is constant (Dickey and Fuller 1979). The variable may become stationary at level or first difference as seen in table 12 and 13 above. Dickey & Fuller's (1979) and Phillips & Perron's (1988) stationarity tests are used in this investigation. To ensure that none of the variables used in these estimations are I(2) or above. The dependent variable LNECFP is stationary at first difference I(1) and the independent variable LNGLOB is stationary at level I(0) while the remaining independent variables LNLAW,LNRQ,LNRD, and LNTRADE are all stationary at first difference I(1).

4.2.4 Descriptive Statistics and Plots of the Variables

Table 14: Descriptive Statistics

	LNECFP	LNLAW	LNRQ	LNGLOB	LNRD	LNTRADE
Mean	20.23333	0.298963	6.362516	4.232102	1.102986	3.217194
Median	20.25693	0.281982	6.350415	4.244342	1.133273	3.230541
Maximum	20.36506	0.468767	6.526504	4.360103	1.214283	3.622511
Minimum	19.99187	0.138502	6.219704	4.014806	0.971926	2.760662
Std. Dev.	0.096102	0.088236	0.106301	0.102458	0.077851	0.295260
Skewness	-0.71174	0.325627	0.276946	-0.55924	-0.35193	-0.078455
Kurtosis	2.830828	2.444735	1.490351	2.193060	1.587468	1.441179
Jarque-Bera	2.739918	0.976602	3.447779	2.536229	3.320912	3.272726
Probability	0.254117	0.613668	0.178371	0.281362	0.190052	0.194687
Observations	32	32	32	32	32	32

The study variables' descriptive statistics are displayed in Table 14. According to the mean data, LNTRADE has the biggest standard deviation of 0.29 across the survey period and LNECFP has the highest yearly average of 20.23. Skewness values show that whereas the distribution of other variables is skewed to the left, the distribution of LNLAW and LNRQ is skewed to the right. Kurtosis results show that no variable's distribution is higher than 3.00, suggesting that every variable has a normal distribution. The Jarque-Bera outputs demonstrate that every research data set have a normal distribution based on the values of the series probability which are all greater than 0.05. Therefore, we cannot rejection the null hypothesis (H_0) which states that, the distribution of the series is normal.

Table 15: Pearson Pairwise Correlation Estimates

Correlation						
t-Statistic						
Probability	LNECFP	LNLAW	LNRQ	LNRD	LNGLOB	LNTRAD
LNECFP	1.000000					

LNLAW	-0.72255	1.000000				
	-5.72470	-----				
	0.0000	-----				
LNLAW	-0.72255	1.000000				
	-5.72470	-----				
	0.0000	-----				
LNRQ	0.650968	-0.36274	1.000000			
	4.696974	-2.13203	-----			
	0.0001	0.0413	-----			
LNRD	-0.69979	0.454212	-0.81667	1.000000		
	-5.36556	2.792501	-7.75087	-----		
	0.0000	0.0090	0.0000	-----		
LNGLOB	-0.73764	0.513088	-0.85289	0.913784	1.000000	
	-5.98372	3.274123	-8.94776	12.32152	-----	
	0.0000	0.0027	0.0000	0.0000	-----	
LNTRADE	-0.76078	0.649549	-0.79664	0.936775	0.904462	1.000000
	-6.42048	4.679253	-7.21881	14.66265	11.61385	-----
	0.0000	0.0001	0.0000	0.0000	0.0000	-----

Pearson Pairwise correlation estimates which ranges from -1 to 1 are display in table 15 above. The closer the coefficient to 1 the stronger the correlation and when the coefficient is closer to 0 it indicates a weak correlation between the variables. LNECFP has a moderate and negative coefficient of (-0.72) correlation with LNLAW, while LNECFP with LNRQ have a moderate and positive coefficient of (0.65) correlation.

LNECFP with LNRD, LNGLOG and LNTRADE all have moderate and negative correlations coefficients of (-0.69), (-0.74) and (-0.76) respectively.

Furthermore, LNLAW and LNRQ have a moderate inverse coefficient of (-0.36). While LNLAW with LNRD, have positive and moderate correlation coefficient of (0.45). On the other hand, LNLAW with LNGOB and LNTRADE have moderate and positive correlation values of (0.51) and (0.65). LNRQ with LNRD, LNGLOB and LNTRADE all have strong and negative correlation coefficients of (-0.82), (-0.85) and (-0.80) respectively. LNRD with LNGLOB and LNTRADE have very strong and positive correlation values of (0.91) and (0.94). Finally, the Pearson Pairwise correlation statistics for LNGLOB and LNTRADE is strongly positive (0.90).

4.2.5 Co-integration using the ARDL Model and a Bounds Test Approach

Pesaran et al. (2001) established the ARDL method to cointegration. It is a combination of distributed lag models and autoregressive models. A time series in any ARDL model is a function of its present value, the lagged values of one or more explanatory variables, and their lagged values.

The ARDL approach to cointegration not only avoids the endogeneity problem by allowing one to distinguish between explanatory and dependent variables, but it also permits the simultaneous estimation of the long-run and short-run components of the model. The issues brought on by the missing variables and autocorrelation are likewise eliminated by this method. Due to their avoidance of potential issues with serial correlation and endogeneity, the cointegration estimations produced by the ARDL method are objective and effective Pesaran, Shin, and Smith (2001).

In contrast to earlier cointegration methods described by Johansen (1988), Engle and Granger (1987), the ARDL approach to cointegration offers certain advantages. The cointegration method known as ARDL bounds testing can be utilized regardless of whether the regressors belong to the I (0) or I (1) class. However, the dependent variable needs to be of I (1) in levels, and none of the explanatory variables can be I (2) or higher.

Short-run equation

$$\Delta \text{LNECFT}=\alpha_0 + \sum_{n=1}^{p} \Delta \text{LNECFT} + \sum_{n=1}^{q_1} \gamma_1 \Delta LNLAW_{t-1} + \sum_{n=1}^{q_2} \gamma_2 \Delta LNQR_{t-1} + \sum_{n=1}^{q_3} \gamma_3 \Delta LNRD_{t-1} + \sum_{n=1}^{q_4} \gamma_4 \Delta LNTRADE_{t-1} + \sum_{n=1}^{q_5} \gamma_5 \Delta LNGLOB_{t-1} \qquad (14)$$

Long-run Equation:

$$\text{LNECFT}=\alpha_0 + \phi_1 \text{LNECFT} + \phi_2 \text{ LNLAW} + \phi_3 \text{LNRQ} + \phi_4 \text{LNRD} + \phi_5 \text{LNTRADE} + \phi_6 \text{LNGLOB} + \varepsilon_t \qquad (15)$$

Lagged Residuals: $z_{t-1} = \phi_1 \text{LNECFT} - \phi_2 \text{ LNLAW} - \phi_3 \text{LNRQ} - \phi_4 \text{LNRD} - \phi_5 \text{LNTRADE} - \phi_6 \text{LNGLOB} \qquad (16)$

We transform Eq. (14) and (15) into an error correction model by reparametrizing it, allowing us to analyze the dynamics in both the short and long runs:

$$\Delta \text{LNECFT}=\alpha_0 + \sum_{n=1}^{p} \Delta \text{LNECFT} + \sum_{n=1}^{q_1} \gamma_1 \Delta LNLAW_{t-1} + \sum_{n=1}^{q_2} \gamma_2 \Delta LNQR_{t-1} + \sum_{n=1}^{q_3} \gamma_3 \Delta LNRD_{t-1} + \sum_{n=1}^{q_4} \gamma_4 \Delta LNTRADE_{t-1} + \sum_{n=1}^{q_5} \gamma_5 \Delta LNGLOB_{t-1} + \phi_1 \text{LNECFT} + \phi_2 LNLAW_{t-1} + \phi_3 LNQR_{t-1} + \phi_4 LNRD_{t-1} + \phi_5 LNTRADE_{t-1} + \phi_6 LNGLOB_{t-1} + \varepsilon_t \qquad (17)$$

The ability to estimate both short- and long-term effects gives equation (17) an edge over Engle and Granger's (1987) approach. A comparable approach to that of Engle & Granger (1987) is seen in equation (17). From (17), the intercept is represented by α_0, the short-term variable coefficients are represented by γ_1-γ_5 parameters, the long-term variable coefficients are represented by ϕ_1 - ϕ_6 parameters, and the error term is represented by ε_t .

ECM

$$\text{LNECFT}=\alpha_0 + \sum_{n=1}^{p} \Delta\,\text{LNECFT} + \sum_{n=1}^{q_1} \gamma_1\, \Delta LNLAW_{t-1} + \sum_{n=1}^{q_2} \gamma_2\, \Delta LNQR_{t-1} + \sum_{n=1}^{q_3} \gamma_3\, \Delta LNRD_{t-1} + \sum_{n=1}^{q_4} \gamma_4\, \Delta LNTRADE_{t-1} + \sum_{n=1}^{q_5} \gamma_5\, \Delta LNGLOB_{t-1} + \phi\, Z_{t-1} + \varepsilon_t \qquad (18)$$

where the departure of ΔLNECFT from its long-run equilibrium is denoted by $\phi\, Z_{t-1}$. The adjustment parameter denoted by ϕ is what brings the long-run equilibrium relationship back to equilibrium after a disruption. According to Wang et al. (2011), ϕ must be statistically significant and negative in order for ΔLNECFT to error-correct. It is assumed that the error term ϵt is serially uncorrelated.

Table 16: Bounds Test

Lags (AIC)	F-statistics'	Remark
3	5.75	Co-integration
	Lower limit at 1% = 3.41	Upper limit at 1% = 4.68
	Lower limit at 5% = 2.62	Upper limit at 5% = 3.79
	Lower limit at 10% = 2.62	Upper limit at 10% = 3.35

The aforementioned bound test yields values for the upper and lower bounds, which are the two important value sets. Should the F value fall below the lower limit, it is not possible to rule out the null hypothesis, which maintains that there is no cointegration. If the F statistic value (5.75) exceeds the upper constraint I (1) obtained from the limits testing (3.79), as indicated in Table 16 above, a long-term cointegration association exist between the variables.

Table 17: ARDL Long-run Test

Variables	Coeff.t	t-Statistics	Proba.
LNLAW	-0.106321	-0.783714	0.4484
LNRQ	0.325142	2.461568	0.0300**
LNGLOB	0.892082	2.477790	0.0291**
LNRD	0.725532	1.668676	0.1210
LNTRADE	-0.576687	-3.069816	0.0097***

Note: This indicates that variables are significant*** at 0.01 and ** at 0.05 levels respectively.

From the table 17 above, shows the long-term ARDL findings suggests that the rule of law and R&D have no long-term link with ecological footprint because the probability values are greater than 5%. The result in the long-run indicates that LNRQ has a positive and significant connection with LNECFP, meaning that 1% increase in regulatory quality increases ecological footprint by 0.33% in the long-run, implying a deterioration to the environmental sustainability. The long run ARDL result for LNGLOB with the coefficient of 0.89 shows a positive and significant outcome between LNGLOB and LNECFP, meaning that a 1% increase in globalization will leads to 0.89% rise in ecological footprint in the long-term, implying a setback to environmental sustainability.

Finally, LNTRADE has a negative and significant relationship with LNECFP, meaning a 1% increase in LNTRADE leads to 0.58% decrease in ecological footprint in the long-run, implying an improvement on environmental sustainability.

Table 18: Results of ECM Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.73565	2.109351	6.985868	0.0000***
D(LNECFP (-1))	0.411273	0.127048	3.237149	0.0071***
D(LNECFP (-2))	0.655743	0.154617	4.241073	0.0011***
D(LNGLOB)	0.235988	0.247673	0.952819	0.3595
D(LNGLOB (-1))	0.707491	0.187603	3.771214	0.0027***
D(LNGLOB (-2))	1.058154	0.253360	4.176490	0.0013***
D(LNRD)	-0.549772	0.220731	-2.490688	0.0284**
D(LNRD (-1))	-0.576292	0.234146	-2.461250	0.0300**
D(LNRD (-2))	0.578309	0.176843	3.270192	0.0067***
D(LNTRADE)	0.230925	0.055884	4.132230	0.0014***
D(LNTRADE (-1))	0.342309	0.096915	3.532047	0.0041***
ECM (-1)*	-0.954130	0.136424	-6.993844	0.0000***

Table 18 above displays the short-term ARDL findings. Specifically, the error correction mechanism (ECM) results show that the ECM is -0.95, indicating that the ecological footprint in Japan is approaching the long-run equilibrium level at a speed rate of 95% annually. The results also show that LNRD is significant and negative at the 5% level, implying that a 1% increase in LNRD will lead to 0.55% decrease in LNECFP, while LNGLOB is positive and inconsequential in the short run. This suggests that a 1% rise in research and development will, in the near term, improve Japan's ecological footprint by 0.55%. Lastly, there is a positive and significant association between LNTRADE and LNECFP. This means that a 1% increase in LNTRADE will translate into a 0.23% increase in LNECFP, suggesting that a 1% rise in trade liberalization will in the short term, result in a 0.23% degradation of Japan's ecological footprint.

Figure 5: Cusum Test

Verifying the model's adequacy is a phase in the estimation process that is further broken into two parts: evaluating the model's stability and performance diagnostics for the residuals.

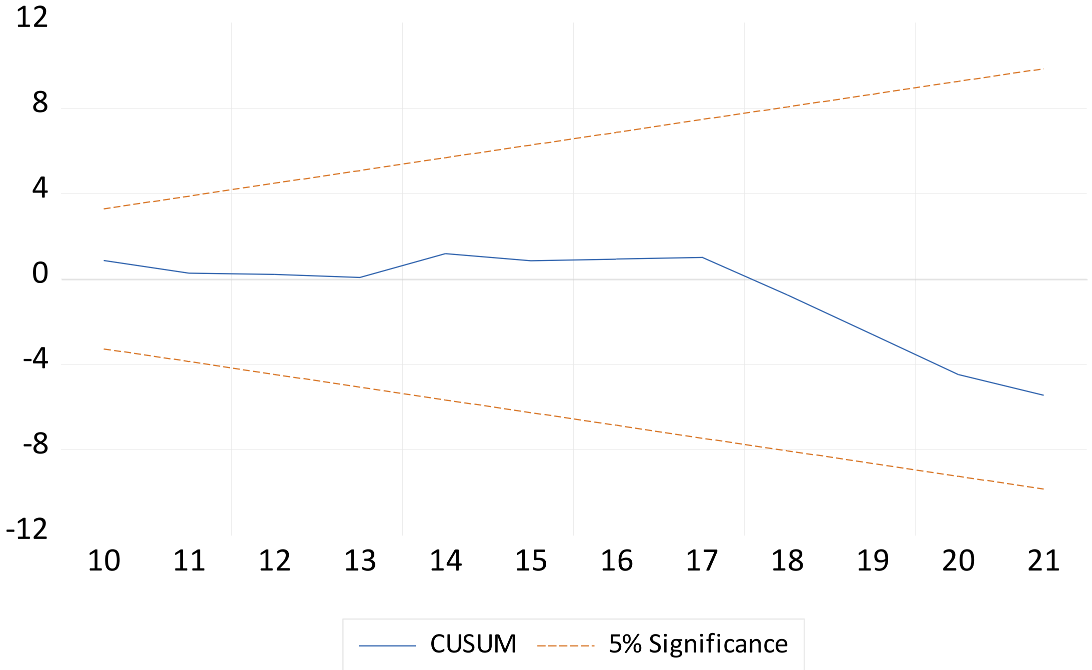

Figure 5: Cusum Test

CUSUM is used to confirm the correctness and stability of the calculated model. Since there are no roots that fall outside of the significance level proposed by Brown et al. (1975), Figure 2 provides evidence that the calculated model satisfies the stability criteria.

4.2.6 Verifying heteroscedasticity and serial correlation

The LM test is utilized, as it is commonly used to verify whether the residuals are serially correlated, and it is confirmed that the serial correlation between the residuals has disappeared. The null hypothesis that there is no serial correlation is not rejected at level 0.05, as shown by Table 9, which shows that there is no evidence of serial correlation in the residuals term of the estimated model. Moreover, Table 9 shows that neither heteroscedasticity nor constant variance exist in the residuals since we do not reject the null hypothesis that there is no heteroscedasticity at level 0.05. The Jarque-Bera test results show that the residuals have a normal distribution.

Table 19: Residual Diagnostic Test

Diagnostic Statistics	Prob. Values	Outcome
LM test	0.06	No serial correlation
Breusch–Pagan–Godfrey	0.11	No heteroskedasticity
Jarque–Bera Test	0.78	Normal

Table 20: The Optimal Lag Selection

Lag 3	LogL	LR	FPE	AIC	SC	HQ
0	257.260	NA	1.20e-15	-17.3283	-17.0454	-17.23972
1	376.230	180.5056*	4.17e-18	-23.0503	-21.070*	-22.43018
2	420.5180	48.86934	3.35e-18	-23.6219	-19.9443	-22.47017
3	490.699	48.40066	9.90e-*	-25.979*	-20.6043	-24.29589*

The ultimate prediction error is referred to as the Akaike Information Criterion, or AIC. The selection of the lag duration in the ARDL is crucial since it makes accurate estimation easier. Because of this, the study uses the optimal lag choice approach, which tries to identify the ideal lag duration choice criterion, and concludes that Lag 3 is the ideal latency to use. Subsequently, the AIC which had the lowest value, was chosen.

4.3 Discussion of Findings

The purpose of our study was to evaluate the connections between Japan's ecological footprint and the country's globalization, trade openness, R&D, regulatory quality, and rule of law. For a short-term connection, an error correcting model was created, and for long-run cointegration, a cointegration test was conducted. The results of the bounds test demonstrate that, dependent factor and the regressors do, indeed, have a long run connection.

The results show that the rule of law has a negative but negligible association with long-term ecological footprint, suggesting that improving the rule of law can improve environmental sustainability, but the coefficient is negligible while regulatory quality has a positive and significant relationship with ecological footprint meaning that, increase in regulatory quality will result in a rise in ecological footprint in Japan in the long-run. This finding, is inconsistent with Dannbach & Mintz's (2011) assertion that, regulatory quality is another important factor to take into account if we are to attain environmental sustainability.

The research also reveals that globalization has a positive and significant relationship with ecological footprint in Japan in the long-run which is expected. This indicate that an increase in globalization (economic, political and social) indices, will certainly increase ecological footprint in Japan in the long-run which imply environmental degradation in Japan. This result is in line with the findings of Figge et al. (2017), who started a discussion about the possible impact of globalization on footprint. Their paper's conclusions imply that globalization increases a country's footprint, but the index's breakdown into its three components shows that only the political component lessens footprint. Interestingly, the results of a comparable study by Rudolph and Figge (2017), which used the same KOF index to examine the short-run impact of globalization on footprint in a panel of 146 countries from 1981 to 2009, were very different.

Furthermore, our finding shows that In Japan, R&D has a negative and substantial short-term relationship with ecological footprint; that is, a rise in R&D will result in a short-term decline in ecological footprint. Imply that an increase in R&D will certainly improve the environmental sustainability in Japan. This result is in line with research of Costa Campi et al. (2015b) who examined the degree to which inventive companies make energy efficiency advancements a priority in their research. Their findings for industrial companies in Spain demonstrate the significance of enterprise scale for energy efficiency innovation. Furthermore, they discovered that businesses are more inclined to innovate for the purpose of improving energy efficiency if their goal is to reduce environmental impacts. Ruiz (2010) conducted an analysis of the correlation between the energy intensity levels observed in the EU-15 member states between 1974 and 2007 and the public funds allotted to energy research. In order to achieve this, he specified a model error correction and performed a Granger causality study. The finding demonstrates that although public investment for energy research contributes to a short-term reduction in the intensity of energy usage, there is a two-way causal relationship between energy intensity and public R&D in energy over the long term. Using the Environmental Kuznets Curve model, Cantos and Balsalobre (2013) demonstrate that public investment on energy-related R&D and innovation initiatives has a negative connection with Spain's greenhouse gas emissions.

Finally, the research finding shows that trade openness has a negative and significant impact on the ecological footprint in Japan in the long-run, imply that an increase in trade liberalization reduces ecological imprint in Japan, meaning an improvement on Japan's environmental sustainability. This research work is consistent with Sun et al. (2020) who looked into how trade openness affected ecological harm in Sub-Saharan African countries between 1990 and 2014. The study used FMOLS and DOLS to determine the long-run equilibrium linkage of the series. The analysis supported the EKC hypothesis, which suggested that, once commerce reached a certain threshold, it would eventually contribute to a reduction in environmental pollution in this region.

Table 21: Granger Causality Tests

Null Hypothesis:	F-Statistic	Prob.	Remark
LNLAW ↗ LNECFP	1.68440	0.2049	
LNECFP↗ LNLAW	4.67750	0.0393**	LNECFP→ LNLAW
LNRQ ↗ LNECFP	5.56522	0.0255*	LNRQ → LNECFP
LNECFP ↗ LNRQ	0.00935	0.9237	
LNRD ↗ LNECFP	4.24154	0.0489**	LNRD → LNECFP
LNECFP ↗ LNRD	0.54222	0.4676	
LNGLOB ↗ LNECFP	3.14903	0.0868	
LNECFP ↗ LNGLOB	0.00194	0.9652	LNECFP ≠ LNGLOB
LNTRADE ↗ LNECFP	16.0499	0.0004	LNTRADE → LNECFP
LNECFP ↗ LNTRADE	0.60948	0.4415	
LNRQ ↗ LNLAW	4.92494	0.0347**	LNRQ → LNLAW
LNLAW ↗ LNRQ	0.17728	0.6769	
LNRD ↗ LNLAW	2.16294	0.1525	
LNLAW ↗ LNRD	1.03906	0.3168	LNLAW ≠ LNRD
LNGLOB ↗ LNLAW	1.98159	0.1702	
LNLAW ↗ LNGLOB	0.03496	0.8530	LNLAW ≠ LNGLOB
LNTRADE ↗ LNLAW	2.69649	0.1118	
LNLAW ↗ LNTRADE	0.82856	0.3705	LNLAW ≠ LNTRADE
LNRD ↗ LNRQ	1.52797	0.2267	
LNRQ ↗ LNRD	3.19847	0.0845	LNRQ ≠LNRD
LNGLOB ↗ LNRQ	4.88893	0.0354**	LNGLOB → LNRQ
LNRQ↗ LNGLOB	0.16721	0.6857	
LNTRADE ↗ LNRQ	0.72108	0.4030	
LNRQ↗ LNTRADE	7.49421	0.0106**	LNRQ→ LNTRADE
LNGLOB ↗ LNRD	3.97631	0.0560	
LNRD ↗ LNGLOB	3.39294	0.0761	LNRD ≠ LNGLOB
LNTRADE ↗ LNRD	1.07290	0.3092	
LNRD ↗LNTRADE	4.58333	0.0411**	LNRD → LNGLOB
LNTRADE ↗ LNGLOB	2.94257	0.0973	
LNGLOB↗ LNTRADE	5.73531	0.0236**	LNGLOB→ LNTRADE

Note: ↗ indicates does not granger causes; ↔ indicates bidirectional association; → indicates unidirectional association; and ≠ indicates no association. The symbols *** and ** show 1% and 5% significant levels, respectively.

Once an ARDL long-term connectedness has been confirmed, there is a relationship between the variables. Depending on the situation, these connections may be one-way, two-way, or even entirely none. Table 11 above shows that, LNECFP and LNLAW have a unidirectional relationship, this means that ecological footprint granger cause rule of law but rule of law does not granger cause ecological footprint. LNRQ and LNECFP have a unidirectional association, meaning that regulatory quality granger causes ecological footprint but ecological footprint does not cause regulatory quality. Similarly, LNRD and LNECFP have a one-way directional connection, this means that R&D granger causes ecological footprint but ecological footprint does not cause R&D. LNTRADE and LNECFP have a unidirectional relationship, this means that trade openness granger causes ecological footprint but ecological footprint does not cause trade openness. However, LNGLOB and LNECFP, LNRD and LNLAW, LNGLOB and LNLAW, LNTRADE and LNLAW, LNRD and LNRQ, LNRD and LNGLOB all have no relationship among the variables.

Furthermore, LNGLOB and LNRQ have a unidirectional connection, this means that globalization granger causes regulatory quality but regulatory quality does not granger causes globalization. Similarly, LNRQ and LNTRADE have one-way relationship, indicating that regulatory quality granger causes trade openness. Finally, LNRQ and LNGLOB have a unidirectional connection, this shows that regulatory quality granger causes globalization but globalization does not granger cause regulatory quality.

4.4 Conclusion and Recommendations

This study examined the short- and long-term impacts of the rule of law, regulatory quality, R&D, globalization, and trade openness on environmental deterioration in

Japan using the ecological footprint as a stand-in for environmental degradation. The research utilizes annual time series from 1990 to 2021 and applied ARDL technique. The crucial value is lower than the F value, according to the results. indicating that the model's variables cointegrate. The results of the ARDL show that whereas regulatory quality has a positive and significant relationship with ecological footprint, the rule of law has a negative but insignificant relationship with it. This implies that long-run environmental degradation in Japan is exacerbated by higher regulatory quality. Likewise, there is a positive and noteworthy correlation between globalization and ecological footprint, this shows that increase in globalization increases ecological footprint or environmental degradation. However, R&D in the short run demonstrate a negative and significant relationship with ecological footprint, meaning that increase in R&D decreases ecological footprint in Japan. And trade openness has a negative and significant connection with ecological footprint meaning an increase in openness to trade decreases environmental degradation in Japan. The research also used the Granger causality test and a number of diagnostic tests to assess the research's robustness, and the results show that our findings are reliable.

In light of the results that have been described, the research has made several recommendations for policy implementation in Japan. Trade openness has been confirmed that it reduces environmental degradation in the long-run, therefore, the Japan’s government and environmentalists should make policy that will facilitates or promotes advance trading. Protecting the environment ought to be given top priority by the government in order to support sustainable trade practices. This can involve putting eco-labeling programs into place, encouraging sustainable production and consumption, and promote the positive effects of international trade on the environment. Furthermore, R&D in the short run reduces environmental deterioration in Japan, based on this outcome the Japan's government should invest more in R&D and also establish collaboration with industries and academia to promotes environmental sustainability in Japan.

Similar to this, the government can impose environmental taxes on actions that have a big influence on the environment, like energy use, garbage disposal, and carbon emissions, to encourage sustainable behaviors and lessen environmental imprint. This may inspire companies and people to embrace greener policies and lessen their environmental impact. Lastly, the Japanese government can raise the general public's understanding of the value of environmental preservation and the advantages of sustainable activities. Public education campaigns, the encouragement of sustainable lifestyles, and the participation of citizens in environmental decision-making are a few examples of how to do this.

Chapter 5

CONLUSION AND RECOMMENDATIONS

5.1 Conclusion

The two factors, globalization and energy consumption have the capacity to advance both economic growth and environmental quality. Based on this, Chapter 3 has examined how, in the case of Japan's economy, GDP, GLO, RENEW, and NATGAS affect CO_2. The research utilized the Granger causality, DOLS, and ARDL model on data from 1990 to 2021.

The results of the ARDL estimation technique demonstrate that there is a negative correlation between renewable energy use and ecological impact both over the short and long terms. This suggests that Japan's environment will get better both now and in the future by adopting renewable energy. Although there is a short-term positive correlation between GDP and ecological imprint, the long-term relationship between the two is negative, indicating that GDP both increases and decreases environmental impact over time. However, natural gas and globalization have a long-term positive association that increases Japan's ecological footprint. This suggests that over time, both natural gas and globalization contribute to Japan's environmental damage. Globalization and renewable energy have a bidirectional causal relationship, as demonstrated by the Granger causality test and the DOLS result, which is in line with the long-run limits test result.

Using an ecological footprint as a proxy for environmental degradation, Chapter 4 looked at the consequences of trade openness both now and in the long- term, globalization, R&D, regulatory quality, and the rule of law on environmental deterioration in Japan. Applying the ARDL approach, the study makes use of annual time series data spanning from 1990 to 2021. The ARDL results demonstrate that while the rule of law has a negative but negligible link with ecological footprint, regulatory quality has a positive and significant relationship with it. This suggests that increased regulatory quality in Japan exacerbates long-term environmental damage. The relationship between globalization and ecological footprint is also significant and positive, indicating that a growth in globalization is associated with an increase in ecological footprint or environmental deterioration. Nevertheless, R&D and ecological footprint have a negative and substantial relationship in the near term, that is, a rise in R&D reduces ecological footprint in Japan. Furthermore, there is a strong negative correlation between trade openness and ecological footprint—meaning, a greater degree of trade openness in Japan is associated with less environmental deterioration.

5.2 Policy Implications

Based on the study's findings, the following expanded policy implications are suggested for Japan to enhance its environmental protection and achieve sustainable economic growth: Japan must recognize the significant link between economic expansion (GDP increase) and ecological imprint, aiming to balance economic growth with environmental sustainability. Japan's Climate Change Performance Index (CCPI) position is continually dropping; it is currently ranked 58th in this year's edition, which is extremely low. In the categories of GHG Emissions, Renewable Energy, and Energy Use, Japan is rated poorly. In terms of climate policy, the nation continues to receive a very low-ranking Climate Performance Ranking, (2024). This indicates a need for cohesive and robust environmental policies. This low ranking reflects a lack of comprehensive and effective environmental policies, which should be addressed through the development and implementation of more stringent regulations. Legally binding commitments to achieve carbon neutrality by 2050 should be established. This includes implementing policies to reduce emissions by 40% from 2018 levels by 2030, ensuring that these targets are both ambitious and achievable. Acknowledging the inadequacies of current policies is crucial, and steps must be taken to strengthen them. These measures will demonstrate a commitment to environmental sustainability and align with global standards.

Improving the enforcement of environmental laws is essential. This includes the Soil Environment Conservation Act, the Water Environment Conservation Act, and the Clean Air Conservation Act. Strengthening the rule of law will ensure that these regulations are effectively implemented and adhered to. Increasing the use of renewable energy sources will help reduce the ecological footprint. Providing incentives for renewable energy adoption and investments in green technology will encourage the transition to more sustainable energy sources. Implementing stringent laws to preserve environmental assets is necessary to ensure strict enforcement and compliance. These laws should cover all aspects of environmental protection, including air, water, and soil quality. Providing long-term financing options and incentives for entrepreneurs investing in green technology and sustainable practices will support the development of environmentally friendly businesses and innovations.

Addressing institutional barriers that hinder effective environmental policy implementation is critical. This includes managing conflicts of interest in environmental management and allocation institutions to ensure unbiased policy enforcement. Increasing political will and support from stakeholders for robust environmental policies is essential for successful implementation. Ensuring adequate resources and capacity for institutions tasked with evaluating and enforcing environmental requirements will improve their effectiveness. Investing in green technology to improve energy efficiency and reduce South Japan's ecological footprint is vital. This includes supporting research and development in sustainable technologies and providing funding for the implementation of these innovations. Considering a temporary increase in environmental regulations can accelerate progress towards sustainability goals, creating a more urgent focus on environmental protection.

By implementing these expanded policy implications, Japan can better align its economic expansion with environmental sustainability. This approach will ensure long-term ecological and economic health, demonstrating a commitment to protecting the environment while fostering economic growth.

5.3 Limitations and Upcoming Research

This thesis employs a comprehensive empirical technique to examine the effects of GDP, rule of law, use of renewable energy, globalization and trade openness on Japan's ecological imprint. First, the main variables of this study are the GDP, legal system, use of renewable energy, globalization and trade openness with an ecological footprint of Japan. As a result, future research can concentrate on other nations or incorporate a huge number of nations that have access to these regressors. Second, because there are limitations on the data's accessibility for the regressors and load capacity factor, this study employs data from 1990 to 2021. Future studies can therefore concentrate on population growth, industrial composition changes, or technological advancements, exogenous shocks (such as global economic crises, pandemics, etc.), biocapacity, biodiversity, gross greenhouse emissions, and other aspects, making considerably more use of current quarterly data. Third, this study's empirical analysis makes use of the ARDL technique. Subsequent research endeavors may examine diverse national contexts with distinct approaches, such as the Heterogeneity and Sensitivity analysis, innovative bootstrap Fourier method.

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