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# Fiscal Sustainability and Energy Transition in Advancing Long-Term Sustainable Development

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## ABSTRACT

Achieving long-term sustainable development requires not only a transition toward cleaner energy systems but also supportive fiscal and institutional conditions that ensure the durability of such transitions. While existing studies largely focus on the environmental effects of renewable energy adoption, limited attention has been paid to how energy transitions interact with fiscal sustainability and governance to shape broader development outcomes. This study addresses this gap by examining the combined roles of renewable energy consumption, energy efficiency, fiscal conditions, and institutional quality in advancing sustainable development across OECD economies. Using a balanced panel of OECD countries from 1995 to 2023, the analysis employs adjusted net savings as a comprehensive indicator of long-term sustainability that captures changes in produced, natural, and human capital. The results indicate that renewable energy adoption is positively associated with long-term sustainable development, although the magnitude of this relationship depends on fiscal discipline and governance effectiveness. Stronger institutions enhance the sustainability benefits of renewable energy deployment. These findings suggest that energy transitions yield the greatest long-term benefits when embedded within sound fiscal frameworks, effective governance structures, and efficiency-enhancing policies. The study offers policy-relevant insights for advanced economies seeking to align climate objectives with fiscal sustainability and inclusive long-term development.

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## Research Highlights

- Fiscal sustainability strengthens long-term sustainable development in OECD economies.
- Energy transition quality enhances wealth accumulation and reduces structural risks.
- Institutional governance amplifies fiscal and energy policy effectiveness.
- Structural heterogeneity reveals diverse sustainability regimes across OECD countries.



## 1. Introduction

Sustainable development has become one of the most topical and complicated issues of modern economies [1]. In its simplest definition, sustainable development attempts to balance between economic development and environmental sustainability as well as social well-being in that the current generation of development will not jeopardize the capacity of the future generations in achieving their own needs. Although this principle is universally known, it is very hard to put it into effective policy practice, especially in the face of rising climate change, escalating financial burdens, and increasing requirements of energy security [2]. These issues have triggered a new interest in how energy systems, public incomes and institutional structures co-evolve to determine the long-term developmental outcomes [3]. The energy system transformation is a key area in the list of numerous dimensions of sustainable development. The relationship between energy production and consumption and the economic growth, environmental quality and social welfare is very closely interconnected. The economies of developed countries have long been supported by fossil fuel-powered energy systems, which have raised the level of industrialization and prosperity, but energy sources have also been the main source of greenhouse emissions, resource consumption, and environmental damage [4]. To this, the governments of the world, especially the advanced economies, have taken a growing interest in adopting renewable energy as part of their sustainability policies [5]. The development of renewable energy is generally perceived as having the ability to decouple the activities of the economy and the damage to the environment and providing greater energy security and diminishing the reliance on the unstable markets of fossil fuels [6].

Although the positive environmental impact of renewable energy use has been extensively recorded, not much is known about the overall effects of renewable energy on sustainable development. Much of the available literature is rather narrow in its approach on either reduced emissions or energy efficiency benefits and tends to view renewable energy as a technological remedy [7]. Nonetheless, sustainable development is multidimensional in nature as it does not exclusively consider environmental performance but also includes economic stability, fiscal stability, and institutional capacity. It is thus essential that the policies of renewable energies are in the environment of the whole economic and governance. Specifically, the significance of energy transition strategies interacting with fiscal sustainability is under researched, though it is becoming increasingly important in the process of policy design [8]. Over the last three decades, the subject of fiscal sustainability has gained a relatively prominent role in developed economies. Demographic aging, financial crises, the expenditures related to the pandemic, and extensive investment of the state in infrastructure and social protection have led to the increased level of public debt in many countries [9]. Meanwhile, the process of energy transition per se needs a significant amount of both public and private

funding, such as subsidization of renewable energy, modernization of the grid, research and development and taking care of vulnerable households. Such financial requirements are important concerns regarding the sustainability of the energy transition plans in the long term, particularly in nations with limited fiscal space [10].

Fiscal sustainability and sustainable development have a complicated and possibly a two-way relationship [11]. On the one hand, good fiscal management can give governments the ability to invest in clean energy, education, and environmental protection, which can aid the development goals on the long-term basis. Conversely, high government debt and structural fiscal instabilities can restrain the capacity of governments to finance such investments, which is likely to negate the efficacy of energy transition policies [5]. On the other hand, the inappropriate formulation of energy policies can increase the fiscal strain in case they are dependent on huge subsidies or create inefficiencies that escalate into the budgetary burden of citizens. The dynamics of interplay between fiscal conditions and energy transition is hence vital to the design of consistent and sustainable sustainability strategies [12]. Irrespective of this significance, the empirical literature has mostly discussed energy transition and fiscal sustainability as different areas of analysis. The research on renewable energy usually pays more attention to the environmental implications, i.e. carbon emissions or air quality, whereas research on the public debt and fiscal balance concentrates on macroeconomic stability and development [13]. Very few contributions are trying to incorporate these views in a singular framework of sustainable development. This fracturing has led to the partial nature of the comprehension of the joint effects of energy and fiscal policies on the development trajectories in the long term [14].

The other weakness of the available literature is the measurement of sustainable development itself. Numerous empirical research works use individual measures, e.g. carbon dioxide emissions or ecological footprint, to represent sustainability outcomes [15]. Although these indicators entail relevant environmental dimensions, they do not represent the bigger picture of sustainability that comprises economic, social, and environmental capital. Subsequently, these studies can ignore trade-offs and complementarities across dimensions of development. It is increasingly being realized that better indicators are required to determine the extent to which development trajectories currently being pursued are truly sustainable. One such overall measure has become adjusted net savings. Adjusted net savings can be used to calculate stock-based sustainability indicator by considering the effects of investment in human capital, depletion of natural resources, and environmental damages, which are useful in tracking changes in the overall wealth of a country [16]. As compared to flow-based indicators, adjusted net savings is more intergenerational in nature and provides information on whether present economic processes are strengthening or weakening the pillars of future prosperity. Adjusted

net savings is a concept with conceptual benefits, but it is still not used in empirical research of energy transition and fiscal sustainability [17].

Besides the fiscal conditions and measurement problems, the institutional quality is a vital factor in influencing the result of sustainable development. Operating efficient institutions have impacts on the process of developing policies, their execution, and enforcement on their effectiveness in terms of efficiently distributing resources and the reliability of commitments in the long term [18]. Strong institutions can help coordinate policy areas, create less regulatory uncertainty, and make sure that such public investments do not have only short-term payoffs. On the other hand, poor governance can lead to inconsistency in policies, poor distribution of resources and reduced sustainability benefits, despite the adoption of ambitious energy goals [19]. The importance of the institutions lies especially in the developed economies, where formal policy frameworks are typically well-developed but are also highly different in their efficiency. The variation in the effectiveness of governments, the quality of regulations and the strength of the public sector can be considered the reason as to why the similar energy policies do not lead to uniform sustainability performance among the countries. However, the empirical studies of the moderating role of the quality of the institutions on the relationship between renewable energy adoption and sustainable development are limited. The majority of the studies assume the institutions as control variables instead of being factual parts of the sustainability process [20].

Another aspect of the energy-sustainability nexus that is very significant yet is largely neglected is energy efficiency. Whereas renewable energy consideration aims at the supply side of energy, energy efficiency deals with demand-side issues because it aims at minimizing the volume of energy needed to generate economic output [21]. Energy efficiency can be improved to reduce the consumption of resources, environmental pressures, and make the economy more competitive. In addition, energy efficiency can be a crucial means of transmission whereby adoption of renewable energy converts into larger benefits in terms of sustainability [8]. An example is that the introduction of renewable energy technologies can stimulate investments in inefficient infrastructure and production processes, which increase the influence on development in the long run [22]. Although this is important, little empirical evidence has been given to the mediating role of energy efficiency in the relationship between renewable energy and sustainable development. Current literature usually focuses on renewable energy and energy efficiency as independent variables, not paying much attention to their interplay in the framework of a more sustainable environment [23]. This exclusion limits our knowledge of how energy transitions impact on long-term development outcomes and constrains the policy implications of empirical evidence.

It is on this background that the current study aims at making a contribution to the literature on sustainable de-

velopment by incorporating the energy transition dynamics, fiscal sustainability and institutional quality in a single empirical model. The study also looks at the interaction of renewable energy use and energy efficiency with fiscal conditions to determine the long-term sustainable development outcome, in terms of adjusted net savings, by looking at OECD economies in the period 1995–2023. The study goes beyond the traditional methodologies that are predominantly narrow in scope and concentrate on the emissions or the short-term economic performance because it is based on a comprehensive sustainability indicator and the inclusion of moderation and mediation analysis. The empirical setting of OECD economies is justified by a number of reasons. To start with, it is due to the fact that OECD countries have been acting as the leaders of renewable energy and climate policy innovation, which makes them a suitable petri dish to study the dynamics of energy transition. Second, the quality of data and the comparability of these economies on the institutional level is relatively high, which increases the credibility of cross-country analysis. Third, OECD countries, even with their high status, have serious problems associated with fiscal sustainability, demographic shift, and changing of the energy system. The common problems give a substantive background to the discussion of the interaction between energy and fiscal as well as institutional aspects.

Policy wise, the research findings in this study are likely to give useful insights to governments inclined to formulate consistent and sustainable sustainability policies. The findings emphasize the need to ensure transformation of energy policies are associated with good fiscal management and robust institutional frameworks. Instead of looking at renewable energy development as a goal on its own, the policymakers ought to look at the interaction of energy, fiscal, and governance policies to support long-term sustainability. The integrated view is especially applicable in terms of increasing fiscal strains and ambitious climate pledges.

The rest of the paper is organized in the following way. Section 2 studies the literature on energy transition, fiscal sustainability and sustainable development that are relevant to the study and identify the gaps that lead to the current study. Section 3 explains the data, variables, and the empirical methodology. Section 4 reports the empirical findings. Section 5 sums up the key findings and offers the guidance on the directions of future research.

## 2. Literature Review

### 2.1. Sustainable Development and Measurement Approaches

Sustainable development has been transformed into a normative concept to an operational framework in terms of economic, environmental, and social policymaking. The initial definitions focus on the intergenerational equity and the necessity to strike a balance between current and future welfare, which is why conservation of natural and human capital as well as economic growth should be prioritized. Consequently, the empirical literature has been

more interested in finding indicators that can represent long-term dynamism in development as opposed to short-term performance results. The conventional empirical research has been based on environmental indicators like carbon dioxide emission, ecological footprint or energy-related pollution to approximate sustainability outcomes. Although these indicators are important to understand the pressure on the environment, they do not give a full picture of sustainable development but only reflect economic resilience and social investment [24, 25]. The shortcoming has encouraged an increment in interest in stock-based sustainability indicators which use modifications in the overall wealth of a particular country. Adjusted net savings has become widely favored as a broad approach to weak sustainability by considering investment in education, loss of natural resources and environmental losses [26, 27]. Empirical research that uses adjusted net savings shows that it is better positioned to predict intergenerational prosperity and long-term development opportunities than one-dimensional indicators [28, 29]. Nevertheless, adjusted net savings has not been used in empirical studies of energy transitions and fiscal sustainability, despite its conceptual benefits, which is a major gap in the literature [30].

## 2.2. Energy Transition and Sustainable Development

The contribution made by the energy systems towards the outcome of sustainable development is a topic of a significant amount of studies. The shift to energy regimes with renewable structural sources is commonly considered a crucial task to be undertaken to decrease environmental pollution and climate change [31, 32]. There is empirical data that tends to prove the point that the consumption of renewable energy leads to the reduction of emissions and the enhancement of the quality of the environment, especially in developed economies [33]. In addition to the environmental advantages, a few studies are conducted to understand the general economic and social effects of the adoption of renewable energy. There are also various job creation, technological innovation, and energy security that are associated with renewable energy and could contribute to sustainable development [34, 35]. Nevertheless, there are ambivalent findings on the development impacts of renewable energy. Other authors note beneficial outcomes in terms of the economic growth in relation to the sustainability indicators, whereas others note weak or context-related relationships [36, 37]. The reason behind these conflicting results can be explained by the fact that the current research has tended to consider renewable energy adoption as a lone phenomenon, without a sufficient amount of attention paid to the wider fiscal and institutional environments within which energy transitions take place. In addition, most empirical studies are on short-term results, including emissions or growth rate of output, as opposed to a long-term measure of sustainability. This scope is, as it restricts the potential of the literature to determine whether the transition to renewable energy is truly a factor that leads to long-term development [38].

## 2.3. Energy Efficiency as a Sustainability Mechanism

Energy efficiency has been a major factor in sustainable development as it minimizes the level of energy needed to generate economic output. Energy efficiency can help decrease the costs of production and the environmental burden, as well as increase competitiveness of the economy [39, 40]. In this respect, energy efficiency is viewed as a first fuel in the sustainability plans. The existing empirical data indicate that reduced energy intensity is related to better environmental performance and in a few instances, an increase in economic efficiency [41, 42]. Nonetheless, there is also a complicated connection between energy efficiency and the general sustainability outcomes. The anticipated gains of efficiency improvements can be undermined by the effects of rebounds, the alteration of the structure, and the heterogeneity of technologies [43]. In spite of this significance, there is little research on the subject of energy efficiency as a mediating factor between renewable energy uptake and sustainable development. The majority of research assumes that renewable energy and energy efficiency are independent policy goals which do not complement each other. This gap restricts the knowledge on the pathways in which the energy transitions impact on the long-term development and reaffirms the necessity of the mediation-based empirical approaches.

## 3. Methodology

### 3.1. Data and Theoretical Description

A balanced panel dataset of the OECD countries between 1995–2023 was used in this study. OECD sample is especially appropriate to the given analysis since these economies have fairly developed fiscal systems, well-developed energy markets, and similar institutional frameworks, but still show a high level of heterogeneity in renewable energy implementation, fiscal sustainability, and the long-term development results. This heterogeneity can be used to have considerable cross-country and time variation that is critical in determining substantial sustainability links.

Adjusted Net savings (ANS) is the dependent variable and is in form of a percentage of gross national income. Adjusted net saving is commonly accepted as a holistic measure of poor sustainability, as it represents the varying amounts of produced, natural, and human capital of a nation by taking into consideration investment in education, systematic consumption of natural resources as well as damage of the environment. ANS presents a more suitable benchmark of sustainable development in the long term and the welfare of the generational development as compared to single-dimensional indicators like carbon emissions.

The important explanatory variables are the consumption of renewable energy, energy intensity, and the level of public debt; fiscal balance these variables all explain the interaction effect between the dynamics of energy transition and fiscal sustainability. The consumption of renewable energy is an indication of advanced cleaner energy

systems whereas energy intensity is an indicator of energy efficiency. The fiscal space used by governments to make sustainable investments without compromising the macroeconomic stability is reflected by public debt and fiscal balance.

It includes a set of control variables to consider more general structural and institutional aspects, such as trade openness, financial development, urbanization, and government effectiveness. These are the variables that are usually highlighted in the literature about sustainable development and can be used to isolate the independent impacts of energy and fiscal factors. All of the variables are taken based on the sources identified by the international community including the World Bank, IMF, UNDP, and Worldwide Governance Indicators, making them consistent and comparable across nations and periods of time.

The scree plot of the principal component analysis of the standardized variables is provided in figure 1. The amount of variance explained by each principal component is represented in the figure. The former variable explains the most important part of the overall variation, which implies that a powerful latent pattern lies behind fiscal sustainability, energy transition, and institutional dynamics among OECD economies. This decrease in explained variance in increasing components indicates that structural sustainability is multi-dimensional, but largely motivated by a limited number of dominating factors. The fact that there are no sharp eigenvalue decreases further has shown that the fiscal, environmental and structural variables do not constitute entirely independent clusters, but are interacting among themselves.

Figure 2 combines the results of clustering into the PCA space, all of which show distinct structural regimes among the OECD observations. The four clusters imply

the different development setups. Certain clusters can be described as more fiscal performance, and renewable energy shares whereas others as having a higher debt or energy intensity build. The fact that clusters are separated in the principal component space proves the hypothesis that fiscal sustainability and energy transition are the two main drivers of structural sustainability typologies of economies.

The K-means solution projected on the PCA dimensions containing the centroid positions is shown in figure 3. The centroids are archetypal structural profiles of every sustainability regime. Strong dispersion among clusters implies that the economies of OECD do not converge evenly to one path of sustainability. Rather, they pursue divergent paths based on financial security, the development of renewable sources of energy, and institutional competence.

A structural equation model representation of the estimated relationships is given in figure 4. The figure indicates direct and indirect impacts of the relationship between fiscal balance, public debt, renewable energy, and energy intensity with sustainable development. The mediation hypothesis is upheld by the positive direction of renewable energy on sustainable development, and both direct and indirect impacts of fiscal variables are maintained. The SEM visualization explains that the quality of energy transitioning is in part passing the impact of fiscal sustainability on long-run wealth accumulation.

Figure 5 demonstrates the allocation of a composite fiscal stress index which is a combination of public debt and fiscal balance. The scatter plot of the observations indicates that there is a wide difference between fiscal resilience among OECD economies. Both the existence of low-stress and high-stress regimes suggests that fiscal sustainability conditions vary across the board, which can affect the success of energy transition policies.

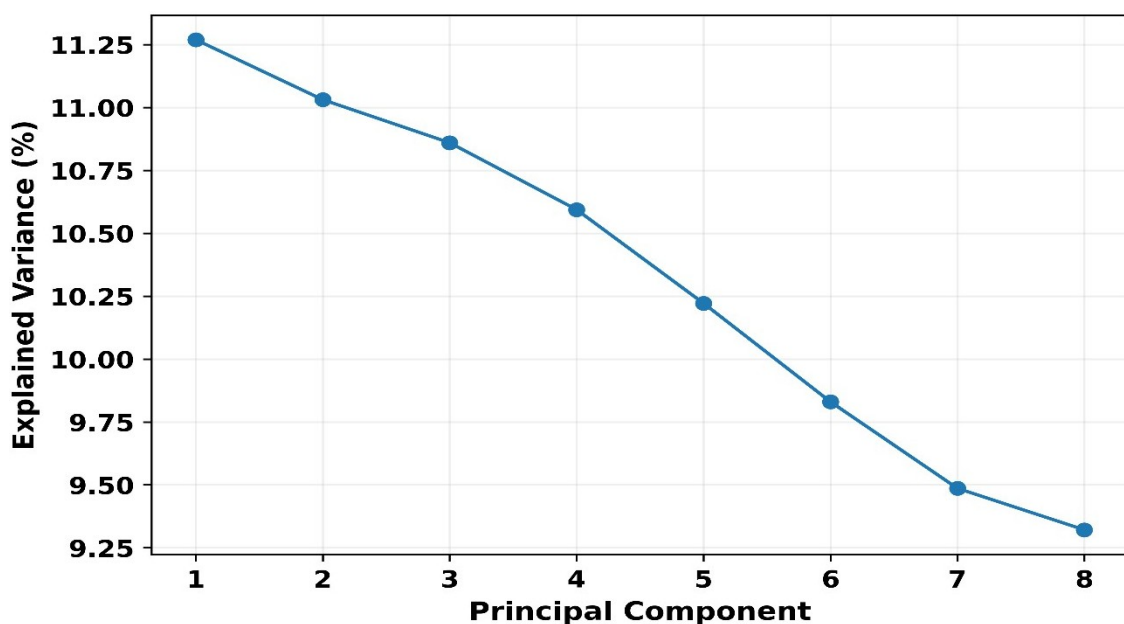


Figure 1. PCA Scree Plot.

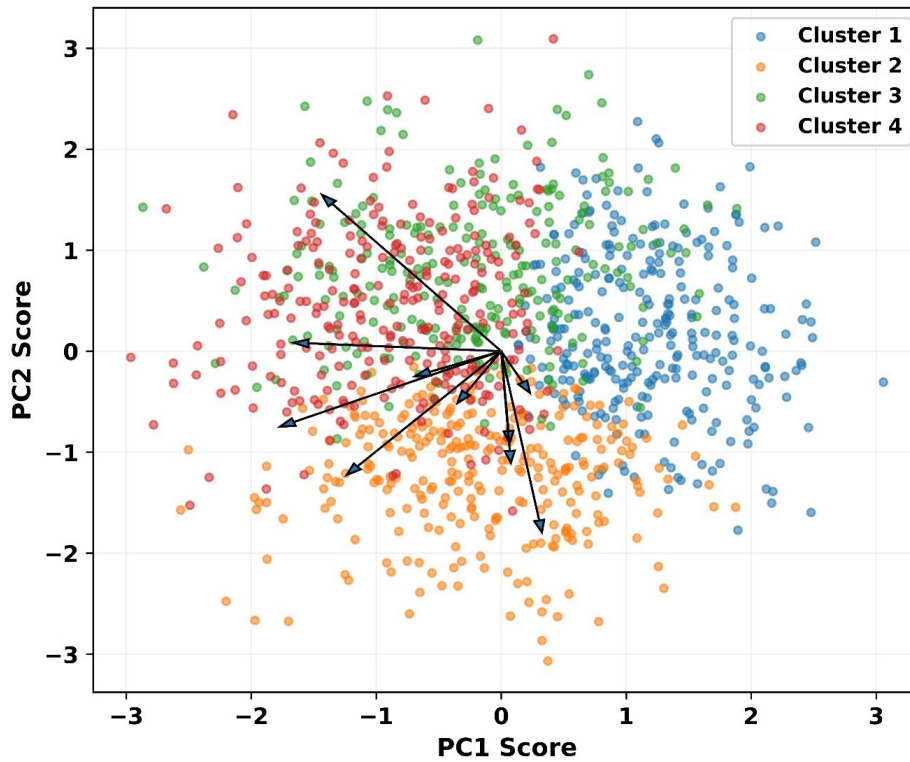


Figure 2. PCA Cluster Biplot.

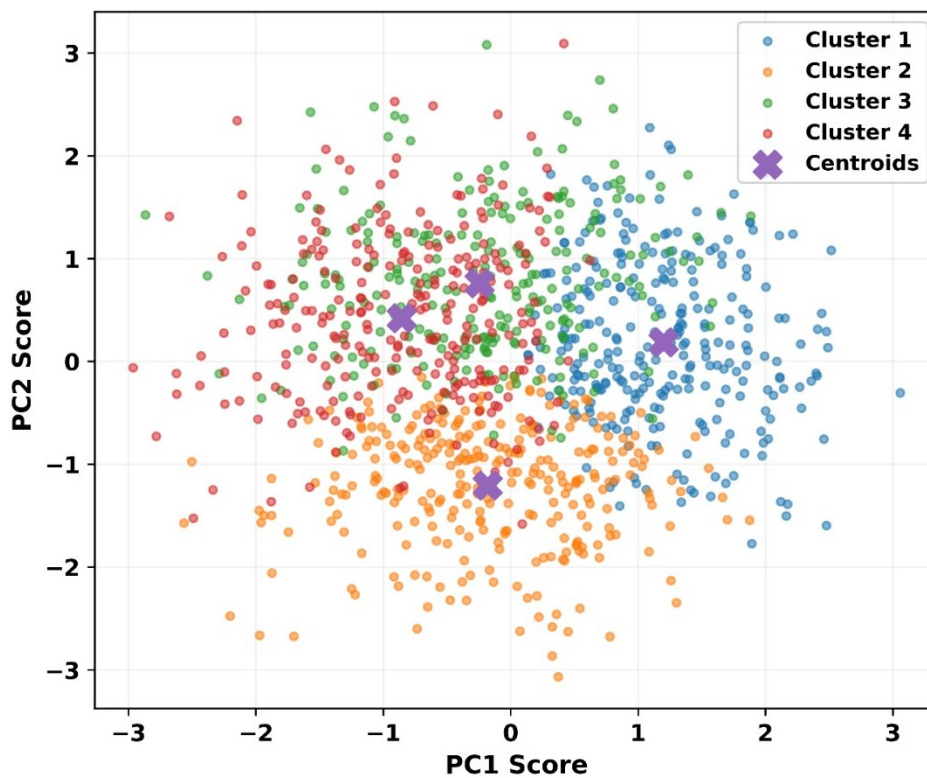


Figure 3. K-means Clusters in PCA Space.

Figure 6 presents the observations as quadrants according to the fiscal balance and adjusted net savings. The four regimes differentiate between stable and unstable fiscal situations with good or poor sustainability per-

formance. This graph illustrates that positive sustainability performance is higher in regimes that are fiscally balanced, which validates the assumption that fiscal sustainability leads to better long-term developments.

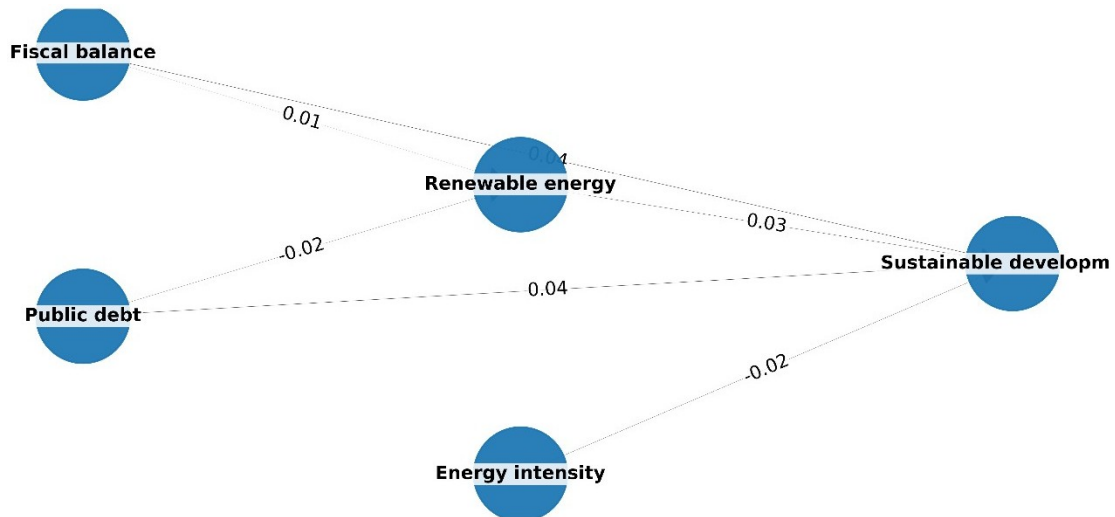


Figure 4. SEM-Style Path Diagram.

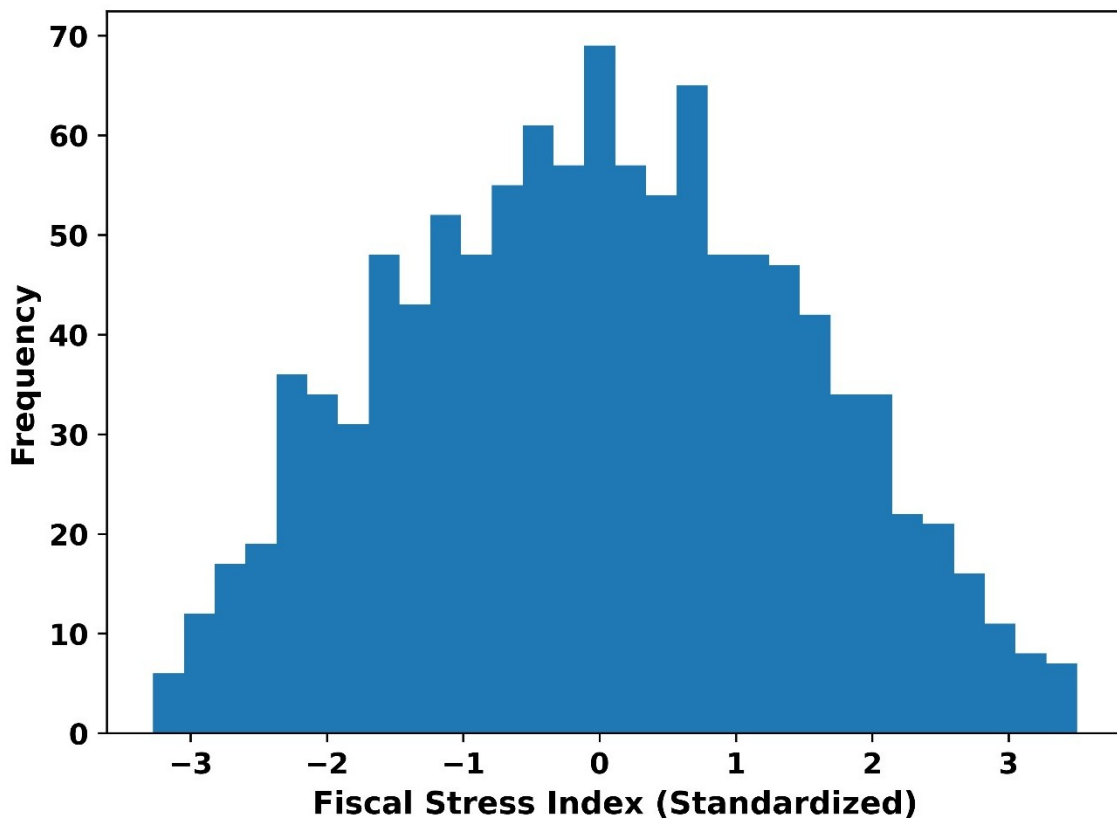


Figure 5. Distribution of Fiscal Stress Index.

To establish aggregate structural change, Figure 7 follows the changes in the first principal component over time. The increase or decline of PC1 score indicates changes in fiscal stringency and intensity of energy transition. The time trend shows that the OECD economies have been undergoing gradual structural realignment into more sustainable configurations, especially since the middle of the 2000s.

The allocation of the sustainability clusters per the three time periods is presented in figure 8. The shift in observations toward clusters of increased renewable energy performance and greater fiscal governance is an indicator of gradual convergence to regimes that are more sustainable. Nevertheless, some clusters are not going away, pointing towards the fact that structural heterogeneity will still be strong.

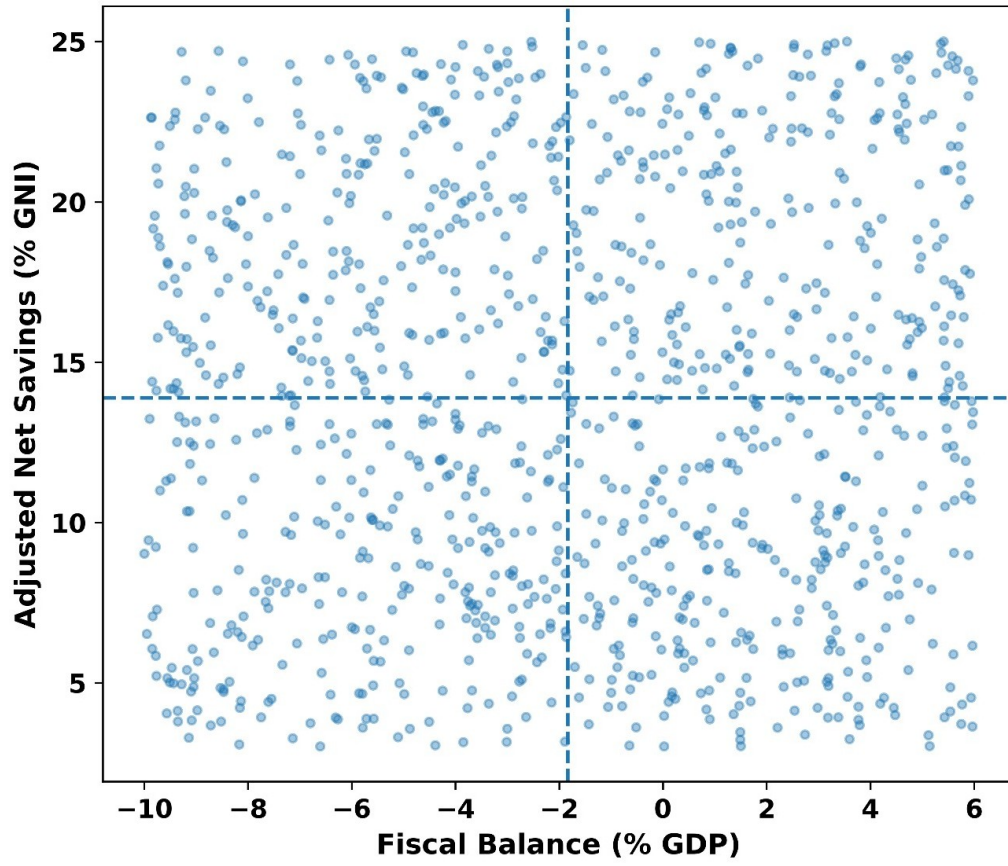


Figure 6. Fiscal Sustainability Quadrant Analysis.

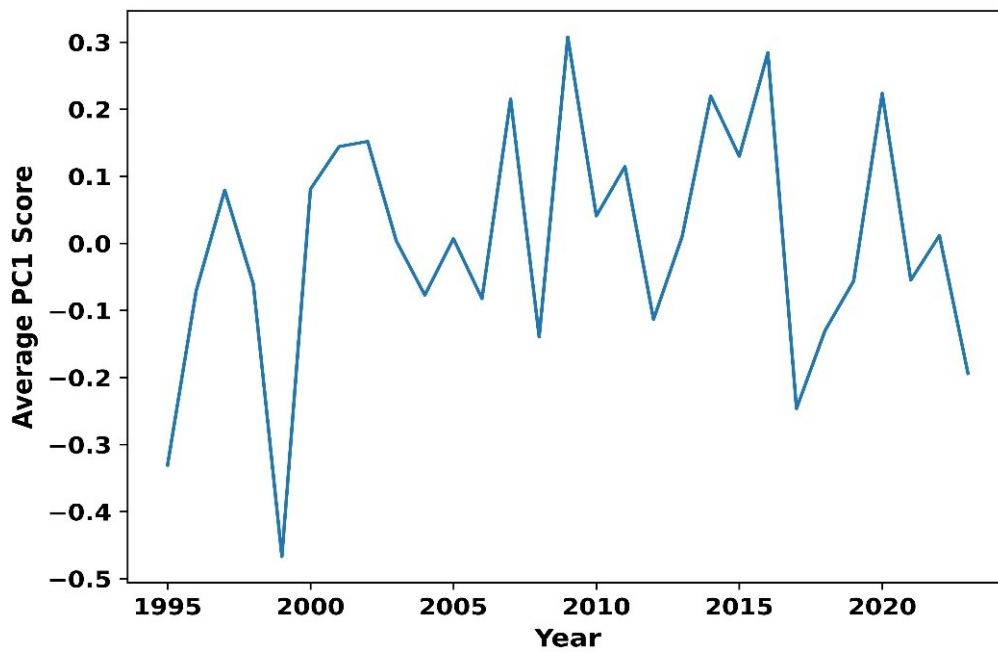
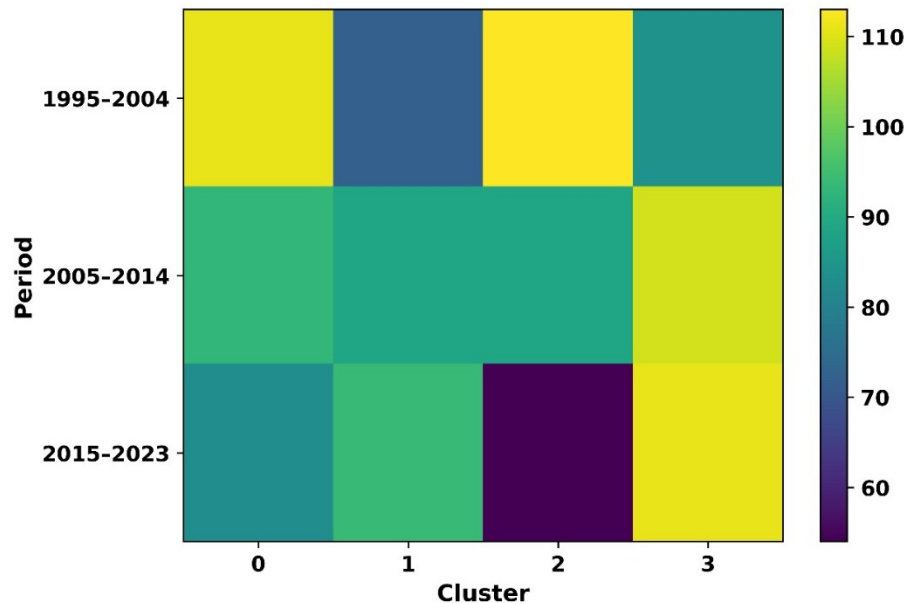


Figure 7. PCA Structural Transformation Over Time.



**Figure 8.** Cluster Distribution Across Periods.

### 3.2. Model Specification

To examine the relationship between fiscal sustainability, energy transition, and long-term sustainable development, the study adopts a panel fixed-effects estimation framework. The baseline empirical model is specified as follows:

$$SUST_{it} = \alpha + \beta_1 REN_{it} + \beta_2 EI_{it} + \beta_3 DEBT_{it} + \beta_4 FB_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where  $SUST_{it}$  denotes adjusted net savings in country  $i$  at time  $t$ ;  $REN_{it}$  represents renewable energy consumption;  $EI_{it}$  denotes energy intensity;  $DEBT_{it}$  and  $FB_{it}$  capture public debt and fiscal balance, respectively; and  $X_{it}$  is vector of control variables. Country fixed effects ( $\mu_i$ ) control for unobserved, time-invariant country specific characteristic such as geography and historical institutions, while year fixed effects ( $\lambda_t$ ) capture global shocks and common time trends. The error term  $\varepsilon_{it}$  represents idiosyncratic disturbances. The fixed-effects method is better than the pooled or random-effects estimators as they reduce the bias in omitted variables that may be caused by unobserved heterogeneity that is probably correlated with energy and fiscal variables. Standard errors are more aggregated on the country level to take into consideration the serial correlation and heteroskedasticity. The estimated coefficients  $\beta_1$  through  $\beta_4$  capture the average within-country effects over time. For example,  $\beta_1$  measures how changes in renewable energy consumption within a country influence its sustainability trajectory, holding other factors constant. This within variation interpretation is particularly useful for policy analysis, as it reflects the impact of domestic policy adjustments rather than cross-country differences.

The reason to decide on the fixed-effects estimator is that it is capable of dealing with the unobserved hetero-

geneity, which can be correlated to the explanatory variables. Regarding the energy and fiscal policy, the institutional structure, as well as energy endowment, and priorities of policy, vary greatly among countries, which are hard to observe, but are systematically connected to the regressors. Such heterogeneity can be overlooked, which can result in biased and inconsistent estimates. The fixed-effects approach is more reliable in giving an estimate compared to pooled ordinary least squares and random-effects models in cases where the strict exogeneity assumption is not satisfied because of correlation between the regressors and unobserved effects. The Hausman specification test can also justify the use of fixed effects instead of random effects. To make the estimation stronger, the standard errors are clustered at the country level, which considers the possibility of the existence of the serial correlation and heteroskedasticity within the panels. This is especially crucial in macro-panel datasets where the effects of shocks and policies can linger on in countries.

## 4. Results and Discussion

Table 1 shows the descriptive statistics of all the variables in the analysis. The findings show that adjusted net savings across countries and over time are significantly different, suggesting that there is a significant heterogeneity in long-term sustainability performance of OECD economies. This dispersion is critical in determining strong empirical relationship in a panel model. The consumption of renewable energy and energy intensity as well are subject to large dispersion, indicating that energy structures, technological advancement, and policy priorities can vary among countries. The fiscal indicators, especially the public debt and fiscal balance are quite volatile, highlighting the disparate fiscal positions and limitations of the OECD governments during the course of the study.

The descriptive statistics also show that at high levels of human development, as well as the quality of the institutional setting, the OECD countries vary significantly in their ability to transform the economic activity into sustainable wealth accumulation. The relevance of studying not just the indicators of energy transition but the fiscal and institutional factors in the analysis of sustainable development outcomes can be verified by this observation.

Table 2 includes the correlation report (lower triangle). The values of correlation coefficients indicate that there should be a positive relationship between renewable energy consumption and adjusted net savings, but the relationship between energy intensity and sustainability outcomes should be negative. Adjusted net savings exhibit a weak correlation with public debt, which indicates the uncertain theoretical relationship between the accumulation of debt and long-term sustainability. Notably, all the correlations are not that high, which eliminates any fears of multi collinearity and suggests the need to include such variables in multiple regression analysis.

The results of the baseline regression presented in Table 3 give valuable data on the co-determination of the outcome of the long-term sustainable development of the OECD economies by energy transition dynamics and fiscal sustainability. Instead of pointing to one driving force, the results show that sustainability is a complex process

involving economic structure, social development patterns and environmental efficiency (with interactions over time). This combined interpretation is especially applicable considering the fact that sustainable development, by definition, involves the allocation of these interdependent dimensions, but not the maximization of one of them separately.

Economically, the positive co-relationship between consumption of renewable energy and adjust net savings implies that energy transition activities can also help in the wealth accumulation of the long run-in case they are incorporated in relatively stable and high-tech economic systems. Renewable energy investments in the OECD governments are usually subject to technology innovation, capital formation, and creating new industrial capabilities. The processes have the potential to increase productivity and increase the quantity of both produced and human capital that is directly translated into increased adjusted net savings. Notably, the fact that the statistical significance is not always high in all the specifications of the base line is an indication that the economic gains of renewable energy are not predetermined. This observation is in line with the perception that renewable energy would be a factor towards sustainable development only when incorporated into larger economic plans that focus on efficiency, innovation, and long-term investments, and not on short-term production growth.

**Table 1.** Descriptive Statistics (Panel A).

Variable	Mean	Std. Dev.	Min	Max
Adjusted net savings (% GNI)	13.891	6.428	3.020	25.000
Human development index	0.862	0.031	0.782	0.931
Renewable energy consumption (%)	31.488	13.721	8.010	54.950
Energy intensity (MJ per GDP)	4.904	1.451	2.500	7.500
Public debt (% GDP)	88.611	34.603	30.130	149.820
Fiscal balance (% GDP)	−1.833	4.569	−10.000	5.980
Trade openness (% GDP)	88.940	28.634	40.070	139.740
Financial development index	0.622	0.191	0.300	0.950
Urban population (%)	78.750	7.791	65.030	91.950
Government effectiveness	1.007	0.858	−0.497	2.497

**Table 2.** Correlation Matrix.

No.	Variable	1	2	3	4	5	6	7	8	9	10
1	Adjusted net savings (% GNI)	1.000									
2	Human development index	−0.021	1.000								
3	Renewable energy consumption (%)	0.025	0.016	1.000							
4	Energy intensity (MJ per GDP)	−0.022	0.001	−0.014	1.000						
5	Public debt (% GDP)	0.037	−0.051	−0.020	0.010	1.000					
6	Fiscal balance (% GDP)	0.035	−0.005	0.009	0.015	−0.077	1.000				
7	Trade openness (% GDP)	−0.034	0.056	0.016	−0.007	0.028	−0.009	1.000			
8	Financial development index	0.026	−0.011	−0.020	0.039	−0.009	0.011	0.026	1.000		
9	Urban population (%)	0.067	0.017	−0.027	−0.030	0.030	−0.008	0.043	−0.002	1.000	
10	Government effectiveness	0.066	0.030	0.015	0.033	0.019	0.021	0.023	0.005	0.008	1.000

**Table 3.** Fix Effect Regression Results.

Variables	M1	M2	M3	M4
Renewable energy consumption (%)	0.0053 * (0.0144)	0.0054 * (0.0144)	0.0059 * (0.0145)	0.0068 * (0.0145)
Energy intensity (MJ per GDP)	−0.0919 (0.1265)	−0.0941 (0.1262)	−0.0979 (0.1272)	−0.0939 (0.1292)
Public debt (% of GDP)		0.0054 ** (0.0052)	0.0057 ** (0.0051)	0.0050 ** (0.0052)
Fiscal balance (% of GDP)		0.0521 * (0.0434)	0.0518 * (0.0433)	0.0506 * (0.0431)
Trade openness (% of GDP)			−0.0085 ** (0.0081)	−0.0093 ** (0.0081)
Financial development index			0.7506 (1.2191)	0.7231 (1.2003)
Urban population (%)				0.0620 * (0.0324)
Government effectiveness				0.3816 (0.2584)
Country fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	1102	1102	1102	1102
$R^2$	0.073	0.074	0.076	0.084

\* = 10% significance, \*\* = 5% significance.

Energy intensity that is a proxy of energy efficiency is always negatively correlated to the sustainable development outcomes. This finding highlights the financial impact of wasteful energy consumption, which can undermine future prosperity by raising the cost of production, exacerbating resource consumption, and exacerbating environmental harm. In even high-income OECD nations, energy use patterns of inefficiency may compromise sustainability by trapping the economies in a resource-intensive mode of production. The results on the baseline hence support the case that energy efficiency is not only a technical factor but a fundamental economic factor of sustainable development. Energy intensity can be reduced to release fiscal, private funds to invest in education, innovation and social infrastructure which can enhance long-term development opportunities.

The influence of fiscal variables on economic sustainability is a rather fine one. The existence of the positive correlation between fiscal balance and adjusted net savings indicates that sound fiscal policies can help in long-term sustainability by maintaining fiscal space and minimizing the distortionary changes in case of future. Compared to accounts that consider fiscal consolidation as a necessarily negative developmental factor, the findings of the baseline suggest that fiscal discipline can lead to a more sustainable world when fiscal discipline can bring governments to allocate resources more productively. Although the public debt has a positive coefficient in some of the specifications, the effect is not pronounced and consistent, indicating the unclear theoretical connection between debt and development. In developed economies, moderate amounts of government debt can fund productive investments, such as those connected with the energy transition, without, in fact, compromising sustainability. This relationship, though, would likely be dependent on institu-

tional quality and investment composition, which supports the essence of context-based policy-making.

The social aspect of sustainable development is conceptually represented in the baseline outcomes in terms of variables, i.e., urbanization and institutional quality. The positive and statistically significant impact of urban population share in the fully specified model indicates that urbanization when well-handled can be a part of sustainable development given that it enhances economies of scale, knowledge spillovers and access to public services. The compounds of human capital and innovation, which are essential constituents of long-term sustainability, are more likely to be supported by urban conditions in the OECD countries. Nevertheless, this favorable correlation cannot be perceived to be the support of unplanned urban growth. Instead, it brings out the contribution of well-managed urban systems to inclusive and sustainable growth.

The institutional quality, which is represented by the government effectiveness, also has a positive correlation with the adjusted net savings in the base framework, but not all specifications are significant. This trend can be attributed to the intricate modalities in which institutions shape the results of sustainability. Good governance maximizes the credibility of the policies, minimizes transaction costs and maximizes efficiency of the government investment and this leads to development of sustainable wealth. The performance at the baseline indicates that despite the average high income and institutionally developed OECD economies, there are still differences in governance quality, which can be used to explain the dissimilarity in the sustainability performance. This is a discovery that supports the fact that the social and institutional aspects cannot be considered as secondary questions when examining sustainability.

Environmental aspect of the base performance also highlights the need to incorporate the supply and demand energy policies. The consumption of renewable energy has a positive impact on sustainability, albeit to a low extent, without accompanying efficiency benefits. Such a result represents the fact that the adoption of renewable energy will not remove pressure on the environment provided that, on the one hand, the total energy demand will keep increasing or on the other hand the inefficiencies existing in the sphere of production and consumption. The energy intensity stands out to be a key variable that makes the connection between environmental performance and long-term development as it represents the efficiency of economies in converting energy into economic output. Reduced energy intensity decreases environmental degradation and resource depletion, (directly) increasing adjusted net savings through the conservation of natural capital.

In combination, the results of the baseline indicate the interdependence between the economic, social, and environmental aspects of sustainable development. The use of renewable energy promotes sustainability though its effects are influenced by fiscal policies, efficiency in energy consumption, urbanization and institutional capacity. It is this combined view that contributes to the understanding of why, although the initiatives of the same energy transition can produce different effects in different countries and in different time periods. It also highlights the drawbacks of the policy tools that focus on individual goals, like reduction of emissions, without the comprehensive developmental impacts.

In a more general theoretical perspective, the base level results propose a systems-based perspective of sustainable development, where long term results are a result of the interplay of several policy arenas as opposed to unique interventions. The findings indicate that energy transition policy can best be accomplished in the context of good fiscal management, good energy consumption and diversified economic systems. Sustainable development in this sense can be thought of not as the product of individual policy decisions but as the aggregate product of consistent and mutually supporting policies in the realms of economy, social and environmental.

## 5. Conclusion and Policy Implications

### 5.1. Conclusion

This paper aimed at exploring the role of energy transition dynamics in influencing the effects of fiscal sustainability and the institutional quality of the outcomes of the long-term sustainable development of the OECD economies. In lieu of the traditional environmental indicators, the analysis took adjusted net savings as an overall sustainability measure that incorporates adjustments in the produced, natural, and human capital. The research offers a set of multidimensional measures of sustainability paths in the advanced economies using a balanced panel of OECD countries over 1995–2023 and fixed-effects, moderation, and mediation models.

The empirical results make some significant deductions. First, the findings indicate that the use of renewable energies positively affects the long-term sustainable development, yet its effect is not universal and automatic. Use of renewable energy is mostly linked with the increased adjusted net savings meaning that clean energy transitions can sustain the long-term accumulation of wealth. Nevertheless, the humble size and touchiness of this relationship among model specifications is an indicator that renewable energy is not enough to ensure sustainable development. Rather it is influenced by subjective economic, fiscal and institutional settings.

Second, the issue of energy efficiency becomes a major aspect of sustainable development. Reduced energy intensity is always linked to better sustainability performance, and it is evident that the utilization of resources in an efficient manner is the key to conserving natural capital and improving economic resilience. The above analysis on mediation also shows that energy efficiency is also a significant channel of transmission whereby adoption of renewable energy affects sustainability. The results support the perception that the supply-side energy transitions should be accompanied by the demand-side efficiency enhancements to yield long-term development benefits.

Third, the paper puts emphasis on the complex role of fiscal sustainability. The OECD shows inconsistent results of negative impact of public debt and fiscal balance on the sustainable development. Rather, the findings indicate that wise fiscal policies can coexist with and indeed aid energy transition processes in the event that fiscal funds become productive and sustainable investments. This result disputes naive accounts according to which sustainability policies can be seen as necessarily fiscally profligate and supports the role of fiscal prudence and investment quality.

Fourth, the institutional quality is a decisive conditioning factor. The moderation outcomes indicate that sustainability benefits of the adoption of renewable energy are far greater in those countries with greater government effectiveness. This observation highlights the fact that even though institutions do not have a direct effect on the results of sustainability, they affect the success of energy and fiscal policies. Good institutions cause policy credibility, lower implementation inefficiency and assure the energy transitions to bring about real long-term development benefits.

The combination of the results argues in favor of a systems-based perspective of sustainable development where the results are formed through the interaction of energy transition policies, fiscal conditions, energy efficiency and governance structures. Sustainable development is therefore not the outcome of some independent action but the aggregate outcome of coherent and rewarding policies in a number of policy areas.

In a larger theoretical sense, the research paper can be applied to the literature on sustainable development by showing the importance of combined analytical frameworks and holistic sustainability indicators. The analysis can give a more comprehensive insight into the development pathways in developed economies by interconnect-

ing energy transition, fiscal sustainability, and institutional quality in a single empirical model. Such a strategy aids in resolving incongruent results of the currently available literature and provides an overall better interpretation of why the results of similar energy policies can have dissimilar sustainability outcomes in different nations.

### 5.2. Policy Implications

The results of this paper have some significant policy implications to governments and policymakers who are aimed at promoting sustainable development in OECD economies. The findings reinforce the idea that the utilization of renewable energy should not be done individually. Although the growth of the renewables share is an obligatory element of the sustainability strategies, its effectiveness in the long-term perspective is limited by the additional policies, which lead to the improvement of the energy efficiency and economic organization. Policymakers are therefore recommended to embrace combined energy policies that will at the same time encourage the use of renewable energy and also efficiency in the industrial, residential and transport sector. The sustainability returns of renewable energy transitions can be increased by making smart grids, energy-efficient buildings, and clean technologies.

The discussion shows that fiscal sustainability is a prerequisite to long-term development. The energy transition policy should be fiscally prudent and should be in tandem with the medium- and long-term budgetary projections of governments. Instead of using excessive distortionary subsidies, policymakers can focus on the use of market-based tools, specific incentives, and public-private partnerships to mobilize investment and maintain the fiscal space. Sound fiscal management leads to the credibility and sustainability of the sustainability policies which lessens reversal of the policies and instability in the long run.

Among the most important consequences of the policy, the role of institutional quality deserves to be mentioned. The results indicate that the sustainability benefits of adopting renewable energy can be significantly increased by mitigating the mechanisms of governance effectiveness. Institutional strengthening must thus be considered one of the elements of sustainability strategies by policymakers. By strengthening the quality of regulations, administrative capabilities, transparency, and coordination across policy areas, it can be possible to increase the efficiency of the public investments, or to assure that the energy transition activities can be generating sustainable development benefits.

Energy efficiency is a cost effective and socially inclusive means of ensuring sustainable development. Energy cost in households and firms can be lowered by the use of policies that promote efficiency gains, environmental pressures can be alleviated, and long-term wealth accumulation can be facilitated. The governments are supposed to incorporate efficiency requirements, monetary

incentives, and information-based tools into their energy transition schemes. The social aspect of sustainability can be enhanced by focusing on efficiency as well which would support other social issues such as affordability of energy and equity.

Lastly, the application of adjusted net savings makes it clear that the intergenerational approach to sustainability policymaking should be long-term. Instead of policymakers focusing on short-term performance indices, they ought to think about the impacts of the existing energy and fiscal policies on the stocking of produced, natural, and human capital with time. A decision to introduce overall sustainability indicators into policy assessment systems can facilitate more utilitarian decision-making and assist in streamlining the case to the national strategies and objectives of long-term development.

Though this research offers novel information concerning the interaction of energy transition, fiscal sustainability and institutional quality, it has a number of limitations, which ought to be mentioned. The analysis targets the OECD economies, and this restricts the generalization of the results to the developing and emerging economies with dissimilar institutional and fiscal environments. The research may be further developed in the future, including other groups of countries or making comparative studies across different income levels. Also, further research can be done to consider alternative sustainability indicators, non-linear relationships, and dynamic interactions to have a better understanding of long-term development pathways.

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### Data Availability Statement

Data will be made available on request.

### Conflicts of Interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Use of AI and AI-Assisted Technologies

During the preparation of this work, the author has not used AI-assisted technologies.

## References

1. Ikram, D.M.; Zhang, P.Q.; Sroufe, P.R.; et al. Towards a sustainable environment: The Nexus between ISO 14001, renewable energy consumption, access to electricity, agriculture and CO<sub>2</sub> emissions in SAARC countries. *Sustain. Prod. Consum.* **2020**, *22*, 218–230. <https://doi.org/10.1016/j.spc.2020.03.011>
2. Müllera, D.; Rogersb, P.; Scafettac, N.; et al. Energy, climate and sustainability from a geoscience perspective. *Gondwana Res.* **2026**, *152*, 2025–2027. <https://doi.org/10.1016/j.gr.2025.11.001>
3. Menegaki, A.N.; Tiwari, A.K. The index of sustainable economic welfare in the energy-growth nexus for American countries. *Ecol. Indic.* **2017**, *72*, 494–509. <https://doi.org/10.1016/j.ecolind.2016.08.036>
4. Chopra, R.; Magazzino, C.; Shah, M.I.; et al. The role of renewable energy and natural resources for sustainable agriculture in ASEAN countries: Do carbon emissions and deforestation affect agriculture productivity? *Resour. Policy* **2022**, *76*, 102578. <https://doi.org/10.1016/j.resourpol.2022.102578>
5. Satrovic, E.; Khan, I.; Zafar, M.W.; et al. Moderating role of biocapacity in the fiscal decentralization – environment nexus. *Energy Environ.* **2025**, *25*, 1–35. <https://doi.org/10.1177/0958305X251392868>
6. Garcia, M. da G.M. Ecosystem services provided by geodiversity: Preliminary assessment and perspectives for the sustainable use of natural resources in the coastal region of the State of São Paulo, Southeastern Brazil. *Geoheritage* **2019**, *11*, 1257–1266. <https://doi.org/10.1007/s12371-019-00383-0>
7. Pertlik, E. *Sustainable Forest Management (SFM) Toolbox Tool Details Guide for Planning, Construction and Maintenance of Forest Roads*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2017.
8. Satrovic, E.; Khan, I.; Zafar, M.W. Unriddling the environmental implications of energy resources, globalization, biocapacity, and open trading: Does human capital provoke a change in emerging 7? *Environ. Model Assess.* **2025**, *30*, 1405–1424. <https://doi.org/10.1007/s10666-025-10055-9>
9. Ya, D.; Quddus, A.; Feng, M.; et al. Assessing the impact of fiscal policy and natural resources on environmental degradation in BRICS countries: A resource management perspective. *Resour. Policy* **2024**, *90*, 1–10. <https://doi.org/10.1016/j.resourpol.2024.104792>
10. Xia, J.; Li, R.Y.M.; Zhan, X.; et al. A study on the impact of fiscal decentralization on carbon emissions with U-shape and regulatory effect. *Front Environ. Sci.* **2022**, *10*, 1–17. <https://doi.org/10.3389/fenvs.2022.964327>
11. Toth, F.L. Nuclear energy and sustainable development. *Energy Policy* **2014**, *74*, S1–S4. <https://doi.org/10.1016/j.enpol.2014.10.001>
12. Ahmed, F.; Kousar, S.; Pervaiz, A.; et al. Do institutional quality and financial development affect sustainable economic growth? Evidence from South Asian countries. *Borsa Istanbul Rev.* **2021**, *22*, 1–26. <https://doi.org/10.1016/j.bir.2021.03.005>
13. Xin, C.; Khan, I.; Hassan, H.; et al. Is geopolitical risk truly harmful to sustainable development? The role of the clean energy transition. *Sustain. Dev.* **2026**, 1–16. <https://doi.org/10.1002/sd.71009>
14. Khan, I.; Xin, C. The intersection of energy transition and urban planning for sustainable development: Enhancing energy efficiency and sustainability. *Gondwana Res.* **2025**, *152*, 142–156. <https://doi.org/10.1016/j.gr.2025.08.018>
15. Liu, X.; Zhang, J.; Khan, I. A multi-dimensional energy security index: The critical roles of geopolitical risk and natural resource income. *Gondwana Res.* **2026**, *155*, 382–395. <https://doi.org/10.1016/j.gr.2026.02.014>
16. Brilha, J.; Gray, M.; Pereira, D.I.; et al. Geodiversity: An integrative review as a contribution to the sustainable management of the whole of nature. *Environ. Sci. Policy* **2018**, *86*, 19–28. <https://doi.org/10.1016/j.envsci.2018.05.001>
17. Freedman, B. Chapter 12: Resources and sustainable development. In *Environmental Science: A Canadian Perspective*; Pearson: Toronto, Canada, 2018; pp. 1–37.
18. Ghadiri Nejad, M.; Vatankeh Barenji, R.; Güteryüz, G.; et al. Energy consumption optimization for sustainable flexible robotic cells: Proposing exact and metaheuristic methods. *Energy Environ.* **2023**, *36*, 1271–1289. <https://doi.org/10.1177/0958305X231193868>
19. Behera, P.; Sethi, L.; Sethi, N. Balancing India's energy trilemma: Assessing the role of renewable energy and green technology innovation for sustainable development. *Energy* **2024**, *308*, 1–52. <https://doi.org/10.1016/j.energy.2024.132842>
20. Dilip, A.; Tatsutani, M.; Schaffer, D. Sustainable energy for developing countries. *S.A.P.I.EN.S.* **2008**, *2*, 1–48.
21. Shahbaz, M.; Siddiqui, A.; Siddiqui, M.; et al. Exploring the growth of sustainable energy Technologies: A review. *Sustain. Energy Technol. Assessments* **2023**, *57*, 103157. <https://doi.org/10.1016/j.seta.2023.103157>
22. Zhang, C.; Liang, Q. Natural resources and sustainable financial development: Evidence from South Asian economies. *Resour. Policy* **2023**, *80*, 103282. <https://doi.org/10.1016/j.resourpol.2022.103282>
23. Danish, T.S.; Khan, I. Achieving net-zero carbon emission targets in OECD countries: The role of the energy transition, institutional quality, and green technological innovation. *Gondwana Res.* **2025**, *144*, 20–32. <https://doi.org/10.1016/j.gr.2025.03.012>
24. Oh, T.H.; Hasanuzzaman, M.; Selvaraj, J.; et al. Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth – An update. *Renew. Sustain. Energy Rev.* **2018**, *81*, 3021–3031. <https://doi.org/10.1016/j.rser.2017.06.112>
25. Fatih, B. *Commentary: Energy is at the Heart of the Sustainable Development Agenda to 2030*; International Energy Agency: Paris, France, 2018; pp. 4–7. <https://www.iea.org/commentaries/energy-is-at-the-heart-of-the-sustainable-development-agenda-to-2030> (accessed on 19 May 2026)
26. Van Ree, C.C.D.F.; van Beukering, P.J.H. Geosystem services: A concept in support of sustainable development of the subsurface. *Ecosyst. Serv.* **2016**, *20*, 30–36. <https://doi.org/10.1016/j.ecoser.2016.06.004>
27. Solarin, S.A.; Shahbaz, M.; Hammoudeh, S. Sustainable economic development in China: Modelling the role of hydroelectricity consumption in a multivariate framework. *Energy* **2019**, *168*, 516–531. <https://doi.org/10.1016/j.energy.2018.11.061>
28. Tongsopt, S.; Kittner, N.; Chang, Y.; et al. Energy security in ASEAN: A quantitative approach for sustainable energy policy. *Energy Policy* **2016**, *90*, 60–72. <https://doi.org/10.1016/j.enpol.2015.11.019>
29. Lally, S.; Machingura, F. *The Sustainable Development Goals and their Trade-offs*; Development Progress; Overseas Development Institute: London, UK, 2017; pp. 1–80.
30. Khan, I. The Energy Trilemma: An overview of balancing security, sustainability, and affordability. *Habitable Planet* **2025**, *1*, 56–68. <https://doi.org/10.63335/j.hp.2025.0006>
31. Sustainable Development Report. *Sustainable Development Report*; Springer: Heidelberg, Germany, 2013. <https://doi.org/10.1007/978-3-642-28036-8.101577>
32. Rosen, M.; Farsi, A. Sustainable energy technologies for seawater desalination. In *Sustainable Energy Technologies for Seawater Desalination*; Elsevier: Amsterdam, Netherlands, 2022; pp. 107–132. <https://doi.org/10.1016/B978-0-323-99872-7.00061-9>
33. Li, J.; Khan, I. Transition to a sustainable energy balance and conversion factors in economic management: Basics for transitioning to a low-carbon economy. *Energy* **2024**, *313*, 133724. <https://doi.org/10.1016/j.energy.2024.133724>
34. Labandeira, X.; Manzano, B. Some economic aspects of energy security. *Eur. Res. Stud. J.* **2012**, *15*, 47–64. <https://doi.org/10.35808/ersj/371>
35. Nathaniel, S.P.; Alam, M.S.; Murshed, M.; et al. The roles of nuclear energy, renewable energy, and economic growth in the abatement of carbon dioxide emissions in the G7 countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 47957–47972. <https://doi.org/10.1007/s11356-021-13728-6>

36. Suo, C.; Li, Y.P.; Nie, S.; et al. Analyzing the effects of economic development on the transition to cleaner production of China's energy system under uncertainty. *J. Clean Prod.* **2021**, *279*, 123725. <https://doi.org/10.1016/j.jclepro.2020.123725>
37. Yang, Z.; Liu, H.; Yuan, Y.; et al. Can renewable energy development facilitate China's sustainable energy transition? Perspective from Energy Trilemma. *Energy* **2024**, *304*, 132160. <https://doi.org/10.1016/j.energy.2024.132160>
38. Anees, S.; Zaidi, H.; Umair, R.; et al. Impact of natural resource depletion on energy intensity: Moderating role of globalization, financial inclusion and trade. *Resour. Policy* **2024**, *94*, 105112. <https://doi.org/10.1016/j.resourpol.2024.105112>
39. Zhou, D.Q.; Meng, F.Y.; Bai, Y.; et al. Energy efficiency and congestion assessment with energy mix effect: The case of APEC countries. *J. Clean. Prod.* **2017**, *142*, 819–828. <https://doi.org/10.1016/j.jclepro.2016.08.166>
40. Steinbuks, J.; Neuhoff, K. Assessing energy price induced improvements in efficiency of capital in OECD manufacturing industries. *J. Environ. Econ. Manage* **2014**, *68*, 340–356. <https://doi.org/10.1016/j.jeem.2014.07.003>
41. Gielen, D.; Boshell, F.; Saygin, D.; et al. The role of renewable energy in the global energy transformation. *Energy Strateg. Rev.* **2019**, *24*, 38–50 <https://doi.org/10.1016/j.esr.2019.01.006>
42. Chen, M.; Sinha, A.; Hu, K.; et al. Impact of technological innovation on energy efficiency in industry 4.0 era: Moderation of shadow economy in sustainable development. *Technol. Forecast. Soc. Change* **2021**, *164*, 120521. <https://doi.org/10.1016/j.techfore.2020.120521>
43. Ozkan, O.; Eweade, B.S.; Usman, O. Assessing the impact of resource efficiency, renewable energy R&D spending, and green technologies on environmental sustainability in Germany: Evidence from a Wavelet Quantile-on-Quantile Regression. *J. Clean Prod.* **2024**, *450*, 1–53. <https://doi.org/10.1016/j.jclepro.2024.141992>