JOEEP

e-ISSN: 2651-5318
Homepage: http://dergipark.org.tr/joeep

Araştırma Makalesi ● Research Article

Green Financial Instruments and Renewable Energy: Toda-Yamamoto Causality Test

Yeşil Finansal Araçlar ve Yenilenebilir Enerji: Toda-Yamamoto Nedensellik Testi

Muhammed Fatih Yürük [a, *]

[a] Dr.Öğr.Üyesi, Dicle Üniversitesi, Sivil Havacılık Yüksekokulu, 21000, Diyarbakır / Türkiye
ORCID: 0000-0001-7429-2278

MAKALE BİLGİSİ

Makale Geçmişi:
Başvuru tarihi: 27 Şubat 2023
Düzeltme tarihi: 22 Mayıs 2023
Kabul tarihi: 19 Haziran 2023

Anahtar Kelimeler:
Toda-Yamamoto Nedensellik Testi
Yenilenebilir Enerji
Yeşil Finans
Amerika Birleşik Devletleri Tahvilleri

ÖZ

Bu çalışmada Amerika Birleşik Devletleri'ndeki yeşil finansal varlıklar ile farklı değişkenler arasındaki ilişki analiz edilmiştir. İklim değişikliğinin dünya çapında önem kazanması ve küresel kalkınmanın teşvik edilmiş olması, yeşil finansmanı önemli kılmıştır. Düşük karbonlu bir ekonomiye geçişi önemseyen dünya hükümetleri çevre dostu yatırımları finanse etme çabaları yeşil finans araçlarını geliştirmiştir. Yeşil finansal varlıkların önümüzdeki yıllarda daha da önem kazanacak olması bu çalışmaya motivasyon katmıştır. Çalışmada yeşil finans ile ilgili birçok değişken kullanılmış ve analiz edilmiştir. Araştırmada Temmuz 2012-Nisan 2022 tarihleri arasında S&P Yeşil Tahvil Endeksi, S&P Küresel Temiz Enerji Endeksi, Invesco WilderHill Temiz Enerji, Amerika Birleşik Devletleri 10 Yıllık Tahvil, Enerji Tüketiminden Kaynaklanan Karbondioksit Emisyonları, Toplam Yenilenebilir Enerji Üretimi değişkenlerinin aylık verileri yer almıştır. Çalışmada Toda-Yamamoto nedensellik testi uygulanmıştır. Toda-Yamamoto nedensellik testinde, serinin aynı seviyede statik olması gerekmemesi büyük bir avantajdır. Test sonucunda, Invesco WilderHill Temiz Enerji ve Amerika Birleşik Devletleri 10 Yıllık Tahvil değişkenleri arasında çift yönlü nedensellik bulunmuştur.

ARTICLE INFO

Article history:
Received: Feb 27, 2023
Received in revised form: May 22, 2023
Accepted: June 19, 2023

Keywords:
Toda-Yamamoto Causality Test
Renewable Energy
Green Finance
United States Bonds

ABSTRACT

This study analysed the relationship between green financial assets in the United States and different variables. The fact that climate change has become important worldwide and that global development has been promoted has made green finance important. The world's governments, caring about the transition to a low-carbon economy and their efforts to finance environmentally friendly investments, have developed green finance tools. The fact that green financial assets will gain more importance in the coming years has added motivation to this study. In the study, many variables related to green finance were used and analyzed. Monthly data for the S&P Green Bond Index, S&P Global Clean Energy Index, Invesco Wilder Hill Clean Energy, United States 10-Year Bond, Carbon Dioxide Emissions from Energy Consumption, and Total Renewable Energy Production variables between July 2012 and April 2022 were included in the research. The Toda-Yamamoto causality test was applied in the study. In the Toda-Yamamoto causality test, it is a great advantage that the series does not need to be static at the same level. As a result of the test, bidirectional causality was found between Invesco WilderHill Clean Energy and the United States 10-Year Bond variables.

1. Introduction

The fact that climate change has become important worldwide and that global development has been promoted has placed green finance in an important position. Green financial instruments such as green bonds, social and sustainable bonds, green loans, and green insurance have become increasingly popular. These green finance instruments were created to finance sustainable projects and support an economy that supports low carbon emissions. The potential of green financial instruments lies in their ability to mobilize private capital towards green investments while at the same time addressing environmental risks and promoting sustainable business practices. Green finance instruments are an important and popular option for renewable energy investments, green buildings, and energy-efficient factories. In 2021, the share of green, social, sustainable, sustainability-linked, and transition bonds

* *Sorumlu yazar/Corresponding author*.
e-posta: *mfyuruk@hotmail.com*

Atıf/Cite as: Yürük, M.F. (2023). Green Financial Instruments and Renewable Energy: Toda-Yamamoto Causality Test. *Journal of Emerging Economies and Policy*, 8(1), 191-203.

(GSS+) issuances reached record volumes of over $1 trillion and accounted for 5% of the global bond market. In 2022, GSS+ issuance maintained its 5% share of the global bond market despite challenging conditions that led to volumes falling to USD 863.4 billion (ClimateBonds, 2023). Green loans, which are an important tool that encourages investors to invest in green projects, are gaining interest in the financial sector. Green financial instruments can help mitigate the risks of climate change, which has become a major problem in the world, by encouraging green investments. This benefit can also contribute to the development of stronger, more resilient, and more sustainable economies. The development of countries with green projects leads to the strengthening of the global economy. Green finance includes important components to drive private equity toward environmentally friendly investments. In the coming years, with the increase in world awareness of climate change, the role of green finance in sustainable development will increase even more. The innovations that green finance will bring will positively impact employment as they will create new business opportunities. Overall, green finance has the potential to make a significant impact on mitigating climate change risks and contributing to a more sustainable and resilient economy. It is thought that this study will contribute to the literature by addressing the extremely important issues of green finance and renewable energy.

As the world moves towards a sustainable future, green financial instruments are gaining importance in the United States. These financial instruments have been developed to support investments in renewable energy. Examples of green finance instruments in the U.S. include green bonds and green loans issued to finance environmentally conscious projects. Among the variables of this study is the S&P Green Bond Index, an index that tracks the performance of global green bonds, which are fixed-income securities designed to finance environmentally conscious projects. The S&P Global Clean Energy Index is an index that tracks the performance of global companies involved in clean energy production, such as solar, wind, and hydropower. This index is important in the context of directing investors to low-carbon emission-based clean energy projects. Another variable is Invesco Wilderhill Clean Energy, an exchange-traded fund (ETF) that invests in companies involved in renewable energy production and conservation. It is very important in terms of directing investors to the field of clean energy through a diversified portfolio of companies. Due to these important situations, selected green finance instruments have been included in the scope of the study.

World energy consumption refers to the total energy produced and consumed by the whole world. Energy consumption is directly proportional to production capacity, economic development, and the welfare level of society. Agencies such as the International Energy Agency, the United States Energy Information Administration, and the European Environment Agency record and publish energy data at regular intervals. By understanding the amount and trend of energy consumption on a global scale, plans, programs, and models can be developed to solve existing energy problems. Thus, it will be possible to take precautions against the problems that may be encountered in the future (Şengöz, 2021). In the energy policies of developed countries, especially the United States, increasing energy efficiency, reducing energy intensity, and giving importance to energy saving comes first. Energy density can be defined as the amount of energy used to achieve a gross domestic product of $1. The new world energy policies of developed countries are not only to increase the amount of energy used per person, but also to develop modern systems that can be usedmost efficientlyy regardless of the type of energy, and to establish the structure that will produce, transmit, and consume the most energy with minimum energy consumption (Pamir, 2003). Figure 1 shows the annual change in actual and projected global energy demand. Primary energy consumption (energy sources that have not undergone any transformation) decreased by 4.5% in 2020. This was the largest decline since 1945. Although significant reductions have also been seen in natural gas and coal, the decline in energy consumption is mainly due to oil, which contributes about three-quarters (World Energy Council, 2021).

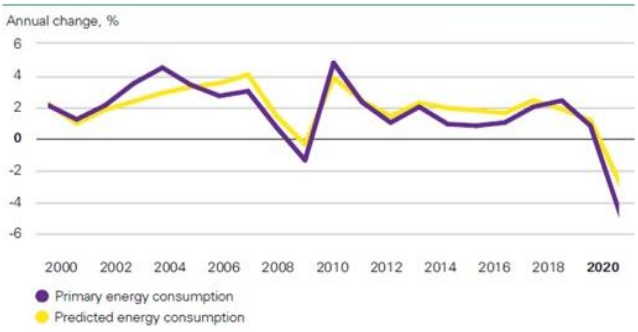


Figure 1. Global energy demand: actual versus predicted (BP, 2021).

Primary energy reversed the sharp decline seen in 2020, providing the largest increase in history with 31 EJs in 2021. In 2021, primary energy was 8 EJ above 2019 levels. in 2021, the increase in primary energy grew by 10 EJ, with China's emerging economy increasing by 13 EJ. Since 2019, primary energy consumption in developing economies has increased by 15% EJ. In contrast, energy demand in developed countries economies in 2021 was also 8 EJ below 2019 levels. In contrast, in the economies of developed countries in 2021, energy demand was 8 EJ below 2019 levels. The increase in primary energy between 2019 and 2021 was driven entirely by renewable energy sources. The low oil demand (-8 EJ) in 2019 and 2021, where the fossil fuel energy consumption level is unchanged, is offset by high natural gas (5 EJ) and coal (3 EJ) consumption, as seen in the graph in Figure 2. In addition, Figure 2 shows the change in primary energy in OECD and non-OECD countries (BP, 2022).

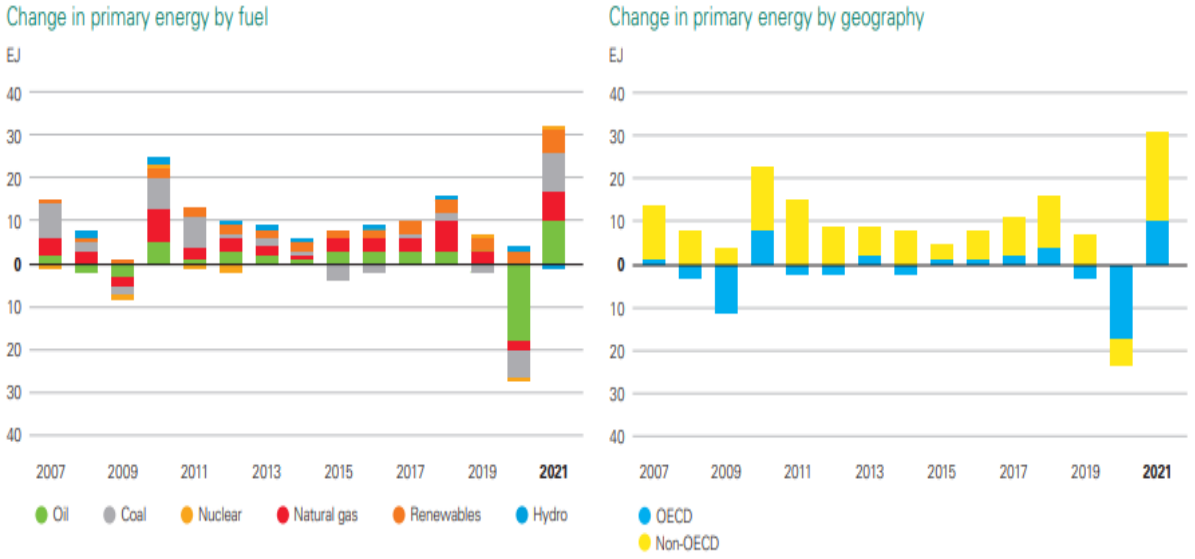


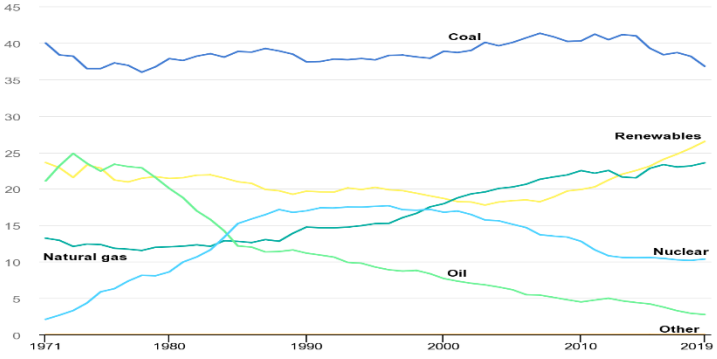
Figure 2. Change in primary energy by fuel and change in primary energy by geography.

Limited resources are insufficient to meet the energy requirements of the increasing population and manufacturing industry worldwide. Global energy consumption is projected to double in 2035 compared to 1998 and triple in 2055. Non-renewable traditional energy sources have become increasingly polluting, threatening the health of living things. The widespread use of traditional energy sources in transportation, housing, and industry increases environmental pollution even more. 95% of the energy consumption in the transportation sector is met by oil (Özkaya, 2004).

Renewable Energy

Because fossil energy resources are not sufficient for the increasing world population, studies on the development of renewable energy technologies are continuing. Commonly used energy sources; hydraulic energy, geothermal energy, biomass energy, solar energy and wind energy (Kaya and Koç, 2015). Renewable energy sources are the biggest candidates that can replace fossil fuels in terms of shaping countries' economic policies. The most important aspect that makes these resources important is that they are inexhaustible. In addition, it is an important advantage that they are environmentally friendly compared to fossil fuels in the process of flowing from production to consumption. Considering that fossil resource reservedness is only in a limited number of places in the world, the fact that renewable energy source is diverse and spread over a wide geography in the world will make countries more independent. In this context, energy dependence on fossil fuels does not have the same effect on renewable energy sources (Ali and Yılmaz, 2021). Despite the global energy shortage in the world, biogas, one of the renewable energy sources that have become an important one, seems to be able to respond to local needs in regions with favourable production conditions. Geothermal energy is an environmentally friendly energy source that contributes to the preservation of air quality. Solar energy, another important renewable energy source, prevents unnecessary and excessive energy consumption by using natural heating and cooling systems. Natural and health-free materials are used in solar energy systems, they are not dependent on the outside. Wind energy, on the other hand, is a stable, reliable, continuous energy source and is not dependent on foreign countries (Şenpınar and Gençoğlu, 2006).

Figure 3. World electricity generation mix by fuel, 1971-



2019 (IEA, 2019).

As seen in Figure 3, coal is one of the leading fuels for electricity production in the world. Coal is 10% ahead of renewable energy sources. Coal accounts for 37% of global electricity and power generation. While the share of coal in energy production was around 40% in the 2000s, it started to decrease in 2015 when renewable energy sources started to grow with the investments made. In 2013, the share of renewable energy sources in electricity generation exceeded the share of natural gas. In 2019, renewable energy sources provided about 27% of global energy. The share of nuclear power has remained stable at around 10% for eight years, while oil provided less than 3% of the world's electricity in

2019 (IEA, 2019).

Table 1: World electricity generation mix by fuel (Units: %), 1971-2019 (IEA, 2019)

Years	Nuclear	Coal	Oil	Natural Gas	Renew.	Other
1971	2.11	39.98	21.08	13.23	23.6	0.00
1980	8.61	37.85	20.06	12.05	21.43	0.00
1990	16.99	37.4	11.18	14.76	19.68	0.00
2000	16.79	38.86	7.7	17.96	18.68	0.01
2010	12.8	40.28	4.49	22.5	19.91	0.01
2015	10.59	39.28	4.22	22.8	23.1	0.02
2016	10.46	38.38	3.79	23.32	24.04	0.01
2017	10.26	38.68	3.29	22.99	24.76	0.02
2018	10.19	38.16	2.93	23.14	25.57	0.01
2019	10.36	36.81	2.77	23.56	26.49	0.01

Table 1 shows the 1971–2019 years between nuclear, coal, oil, natural gas, and renewables. The percentage change in energy sources is given. As can be seen in the table, the share of renewable energy sources in electricity production has started to increase since 2012. Despite this increase, the fact that there is no significant decrease in the shares of other energy sources shows that renewable energy investments are still not at the desired level. In particular, the share of coal in electricity generation is at very high levels. Despite the advantages of renewable energy sources, their share of total energy is still low. The main reasons for this situation are the continued subsidies to fossil fuels, the fact that the total cost of pollution is not included in the cost of fossil fuels, and the high installation costs of new renewable energy investments. The pace of energy demand in developed countries is slowly increasing. In this case, energy consumption habits do not change immediately, and they take time to change. In developing countries, on the contrary, the energy demand is increasing rapidly, and fossil fuels meet this demand. In the current system, it is not easy for the energy produced by renewable energy sources to compete with fossil fuels in terms of pricing. Taking these issues into consideration, renewable energy technologies should be encouraged by international authorities and states to reach an optimal level of renewable energy investments since they are not self-developing systems and it is almost impossible to compete with fossil fuel technologies (Bayraç and Çildir, 2017). Some countries in the world are taking important steps in terms of incentives. One of these countries, Germany, has taken important steps in energy with Europe's largest economy. Compared to 1990, Germany's GDP increased by 46% in 2019, while coal consumption decreased by 60%, oil consumption by 20%, nuclear use by 39%, and energy losses by 415%. In the same per period use of hydro increased by 10%, while the use of wind, solar, etc. increased by 89627%. Germany increased R&D expenditures on energy efficiency by 893% and R&D expenditures on renewable energy by 99% in 2019 compared to 1990. reduced fossil fuel R&D spending by 82%. While this situation shows the importance Germany attaches to renewable energy investments, it has been exemplary in its sensitivity to fossil fuels (Naimoğlu, 2021).

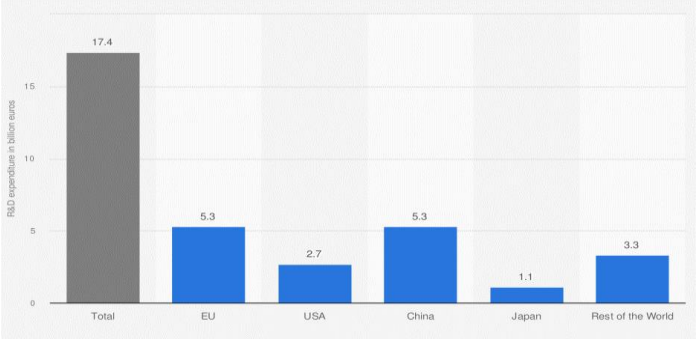


Figure 4. Total global research and development (R&D) spending on energy in 2020, by region Source: Statista, 2022

The graph in Figure 4 shows the amount of money spent on energy R&D studies at the global level as billions of euros. European Union countries and China are seen in the first place with R&D expenditures of 5.3 billion euros. The USA spent 2.7 billion and Japan spent 1.1 billion euros on R&D in energy. The total R&D expenditures of other countries in the world remained at 3.3 billion euros. In total, the amount spent on energy investments is 17.4 billion euros. Of this amount, €13.3 billion in R&D spending on renewable energy.

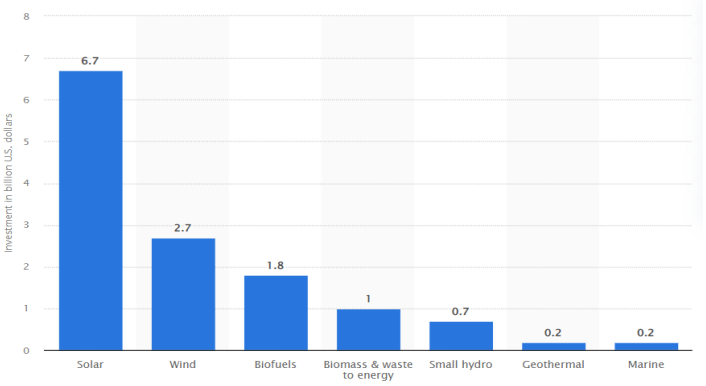


Figure 5. Research and development investment in renewable energy worldwide in 2019, by sector Source: Statista, 2022.

In the graph in Figure 5, billions of dollars of research and development investments made in renewable energy sectors around the world in 2019 are given. As can be seen in the chart, approximately 6.7 billion dollars of R&D investments were made in the solar energy sector in 2019. Subsequently, R&D investments of approximately 0.2 billion dollars were made for the wind energy sector (2.7), biofuels (1.8), biomass and waste to energy (1), small hydro (0.7), geothermal (0.2), and marine energy sectors (Statista, 2022). In particular, the investment made in solar energy systems is remarkable. The fact that the sun has a geographical impact on many regions of the world, is one of the factors that

attract investment in clean energy.

Carbon Dioxide (Co_2) Release and Effects

Oil, natural gas, coal, etc. are fossil fuels and contain carbon. With the combustion of these fuels as a result of individual and corporate uses, carbon dioxide gas is emitted into the atmosphere. With the increase in industry, the release of carbon dioxide gas into the air causes air pollution. The pollution of this gas in the air has started to reach frightening levels today. Climate changes that occur on a global scale are called "global warming." With the increase in global warming, living things on Earth have been exposed to danger. This situation has become the centre of attention around the world and has become a common environmental problem. Efforts are being made on a global scale to overcome this problem. Especially in the 1990s, the use of renewable energy sources against fossil resources came to the forefront (Karaaslan et al., 2017). The first global struggle against climate change brought about by global warming was the preparation of the United Nations Framework Convention on Climate Change. Developed countries have higher carbon emissions than developing and underdeveloped countries. Therefore, the Convention is based on the approach of imposing additional responsibilities on developed countries. The Kyoto Protocol, which was prepared in parallel with this convention, was opened for signature in 1997 and entered into force in 2005 (Çıtak, 2016).

Figure 6. Annual CO_2 emissions (Source: Our World in Data based on the Global Carbon Project (2022)).

Studying the change in carbon dioxide emissions, which have reached dangerous dimensions around the world, is important in terms of finding solutions to this global problem. Figure 6 shows the annual change in carbon dioxide (CO_2) emissions from fossil fuels and industry. The graph shows the change in global emissions from the mid-18th century to the present. It seems that carbon dioxide emissions were very low before the Industrial Revolution. Even from the 20th century until the mid-century, emissions growth was still slow. Globally, 6 billion tons of CO2 were released in 1950, while it increased to over 22 billion tons in 1990. Even though the increase has slowed down in the last few years, more than 34 billion tons of CO2 are still emitted into the world every year (ourworldindata.org, 2021).

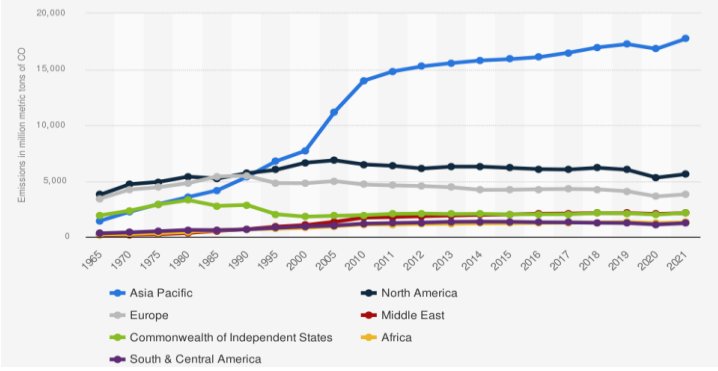


Figure 7. Carbon dioxide emissions from energy worldwide from 1965 to 2021, by region, (Statista, 2022).

Figure 7 shows carbon dioxide emissions from energy worldwide from 1965 to 2021 with a million metric tons of carbon dioxide units of measurement, according to the regions. As the chart shows, the Asia-Pacific region produced 17.74 million metric tons of carbon dioxide emissions in 2021, more than the total emissions of all other regions. China alone has produced about 60% of Asia-Pacific carbon dioxide emissions. This amount constitutes 31% of the global total. According to 2021 data, the second region with the most CO2 in the environment was North America, with 5.6 million metric tons. Carbon emissions in Europe, North America, and the Asia-Pacific region increased by about 5% in 2021 compared to 2020 levels (Statista, 2021).

Table 2. Global carbon dioxide emissions from energy 1965-2021, by region (Statista, 2022).

Years	Asia Pacific	North America	Europe	Middle East	Commonwealth of	Africa	South & Central
1965	1.431	3.774	3.428	137	1.919	194	306
1970	2.235	4.701	4.226	172	2.337	230	391
1975	2.932	4.916	4.442	225	2.896	314	492
1980	3.556	5.381	4.801	339	3.28	433	606
1985	4.161	5.213	5.398	532	2.761	582	591
1990	5.351	5.683	5.46	671	2.848	662	653
1995	6.764	5.994	4.805	898	2.017	720	797
2000	7.696	6.628	4.789	1.045	1.798	792	915
2005	11.175	6.846	4.984	1.339	1.872	937	1.006
2010	13.976	6.475	4.675	1.71	1.939	1.096	1.174
2015	15.91	6.167	4.207	1.997	2.007	1.211	1.338
2020	16.829	5.296	3.608	2.044	1.985	1.223	1.095
2021	17.735	5.602	3.794	2.117	2.133	1.291	1.213

Data by region for worldwide energy-related carbon dioxide emissions from 1965 to 2021 are shown in Table 2. As can be seen in the table, while the Asia region had carbon emissions of 1,431 million metric tons in 1965, they increased to 17,735 million metric tons in 2021. In the Middle East and Africa regions, it is seen that carbon emissions are decreasing. It is seen that carbon emissions from Asian and North American regions are quite high in the world. Globally, especially in these problematic regions, studies and sanctions to reduce carbon emission amounts are important for the survival of living beings and increasing the quality of life. If these issues are not taken into consideration, the number of diseased creatures will likely increase in the coming years. This means distress in the health care systems of governments and extra costs and expenses. These expenditures will lead to a decrease in gross national product and a decrease in welfare. For this reason, the only way to prevent carbon emissions is to switch to renewable energy systems. This transition is only possible with the joint efforts of all countries on a global scale. With the incentive to be given to the green financial instruments and renewable energy source investments of the states, the carbon emissions seen in the graph and table given above will be reduced. Of course, these incentives must be followed by the authorities. It is necessary to investigate whether incentives translate into investments to reduce carbon emissions.

2. Literature

In the literature, it is seen that many studies have been carried out to determine the relationship between causality analyses. Hamdi (2013) examines the export-based growth hypothesis in Tunisia and Morocco. Two contradictory results were found in the study using the analysis of Toda and Yamamoto (1995). Second, while there is evidence of export-led growth in Tunisia, in Morocco the results reveal an import-based growth policy. Şentürk and Akbaş (2014) examined the relationship between variables as in other studies. The authors examined the existence of a mutual relationship between economic growth, the unemployment rate, and the inflation rate. Toda-Yamamoto (1995) and bootstrap causality tests were performed to determine the causal relationship between variables. As a result of the study, they determined a two-way causal relationship between the industrial production index, the inflation rate, and the unemployment rate.

Another causality analysis of the tourism sector was made by Topallı (2015). The author used the Toda-Yamamoto causality analysis test. In the study where the causal relationship between tourism and economic growth was examined with Toda-Yamamoto, it was found that there is no causal relationship between tourism to economic growth or from economic growth to tourism in Turkey. Küçükaksoy et al. (2015) tested the validity of the "export-based growth hypothesis" of the Turkish economy. The hypothesis claims that there is a causal relationship between real exports and real gross domestic product. The Johansen cointegration test, Gregory-Hansen cointegration test, Toda-Yamamoto causality test, fully modified ordinary least squares (FMOLS), canonical cointegrating regression (CCR), and dynamic ordinary least squares (DOLS) methods were used in this study. As a result of the study, the authors found a long-term relationship in the Gregory-Hansen cointegration test. In the Toda-Yamamoto test, a two-way causality was found between real exports and real GDP. In FMOLS, CCR, and DOLS methods, the increase in long-term real exports increases the gross domestic product. Thus, they proved the hypothesis of growth based on exports, which is the main purpose of the study. Genç and Tandoğan (2015) have examined information and communication technologies, which is an important topic that has attracted the attention of researchers in recent years. In their studies, they examined the effect of information and communication technologies on total factor efficiency. Toda and Yamamoto used the rationale of innocence. According to the results of the causality study by Toda and Yamamoto, they determined the bidirectional causal relationship between information and communication technologies and factor efficiency.

Najahi et al. (2016) investigated the causal relationship between structure and performance in the banking sector. Najahi et al. (2016), who used the Toda-Yamamoto causality test like other authors, Siami-Namini (2017) studies the relationship between exchange rate and stock price. Researcher Toda-Yamamoto performed the analysis using the causality test. A study has shown that there is no significant evidence of a relationship between stock prices and the exchange rate. Dritsaki (2017) examined the relationship between inflation and nominal interest. Using the causality test of Toda and Yamamoto (1995), the author stated that the nominal interest rate has a positive relationship and greatly affects inflation in the three countries.

In her study, Arkhipova (2017) addressed the characteristics of green finance and its development prospects on a global, regional, and national scale and aimed to determine the efficiency and effectiveness of green practices in the financial system. The methodology of the research includes the systemic analytical approach, the comparison of national and regional samples of its practical application, and the statistical analysis of data sets provided by international organizations, national authorities, and financial institutions. While the classification and typology of green financial instruments and institutions are examined, the state of green infrastructure is also determined. Research shows that green finance captures the interdisciplinary approach and ideas of sustainable development and responsible finance. The author stressed the importance of the active participation of emerging countries in the process of promoting "green" initiatives. As a result of the article, it is stated that the new financial reforms will bring multilateral benefits to the global economy in the form of financial recovery and environmental advantages.

Takumah and Iyke (2017), who investigated the relationship

between tax revenues and growth in Ghana, used the Toda-Yamamoto test. The author identified a one-way causality in Ghana from tax revenue to economic growth. Yenilmez and Erdem (2018) have included the issue of energy, which is also an important issue, within the scope of the study. They sought an answer to the question of whether there is a relationship between energy and economic growth. "What is the impact of the types of energy consumed in Turkey and the EU on economic growth?" They tried to find the answer to the question by using the Toda-Yamamoto causality test. As a result of the study, they determined a one-way causal relationship between natural gas consumption and economic growth in Turkey and between oil consumption and economic growth in the EU.

A study on renewable energy, which is an important issue that the whole world attaches importance to and undertakes, was conducted by Alper (2018). The researcher, like other researchers, used the Toda-Yamamoto causality analysis test. The relationship between the use of renewable energy and economic growth in Turkey and the direction of the relationship was tried to be determined. The results of the analysis showed that the variables are co-integrated in the long term and that a 1% unit increase in renewable energy use will increase economic growth by 0.19%. Unlike other studies, Canöz (2018) used the Toda-Yamamoto causality test. The author analyzed the relationship between the current confidence indices and the Borsa Istanbul 100 Index. According to the results of the analysis, it was determined that there is a one-way causal relationship between stock returns and consumer confidence. Another researcher using the Toda-Yamamoto causality approach, Dilara and Karış (2019), found a relationship between the current account deficit and energy imports. According to the test results, a one-way and negative causality relationship was determined from the current account deficit variable to the foreign direct investment variable, while no statistically significant relationship was found between the other variables in which the causality effect was examined.

Abumdallala (2019) empirically analyzed the dynamic relationship between imports and inflation in Palestine. Toda and Yamamoto (1995) used causality testing for the analysis. As a result of the study, it was found that the null hypothesis that INF does not cause IMP was rejected, while the INF ratio was not rejected at the level of 5% significance of IMP. Dinç (2019) studied the slowdown of China's growth rate after 2010. In the study, the causal relationship between China's exports, public expenditures, and economic growth was investigated by the Toda-Yamamoto causality test. As a result of the study, the author found a two-way causality relationship between China's economic growth and public expenditures and a one-way causality relationship between its exports and economic growth. Chauhan et al. (2020) touched on the mismatch between fossil fuels on the one hand and carbon emissions on the other. A causality analysis was conducted for India. According to the results of the Toda-Yamamoto causality test, they found a two-way causality that shows that energy consumption triggers economic growth while economic growth demands energy.

Dou et al. (2020) have studied green bonds, one of the basic tools of green finance. They talked about the importance of green bonds, which occupy an important place in the green industry. Y noted that whether green bonds should be selected for businesses that meet the green bond standards has become an important theoretical and practical issue, and therefore it is important to investigate the issue. In their study, the authors used the Logit model to demonstrate the impact of policy differences on the choice of green bond financing instruments. As a result of the study, they noted that under the policy difference caused by "multi-sectoral supervision" in China's bond markets, important factors affecting enterprises' labelled green bond issuance are bond type and fundraising purpose.

Pekmezci (2020) was another researcher who used the causality analysis of Toda-Yamamoto (1995), which is used in the case of variables with different degrees of stability, to determine the relationship between variables. The researcher investigated the relationship between tourism and economic growth. As a result of the study, a single, spreading, short-term relationship was detected between the variables examined. Meçik and Koyuncu (2020) use Toda-Yamamoto causality testing, which is effective in terms of my use, like many authors. They investigated the relationship between migration and economic growth in Turkey. As a result of the study, it was determined that there is a one-way causality from migration to economic growth.

Lăcătuş (2020) notes in his study that as the interest in multinational companies has increased in recent years, stock markets have also begun to show increasing interest in green bonds. In his study, the author tried to present the development framework of green bonds, their effects on the capitalist economy, principles and concepts, and development stages. The stages of bond issuance, from asset management to reporting and auditing, were also discussed. Qualitative research methods were used to measure the performance of green bonds, and market changes and trends were calculated with a standard deviation. The market leaders of green bonds and the value of investments in the environmental economy are presented in detail, noting that the majority is devoted to mitigation, with only a quarter allocated to bonds. In conclusion, green bonds have become popular and innovative financing instruments and play an important role in sustainable growth.

In his article, Brühl (2021) provides a perspective on the introduction of tax regulations for sustainable finance while at the same time stating that reforming senior management remuneration or providing tax incentives for green investments in the real economy can be effective in the development of sustainable finance. In another study, Lyeonov et al. (2021) analyzed approaches to defining a green brand. The purpose of their work is to analyze the critical components and parameters of the green brand to develop an effective promotional program. The authors developed an approach to predicting green brands based on

the Mark Fetcher model, content analysis, and the Fishbourne method. The authors analyzed the green brands of three industrial companies. As a result of the study, it is proven that the main factors influencing the green brand are the transparency of the company is not only financial but also non-financial results.

The main objective of the study by Sannikova (2021) is to analyze the package of measures proposed by the European Commission to help improve the flow of money to finance the transition to a sustainable economy. The author explored the problems in the development of legal regulation of sustainable finance in Russia, in particular the creation of a national classification of green projects and the national verification of sustainable financial instruments. A comparative legal review of EU and Russian legislative drafts on green finance has revealed similar approaches to the formulation of regulatory rules. In her study, the author explains the expectations for green finance in the context of digitalization. Based on a study on best practices (Green Assets Wallet, Green Bonds, etc.), it was concluded that digital solutions for sustainable finance are still not well developed at the moment.

Peterson's (2021) aim in the paper is to address certain problems in sustainable finance and suggest solutions. It proposes that there should be more emphasis on how finance can contribute to sustainability. The paper also suggests that light regulation may be necessary to promote a sustainable finance sector. It advocates for a bottom-up approach to growing the sector and encourages voluntary disclosures of environmental, social, and governance (ESG) practices. Lastly, it suggests that short-term financial instruments can complement long-term instruments in sustainable financing.

Kambur and Aksoy (2022) sought an answer to the question of whether investments made in tourism affect growth. They investigated the causal relationships between investments in productivity and GDP using Granger and Toda-Yamamoto causality tests. If the results of the study are summarized, it is revealed that investments in tourism positively affect economic growth and development. In another study using the Toda-Yamamoto causality analysis test, Yurtkuran (2022) aims to test the relationship between tourism and carbon dioxide (CO2) emissions. If the study results are considered in general, it is seen that there is a two-way causal relationship between tourism and CO2 emissions.

Hadaś-Dyduch et al. (2022) analyzed the green bond market in the Visegrad Group of countries and determined the benefits and factors that influence the issuance of green bonds. The specific aim is to conduct a spatial-temporal analysis of green bond yields in these countries using research methods such as literature and report analysis, statistical data analysis, and the dynamic time-warping method. This research confirms that green bonds have potential in the global debt market and that factors such as capital mobilization, investor demand, and reputational benefits are important in encouraging the issuance of green government bonds.

3. Data Set

In the analysis phase of the study, six variables that are thought to be related to the environment were used. The variables are shown in Table 3. Monthly data for the periods of July 2012–April 2022 were included in the study.

Table 3. Variables

No it	Variable	UnitE
1	S&P Green Bond Index (SPGB)	USD
2	S&P Global Clean Energy Index (SPGCE)	USD
3	Invesco WilderHill Clean Energy (IWCE)	USD
4	United States 10-Year Bond (USB)	USD
5	Total Energy CO_2 Emission (TECE)	Million Metric Tons
6	Renewable Energy Production (REP)	Trillion Btu

4. Results

In Granger causality tests, the series included in the study must be made static. However, there is no such requirement in the Toda-Yamamoto (T-Y) test. It is not important in the T-Y test whether the stationary degrees of the series are the same or different. Therefore, the series was not tried to be made static in the study. To apply the T-Y test, we need to know about two situations. The first case is the determination of the appropriate delay length (k) by VAR analysis, while the second is the determination of the highest degree of integration (dmax). k is the optimal delay number. One of the most important points in the T-Y test is that the maximum degree of integration of the variables should not exceed the appropriate delay length of the model. Otherwise, it will not perform a T-Y test. After these two important issues, the equation T-Y will be solved by calculating k+dmax.

Table 4. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-2866.7	NA	1.95e+15	52.2	52.4	52.3
1	-2248.7	1157.4	4.94e+10	41.6	42.7*	42.1
2	-2195.0	94.7	3.60e+10	41.3	43.24	42.10
3	-2156.4	63.9	3.48e+10	41.3	44.08	42.41
4	-2114.7	64.5	3.22e+10	41.2	44.86	42.67
5	-2060.9	77.1	2.45e+10	40.9	45.42	42.71
6	-1979.4	108.2	1.15e+10	40.0	45.48	42.24
7	-1885.4	***114.6****	***4.41e+09****	39.0	45.3	***41.5****
8	-1845.2	44.6	4.69e+09	***38.9****	46.1	41.8

Note: LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

In the study, the delay length of the series was calculated by VAR analysis. As can be seen in Table 4, the information criterion for which the most stars are marked is 7 delay lengths, so 7 is selected as the delay length (k). It has been explained above that it is not important for the T-Y test that

the series have the same or different degrees of stability. In the T-Y tests, the stability of the series is not important, but the stationary degrees of the series are examined to determine the maximum integration (dmax) degrees of the variables. For this, the Augmented Dickey-Fuller test (ADF) was applied to the series.

Table 5. ADF Test Results

	Intercept Model		Intercept and Trend Model	
Variables	**t-Stat.**	**Prob.**	**t-Stat.**	**Prob.**
SPGB	-6.109	0.000	-6.107	0.000
SPGCE	-7.462	0.000	-7.663	0.000
IWCE	-8.179	0.000	-8.133	0.000
USB	-9.077	0.000	-9.035	0.000
TECE	-3.696	0.006	-3.675	0.028
REP	-11.168	0.000	-11.209	0.000

The results of the ADF unit root test, which includes t-statistic, intercept, intercept, and trend, are shown in Table 5. The value in parentheses next to the t-statistic results is about the level at which the variables become static. All variables are set to step 1. It is indicated in the table that it has become stationary. It also became static at level 1 if the series included Intercept, Intercept, and Trend. Since all variables are static at the first level, the highest degree of integration is 1. Thus, the maximum degree of integration of the variables (dmax) received a value of 1. One of the important points of the T-Y test was that the dmax value of the variables was not greater than the appropriate k value of the model. In this study, k = 7 and dmax = 7 were found. Since k > dmax, the equation T-Y could be applied.

$$k+dmax=7+1=8 \quad (1)$$

With the help of the values found above, a T-Y equation with a delay of 8 will be solved. When questioning causality in the T-Y test, it is tested whether the underlying coefficients are different from zero or zero.

Table 6. Wald Test (SPGCE-----→ REP)

Test Statistic	Value	df	Probability
Chi-square	5.340320	8	0.7207

Null Hypothesis: C(17)=C(18)=C(19)=C(20)=C(21)=C(22)

Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(17)	0.080228	0.118474
C(18)	-0.055366	0.125850
C(19)	-0.022896	0.084591
C(20)	0.081657	0.088258
C(21)	-0.09915	0.086073
C(22)	-0.019125	0.086727
C(23)	0.004971	0.089854
C(24)	0.044824	0.062154

Table 6 shows the result of the causality test from SPGCE to REP as an example. The probability value resulting from the test is not used for rejection or acceptance of the null hypothesis. For this, the actual probe value is calculated using the Chi-square value and k degrees of freedom shown in the table as a result of the test. The actual probe was calculated by Chika Redispersion with the help of Excel for the test given as an example. value is shown below.

= Chi-square Distribution (value, k degree of freedom)

= Chi-square Distribution (5.34032,7) = 0.6185

The above example test is applied to all variables then the actual probe. values are calculated to determine the acceptance or rejection of the null hypothesis.

H_0: There is no causality between variables.

H_a: There is causality between variables.

Table 7. Toda-Yamamoto Causality Test Results

Variables	Prob.	Causality Status
SPGB → REP	0.882	There is causality. (H0 rejection)
SPGCE → REP	0.619	There is causality. (H0 rejection)
IWCE → REP	0.023	Causality does not exist.
USB → REP	0.047	Causality does not exist.
TECE → REP	0.000	Causality does not exist.
SPGB → TECE	0.771	There is causality. (H0 rejection)
SPGCE → TECE	0.011	Causality does not exist.
IWCE → TECE	0.025	Causality does not exist.
USB → TECE	0.038	Causality does not exist.
REP → TECE	0.000	Causality does not exist.
SPGB → SPGCE	0.002	Causality does not exist.
IWCE → SPGCE	0.000	Causality does not exist.
USB → SPGCE	0.061	There is causality. (H0 rejection)
TECE → SPGCE	0.001	Causality does not exist.
REP → SPGCE	0.000	Causality does not exist.
SPGCE → SPGB	0.000	Causality does not exist.
IWCE → SPGB	0.000	Causality does not exist.
USB → SPGB	0.000	Causality does not exist.
TECE → SPGB	0.000	Causality does not exist.
REP → SPGB	0.000	Causality does not exist.
SPGB → USB	0.065	There is causality. (H0 rejection)
SPGCE → USB	0.001	Causality does not exist.
IWCE → USB	0.533	There is causality. (H0 rejection)

TECE → USB	0.165	There is causality. (H0 rejection)
REP → USB	0.213	There is causality. (H0 rejection)
SPGB → IWCE	0.218	There is causality. (H0 rejection)
SPGCE → IWCE	0.001	Causality does not exist.
USB → IWCE	0.669	There is causality. (H0 rejection)
TECE → IWCE	0.022	Causality does not exist.
REP → IWCE	0.218	There is causality. (H0 rejection)

Table 7 shows the Toda-Yamamoto causality test results. The probe given in the table If their value is less than 0.05, the null hypothesis will be accepted, while if it is greater than 0.05, the null hypothesis will be rejected. In this case, from SPGB to REP, SPGCE to REP, SPGB to TECE, SPGB to USB, IWCE to USB, TECE to USB, REP to USB, SPGB to IWCE, USB-to-IWCE, USB-to-SPGCE, and REP to IWCE, causality was found between variables at a significance level of 5%. Bidirectional causality was found between IWCE and USB variables.

Conclusion-Evaluation

Environmental awareness increases in importance in the field of finance as well as in every other field. The way to leave a livable universe to future generations is to plan green and nature-friendly projects and investments. Therefore, financial institutions provide various forms of financing support to realize the aforementioned investments. Today's Ukraine-Russia war and the fossil energy crisis that followed brought the issue of green finance to the agenda and became a source of motivation for this study. In the coming years, the issue of green finance and renewable energy will increase in importance. This study analysed the relationship between green financial assets in the United States and different variables. The results obtained using data from the United States, which is a developed country, will be a reference for other developed and developing countries.

Monthly data for the S&P Green Bond Index, S&P Global Clean Energy Index, Invesco WilderHill Clean Energy, United States 10-Year Bond, Carbon Dioxide Emissions from Energy Consumption, and Total Renewable Energy Production variables between July 2012 and April 2022 were included in the research. The Toda-Yamamoto causality test was applied in the study. In the Toda-Yamamoto causality test, it is a great advantage that the series does not need to be static at the same level. As a result of the test, the United States 10-Year Bond to the S&P Global Clean Energy Index, the S&P Green Bond Index to Renewable Energy Production, the S&P Global Clean Energy Index to Renewable Energy Production, the S&P Green Bond Index to Total Energy CO2 Emission, the S&P Green Bond Index to the United States 10-Year Bond, the Invesco WilderHill Clean Energy to the United States 10-Year Bond, Causality was determined from Total Energy CO2 Emission to the United States 10-Year Bond, from Renewable Energy Production to the United States 10-Year Bond, from the S&P Green Bond Index to Invesco WilderHill Clean Energy from Renewable Energy, from the United States 10-Year Bond to Invesco WilderHill Clean Energy from Renewable Energy, and from Renewable Energy Production to Invesco WilderHill Clean Energy. Bidirectional causality has been identified between the Invesco WilderHill Clean Energy and United States 10-Year Bond variables.

As can be seen, there is causality between green financial assets. The variable related to CO2 emissions was causally found only between the S&P Green Bond Index and the United States 10-Year Bond, among other variables. As CO2 emissions increase, this situation in the United States 10-Year Bond can be interpreted as increasing exports, increasing energy inputs, and increasing CO2 emissions, but the bonds are appreciated. Another interpretation can be made as follows: the green bonds in force in the current system do not provide a real reduction in carbon emissions. Projects related to green bonds could also see reductions in carbon emissions if they were to radically transform the bond issuer's activities in a way that is sufficient to reduce carbon emissions (Ehlers et al., 2020). Since these are not done, green bond issuance does not reduce carbon emissions but causes them to increase. While the variable "renewable energy production" appears to be associated with some green financial assets, no relationship is related to carbon emissions. The fact that carbon emissions do not change as the use of renewable energy increases can be interpreted as showing that investments that still cause carbon emissions to not decrease are increasing. As a result, although there are studies to increase environmental awareness and reduce carbon emissions, they are not sufficient. In addition, when countries issue green bonds, there may be signs of a decrease in carbon emissions by supporting enterprises that produce radically green projects. With the increase in the use of renewable energy sources, carbon-emitting enterprises, actions, exports, and imports need to be reduced. Otherwise, the increase in renewable energy sources will not provide maximum benefit.

Global investments in renewable energy sources and energy efficiency have decreased by 3% in 2017. There is a risk of a further slowdown, which threatens the widespread adoption of green energy that is necessary for energy security and meeting climate and clean air objectives. Fossil fuels still dominate energy investments. This is primarily due to the lack of interest from financial institutions in green projects, as they pose various risks and offer lower returns. Some developed and developing economies still pursue coal-based energy policies. The extra CO2 emissions from new coal-fired power plants can negate emission reductions made by other countries. Finance plays a critical role in developing infrastructure projects, including energy projects. Financial institutions need to open new files for green projects and increase funding for environmentally beneficial investments through new financial tools and

policies, collectively known as "green finance." These tools include green bonds, green banks, carbon market instruments, fiscal policies, green central banking, financial technology, community-based green funds, etc. If they want to achieve sustainable development goals, they need to give more attention to green projects than fossil fuel projects. (Sachs et al., 2019).

It has been observed that the vast majority of academic studies on green finance and its tools focus on understanding the conceptual framework and discussing its applicability. In this study, the relationship between green finance instruments and renewable energy variables was statistically calculated. In the literature, the causal relationship between economic growth and renewable energy has been examined. Yenilmez and Erdem (2018) identified a one-way causality relationship from natural gas consumption to economic growth in Turkey and from oil consumption to economic growth in the EU. Alper (2018) examined the relationship between economic growth and renewable energy use using the Toda-Yamamoto causality test. Chauhan et al. (2020) examined the relationship between fossil fuel energy consumption and economic growth.

Further research can be conducted to analyze the relationship between green financial assets and other variables beyond those included in this study. The study can be expanded to include data from other countries to provide a more comprehensive analysis of the relationship between green financial assets and different variables. Future research can focus on the impact of government policies and regulations on the performance of green financial assets. The study can be replicated using different statistical methods to validate the findings. Further research can be conducted to analyze the impact of climate change on the performance of green financial assets. Future research can focus on the role of institutional investors in promoting the growth of green financial assets. The study can be expanded to include a larger sample size to increase the statistical power of the analysis. Further research can be conducted to analyze the impact of technological advancements on the performance of green financial assets. Future research can focus on the impact of social and environmental factors on the demand for green financial assets.

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