Received on: 04 July 2024 **Revised on: 21 September 2024** **Accepted: 29 September 2024**

RESEARCH ARTICLE
DOI: 10.47703/ejebs.v68i3.426

The Role of Energy Intensity and Investment in Reducing Emissions in Türkiye

Aizhan M. Baimukhamedova[1]*

[1] Gazi University, Ankara, Turkey

Corresponding author:
*Aizhan M. Baimukhamedova – PhD, Associated Professor, Gazi University, Ankara, Turkey. Email: djanin65@gmail.com

How to cite this article:
Baimukhamedova, A.M. (2024). The Role of Digital Technologies in Promoting Gender Equality in Kazakhstan. Eurasian Journal of Economic and Business Studies, 68(3), 127-140.

Conflict of interest:
author(s) declare that there is no conflict of interest.

EJEBS

ABSTRACT

Addressing the challenge of rising carbon dioxide (CO2) and greenhouse gas (GHG) emissions is a critical priority in global efforts to combat climate change. The primary aim is to assess the relationship between energy intensity, private investments in energy, renewable energy consumption, export-related factors, and their influence on CO2 and GHG emissions in Turkey. The study employs a multi-level approach using correlation and regression analyses to explore the impact of the selected variables. A Bayesian correlation analysis was conducted to evaluate the strength of relationships between variables, and a regression model was used to test the significance of each factor. Data were gathered from official sources on energy intensity, renewable energy consumption, private investments in energy, and export-related variables in Turkey from 2007 to 2022. The study employed the JASP statistical software. The analysis showed that energy intensity and private energy investments are the most significant predictors of CO2 and GHG emissions. Energy intensity exhibited a strong negative correlation with CO2 emissions per capita ($r = -0.717$, $BF_{10} = 10.456$) and GHG emissions ($r = -0.802$, $BF_{10} = 44.224$), highlighting the critical role of energy efficiency in reducing emissions. Renewable energy consumption also played a role, though its influence was less pronounced than energy efficiency and investment. Based on the findings, it is recommended that policymakers prioritize energy efficiency improvements and create incentives for private investment in renewable energy technologies. Future studies should focus on sector-specific energy efficiency improvements and policy frameworks to enhance private sector engagement in clean energy initiatives.

KEYWORDS: Energy Intensity, Emissions, Sustainable Development, Green Energy, Economic Growth, Green Economy, Fuel Export, Turkey

SCSTI: 06.35.31

JEL Code: Q10, Q43, O13

FINANCIAL SUPPORT: The study was not sponsored

1. INTRODUCTION

The issue of rising carbon dioxide (CO_2) emissions and total greenhouse gas (GHG) emissions has become a central challenge in addressing climate change on a global scale. As nations strive to meet international climate goals such as those outlined in the Paris Agreement, reducing emissions has taken on a critical role in mitigating the impact of climate change (Liu et al., 2020). However, achieving significant reductions in emissions remains a complex task, as it requires coordinated efforts across various sectors, including energy, industry, and transportation. A vital aspect of this challenge is the influence of factors such as energy intensity, investment in energy infrastructure, and the transition to renewable energy sources in shaping emission trends.

Globally, energy intensity - the amount of energy used per unit of economic output - is a significant factor in emissions. High energy intensity indicates inefficient energy use, often leading to higher emissions. Similarly, private investment in energy infrastructure, particularly clean and renewable energy technologies, is crucial in transitioning to lower-carbon economies. Investments in energy efficiency, renewable energy projects, and new technologies are essential to offset the heavy reliance on fossil fuels, contributing to CO_2 and GHG emissions (Holechek et al., 2022). Despite global progress in renewable energy consumption, the rate at which countries adopt clean energy solutions varies significantly.

Additionally, natural resource rents, especially in resource-rich countries, play a significant role in the economic reliance on carbon-intensive industries such as fossil fuel extraction. This reliance further complicates efforts to transition to a low-carbon economy, as many countries face a trade-off between short-term economic gains and long-term sustainability goals. While exports of fuels and metals continue to be critical drivers of economic growth in many nations, they also contribute significantly to emissions. In the context of Turkey, the challenge of balancing economic development with environmental sustainability is particularly relevant. As a developing economy with a growing industrial base, Turkey faces unique pressures to reduce emissions while maintaining economic growth. Turkey’s energy sector has historically depended on fossil fuels, and its energy intensity remains relatively high compared to more developed economies (Celik & Özgür, 2020; Yildizhan et al.,2023). Although there have been efforts to increase renewable energy consumption and attract private investment into the energy sector, the pace of this transition remains insufficient to achieve significant emissions reductions.

Given the critical role that energy intensity, private investment in energy infrastructure, and renewable energy consumption play in reducing emissions, studying the interplay of these factors in Turkey's context is highly significant. Understanding how Turkey can leverage energy efficiency improvements and attract more investment in clean energy technologies will be crucial for its ability to reduce emissions while sustaining economic growth. Addressing these issues is vital for Turkey’s environmental goals and contributes to global efforts in combating climate change.

The study aims to analyze the determinants of CO_2 emissions per capita and GHG emissions by exploring the influence of energy intensity, private investment in energy, renewable energy consumption, and export-related variables.

2. LITERATURE REVIEW

The relevance of studying energy intensity and investments in clean technologies was driven by global challenges related to the increase in carbon dioxide (CO_2) and greenhouse gas (GHG) emissions in the context of economic growth. As economic activity grew, energy consumption increased, putting more strain on the environment, particularly in countries with high energy intensity. Inefficient energy use in sectors such as industry and transportation led to significant emissions. Research showed that investments in clean technologies were crucial in reducing dependence on fossil fuels and lowering emissions. However, the pace of these changes, especially in developing economies, needed to be increased. Analyzing global and regional trends and the experiences of countries like Turkey was critical for finding solutions to reduce energy intensity and successfully integrate renewable energy sources.

Caiado et al. (2017) emphasized that investments in clean technologies were vital to reducing energy intensity and environmental impact, especially in developing economies like Turkey. At the same time, Spaiser et al. (2017) highlighted the conflict between economic growth and environmental sustainability, pointing out that a traditional focus on economic growth in countries heavily reliant on fossil fuels exacerbated the problem of energy intensity. Østergaard et al. (2020) noted that transitioning to renewable energy sources, such as wind, solar, and geothermal, could significantly reduce dependence on fossil fuels. In countries where the potential of renewable energy was not yet fully realized, this was seen as a critical step toward achieving environmental sustainability. In this context, Ruggerio (2021) stressed the importance of implementing new energy models to reduce energy intensity. However, the author noted that successfully implementing such changes required technological modernization and political will, especially in countries where traditional energy sectors depended on fossil fuels.

In countries with high energy intensity, inefficient energy use has increased emissions, necessitating enhanced measures to improve energy efficiency. Sen and Ganguly (2017) emphasized that special attention had to be paid to the industrial and transport sectors, which were key contributors to energy consumption and emissions. Malik et al. (2019) noted that developing countries faced significant barriers to adopting renewable energy, such as insufficient political support and financing challenges, which hindered the effective utilization of renewable energy sources. Fadly (2019) pointed out that a successful transition to a low-carbon economy required active participation from the private sector and the creation of financial incentives. Brazil served as an example, where effective financial mechanisms supported the development of renewable energy projects, while in Nigeria, such programs faced numerous obstacles (Isah et al., 2023), slowing down reductions in energy intensity. In his study, Cantarero (2020) highlighted the importance of community involvement and creating inclusive energy systems to accelerate the transition to renewable energy. Moreover, in countries with high energy intensity, the participation of local communities and businesses in decision-making was a key factor for successfully implementing renewable energy sources.

The literature on natural resource rents and fuel exports highlighted their significant impact on carbon emissions, especially in resource-dependent countries. Ertimi et al. (2021) pointed out the importance of effective natural resource management in oil-dependent countries, noting that proper strategies, such as those in Norway, could help minimize the resource curse, utilize oil revenues for sustainable economic growth, and protect the environment. Saqib et al. (2022) added that in GCC countries, an increase in natural resource rents was linked to rising CO_2 emissions, demonstrating the importance of transitioning to renewable energy to reduce the carbon footprint. Despite economic benefits, the use of fossil fuels increased environmental pressure. Huang et al. (2021) also emphasized that natural resource rents exacerbated the negative ecological impact of rapid economic growth and urbanization, creating complex trade-offs between economic development and sustainability. Yan et al. (2023) explored the importance of green investments and fiscal policies to reduce dependence on natural resources and fossil fuels. Thus, for countries with a high share of natural resource rents, consistent measures were needed to stimulate the transition to clean energy and reduce carbon emissions.

To build on the findings from the literature, it becomes evident that energy intensity, private investment in clean technologies, and the consumption of renewable energy play critical roles in shaping environmental outcomes. Additionally, the impact of fuel and metal exports on emissions cannot be overlooked. Therefore, the following hypotheses were developed:

Hypothesis 1. CO2 emissions per capita significantly depend on energy intensity, private investment in energy, and renewable energy consumption.

Hypothesis 2. GHG emissions (kt of CO2 equivalent) are significantly influenced by energy intensity, private investment in energy, and exports of fuel and metals.

3. METHODOLOGY

A multi-level analytical framework was employed to investigate the complex relationships between key economic and environmental variables affecting CO2 and GHG emissions. The analysis was structured in stages, starting with bivariate analyses and concluding with Bayesian correlation and regression analysis to test hypotheses regarding the significance of selected predictors.

The initial stage involved profile plots for bivariate exploration of the data. This approach provided both a visual and statistical assessment of the relationships between individual variables, focusing on energy intensity, private energy investment, renewable energy consumption, and export-related variables. Profile plots were used to identify preliminary patterns and potential interactions among variables, setting the stage for more robust confirmatory analysis. The goal of this stage was to develop a qualitative understanding of the data and to identify potential interactions or multicollinearity between the variables.

Following the visual inspection, Bayesian correlation analysis was conducted to quantitatively assess the relationships between variables. Unlike traditional correlation methods, the Bayesian framework allows for the incorporation of prior information, offering a more nuanced interpretation of the strength and direction of these relationships. Bayes factors (BF_{10}) were used to compare models with predictors against a null model, thus providing evidence in favor of each predictor. The Bayesian approach was chosen for its flexibility in handling uncertainty and for its capacity to provide more reliable insights, particularly in cases where prior knowledge from existing literature is available, as in environmental studies.

A null model was included as a baseline for comparing more complex models with predictors. The null model assumed that none of the predictor variables had a significant effect on the dependent variable (CO2 emissions per capita or GHG emissions). This step was essential for evaluating whether the inclusion of specific predictors enhanced the explanatory power of the models. By using Bayes factor analysis, predictor-based models were compared against the null model to determine whether the predictors significantly contributed to explaining variations in the dependent variables. A Bayes factor greater than 1 indicated that a predictor-based model was favored over the null model.

In the final stage, regression analysis was employed to quantitatively assess the significance and impact of each predictor on CO2 and GHG emissions. The regression models evaluated both the individual significance of predictors, such as energy intensity, private investment in energy, renewable energy consumption, and export-related variables, and the overall model fit, using R^2 and adjusted R^2 to measure how well the models explained the variance in emissions. Bayesian regression models were utilized alongside traditional methods to ensure a robust comparison, further strengthening the understanding of the relationships between the predictors and emissions. Two main hypotheses were tested in this analysis.

The choice to employ profile plots, Bayesian correlation analysis, and regression analysis was driven by the need to address both the complexity and uncertainty present in economic and environmental data. The Bayesian framework provided a flexible way to interpret relationships in the presence of prior information, particularly when dealing with multiple interconnected predictors like energy consumption and emissions. Combining both exploratory (bivariate) and confirmatory (regression) techniques ensured that visual data inspection and statistical testing contributed to a comprehensive understanding of the relationships between the predictors and emissions outcomes. This multi-level approach enabled a robust interpretation of the data, leading to informed conclusions and practical recommendations.

4. FINDINGS AND DISCUSSION

The analysis aimed to provide a detailed examination of the factors influencing CO2 emissions per capita and total GHG emissions, focusing on energy intensity, private investment in energy, renewable energy consumption, and export-related variables. The analysis structure was designed to comprehensively explore how each factor contributed to emission trends through a multi-step approach, combining both exploratory and confirmatory techniques.

Initially, pairwise relationships using profile plots were analyzed to explore the connections between the variables. This step provided a preliminary understanding of the factors most strongly associated with CO2 and GHG emissions changes. Following this, a Bayesian correlation analysis was performed to account for uncertainty and offer more robust insights into the strength and direction of these relationships. Finally, a regression analysis tested the significance of each predictor, quantifying their respective contributions to explaining variations in emissions.

The first model examines the connection between several economic and energy variables and CO2 emissions per capita (Figure 1).

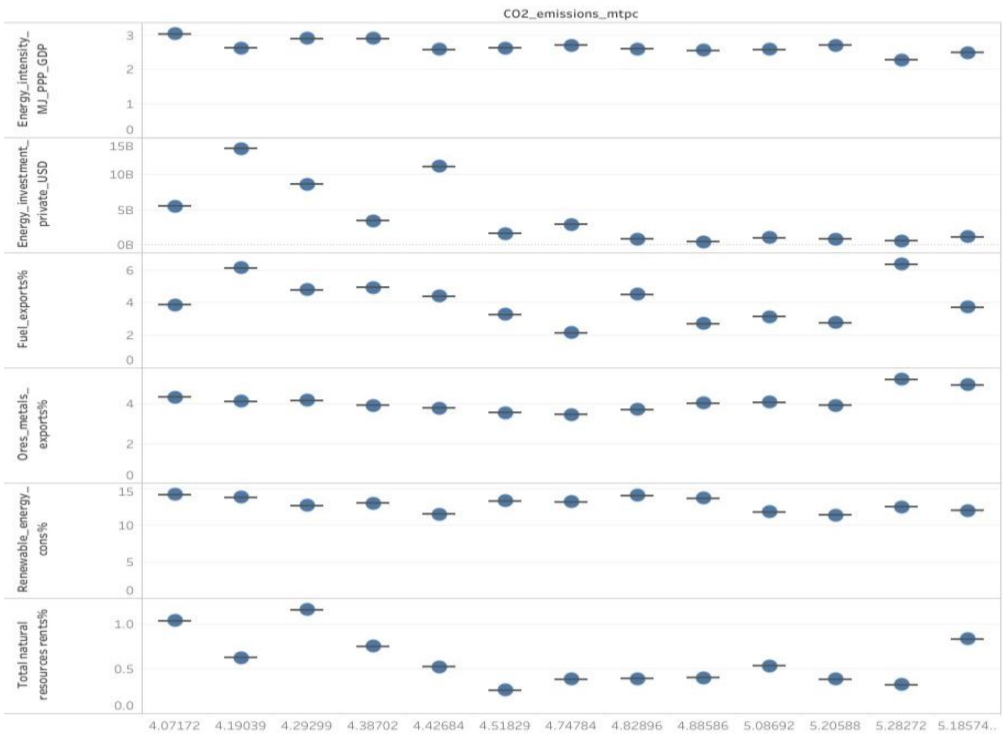

FIGURE 1. Model 1 CO2 emissions per capita

Note: compiled by authors

Key indicators such as Energy Intensity (MJ/$2017 PPP GDP) and Fuel Exports (% of merchandise exports) demonstrate a moderate correlation with CO2 emissions. Countries with higher energy intensity, which indicates less efficient energy use, tend to show higher emissions. Additionally, economies heavily reliant on fuel exports, such as Turkey, typically have higher emissions due to their dependence on carbon-intensive fossil fuel industries. In Turkey, despite efforts toward energy efficiency, the reliance on fossil fuel exports continues to drive emissions upward.

On the other hand, Access to electricity (% of population) and Ores and metals exports (% of merchandise exports) show weaker associations with emissions. While increased electricity access is often tied to industrial growth, this factor alone does not significantly drive emissions in the model. In Turkey, widespread access to electricity exists, but emissions are more closely tied to the energy sources used rather than access itself. Similarly, the export of ores and metals does not appear to have a strong impact on emissions, as their production is less carbon-intensive than energy sectors.

The second model analyzes the relationship between the economic and energy variables, with Total GHG emissions (kt of CO2 equivalent) as the dependent variable (Figure 2).

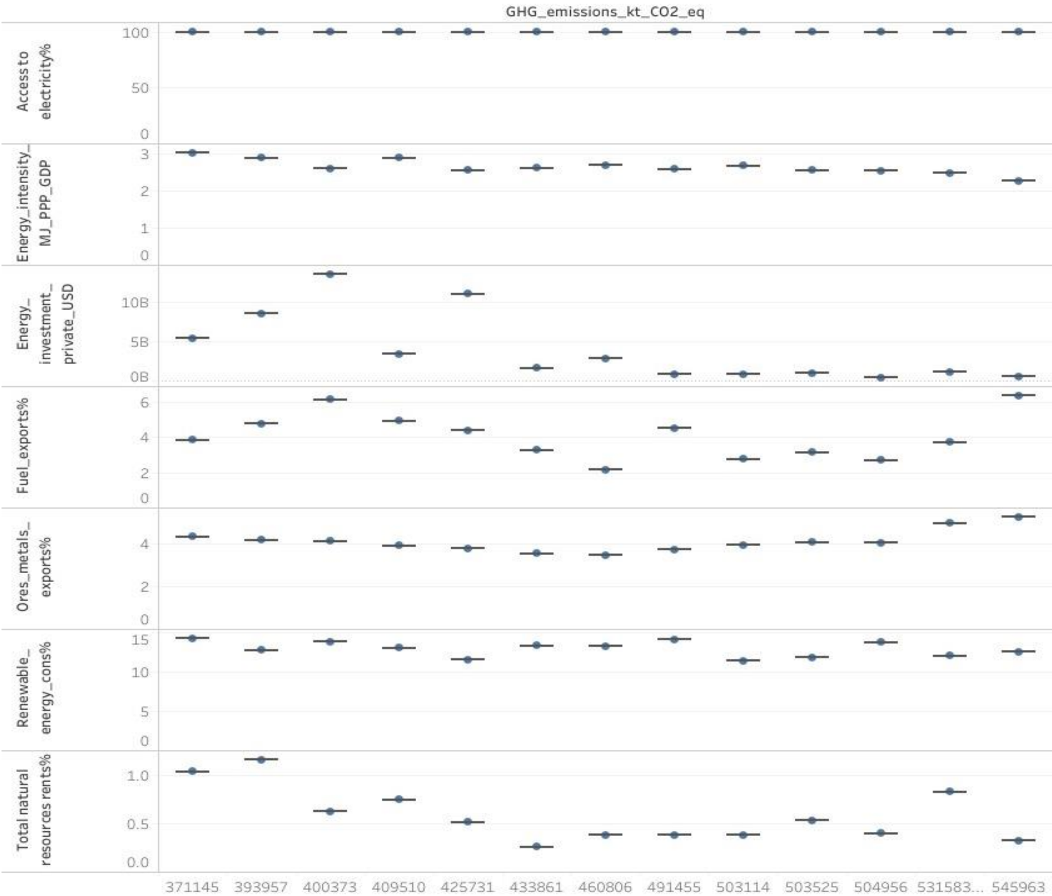

FIGURE 2. Total GHG emissions

Note: compiled by authors

Renewable Energy Consumption (% of total final energy consumption) and Private Investment in Energy (USD) reveal a more substantial inverse correlation with CO2 emissions. Countries with higher renewable energy consumption and greater private investment in the energy sector tend to have lower emissions. In Turkey, increased investments in renewable energy, particularly solar and wind, have begun to reduce the country's emissions, offsetting the negative impact of fossil fuel consumption. Targeted investments and a shift towards renewables can effectively reduce carbon footprints.

Finally, Total natural resource rents (% of GDP) display only a weak correlation with emissions, indicating that economic reliance on natural resource extraction has a limited impact on CO2 levels in Turkey. The relatively small share of natural resource rents in the Turkish economy means other sectors dominate emission generation.

Energy Intensity and Fuel Exports exhibit moderate positive correlations with GHG emissions, underscoring the role of energy inefficiency and fossil fuel dependence in driving emissions. Turkey's high fuel export reliance and relatively high energy intensity contribute to its greenhouse gas emissions, although recent efforts to improve energy efficiency are expected to mitigate this impact gradually.

Private Investment in Energy and Renewable Energy Consumption again show a stronger inverse correlation with GHG emissions, reinforcing the importance of renewables and energy investments in reducing emissions. In Turkey, rising private sector investments in cleaner energy technologies, alongside increasing renewable energy consumption, are helping curb GHG emissions growth despite industrial and economic expansion.

The remaining variables, Access to electricity, Ores and metals exports, and Total natural resources rents, exhibit weak relationships with GHG emissions. Like the first model, these indicators are relatively minor in driving greenhouse gas emissions in Turkey's context. The country's energy mix and industrial activities are more impactful than these specific economic variables.

A correlation analysis will be conducted and displayed in Table 1 to quantify the relationships observed in both models.

TABLE 1. Correlation matrix

Variable		**CO2_emissions_mtpc**	**GHG_emissions_kt_CO2_eq**	**Renewable_energy_cons%**	**Total natural resources rents%**	**Energy_intensity_MJ_PPP_GDP**	**Ores_metals_exports%**	**Fuel_exports%**
CO2_emissions_mtpc	Pearson's r	—						
	BF_{10}	—						
GHG_emissions_kt_CO2_eq	Pearson's r	0.978***	—					
	BF_{10}	666546.918	—					
Renewable_energy_cons%	Pearson's r	-0.511	-0.393	—				
	BF_{10}	1.445	0.762	—				
Total natural resources rents %	Pearson's r	-0.526	-0.559	0.088	—			
	BF_{10}	1.596	2.039	0.354	—			
Energy_intensity_MJ_PPP_GDP	Pearson's r	-0.717*	-0.802*	0.318	0.658	—		
	BF_{10}	10.456	44.224	0.568	5.080	—		

Ores_metals_exports%	Pearson's r	0.371	0.405	-0.187	0.279	-0.397	—	
	BF_{10}	0.693	0.805	0.405	0.503	0.773	—	
Fuel_exports %	Pearson's r	-0.245	-0.180	0.132	0.215	-0.177	0.498	—
	BF_{10}	0.459	0.399	0.371	0.428	0.397	1.333	—
Energy_investment_private_USD	Pearson's r	-0.740*	-0.717*	0.072	0.426	0.290	-0.129	0.468
	BF_{10}	14.545	10.433	0.350	0.888	0.520	0.370	1.114

Note: compiled by authors

This will outline the key variables influencing CO2 and GHG emissions to clarify the significance of factors such as energy intensity, fuel exports, renewable energy consumption, and private investments in driving emissions in Turkey and other similar economies. The interpretation of the correlation analysis reveals several significant relationships among the variables, particularly concerning CO2 emissions per capita and total greenhouse gas (GHG) emissions. A strong positive correlation is observed between CO2 emissions per capita and GHG emissions (kt of CO2 equivalent), with a Pearson's r value of 0.978 and a substantial Bayes factor (BF_{10}) of 666546.918, indicating a robust association. The relationship emphasizes the consistency between the two emissions measures, reinforcing that both metrics effectively capture the overall environmental impact of energy consumption and production.

Moving to renewable energy consumption, a negative correlation is found between CO2 emissions per capita and Renewable energy consumption, with a Pearson's r value of -0.511. Although this correlation is moderately intense, the Bayes factor (BF_{10}) of 1.445 indicates limited evidence in favor of the relationship. Renewable energy consumption also shows a weaker negative correlation with GHG emissions (-0.393), further suggesting that increasing the share of renewables in the energy mix contributes to lower emissions. However, the effect is not as pronounced. The weak associations between Renewable energy consumption and both types of emissions highlight the need for more robust policy measures to enhance the impact of renewables on reducing carbon footprints.

An analysis of Total natural resource rents reveals negative correlations with CO2 emissions per capita (-0.526) and GHG emissions (-0.559), indicating that countries relying less on natural resource rents experience lower emissions. The Bayes factors for these relationships are 1.596 and 2.039, respectively, showing moderate evidence supporting the correlations. Resource extraction and economic dependency on natural resources are closely tied to carbon-intensive industries, explaining the observed relationships. However, the positive but weak correlation between Natural resources rents and Renewable energy consumption (0.088) implies that resource-rich countries may need to sufficiently transition to cleaner energy sources, underscoring the complexity of energy policies in resource-dependent economies.

In terms of energy efficiency, Energy intensity demonstrates a strong negative correlation with both CO2 emissions per capita (-0.717) and GHG emissions (-0.802), with significant Bayes factors (10.456 and 44.224, respectively). This points to the crucial role of energy efficiency in reducing emissions. As countries lower their energy intensity, they tend to see reductions in emissions, reinforcing the need for continued investments in energy-efficient technologies. Energy intensity does not exhibit a notable correlation with Renewable energy consumption (0.318), indicating that efficiency improvements do not always coincide with increased renewables, highlighting potential gaps in integrated energy policies.

The relationships between emissions and export-related variables, such as Ores and metals exports and Fuel exports, are weaker.

Ores and metals exports show a weak positive correlation with CO_2 emissions (0.371) and GHG emissions (0.405), indicating that the export of these resources has a minor impact on emissions. The Bayes factors for these relationships are below 1, indicating limited evidence supporting these correlations. The lack of significant associations between Ores and metals exports and Renewable energy consumption (-0.187) or Energy intensity (-0.397) further indicates that this sector's contribution to emissions may be secondary compared to other industrial activities.

Fuel exports, often linked to fossil fuel economies, show weak negative correlations with CO_2 emissions (-0.245) and GHG emissions (-0.180), as well as weak positive correlations with Renewable energy consumption (0.132) and Ores and metals exports (0.498). The feeble nature of these correlations and the low Bayes factors indicate that fuel exports alone do not significantly drive emissions but rather work in tandem with other economic factors. Countries with high fuel exports may still be able to mitigate emissions through policy measures, such as increasing renewable energy use and improving energy efficiency.

Finally, Private investment in energy shows a robust negative correlation with both CO_2 emissions (-0.740) and GHG emissions (-0.717), accompanied by high Bayes factors (14.545 and 10.433). The critical role of private investment in reducing emissions, mainly through developing clean energy infrastructure, is emphasized. However, private investment does not show a significant relationship with Renewable energy consumption (0.072), pointing to the possibility that not all private investments are directed towards renewable energy projects.

Table 2 contains the results of the regression analysis for model 1.

TABLE 2. Regression analysis -model 1

Model 1	P(M)	P(M|data)	BF_M	BF_{10}	R^2
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.271	122.478	1.000	0.919
Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.009	0.164	21.363	0.201	0.823
Null model	0.500	0.061	0.064	0.001	0.000
Energy_investment_private_USD	0.045	0.057	1.267	0.014	0.547
Renewable_energy_cons% + Energy_investment_private_USD	0.009	0.046	5.272	0.057	0.758
Energy_intensity_MJ_PPP_GDP	0.045	0.042	0.926	0.010	0.514
Renewable_energy_cons% + Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.002	0.271	122.478	1.000	0.919
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.002	0.164	21.363	0.201	0.823
Renewable_energy_cons% + Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.002	0.061	0.064	0.001	0.000
Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.057	1.267	0.014	0.547

Note: complied by authors based on calculations

The comparison of predictors examining CO2 emissions per capita demonstrates that the combination of Renewable energy consumption (% of total energy consumption), Energy intensity (MJ/$2017 PPP GDP), and Private energy investment (USD) is the most robust set of predictors, with a posterior probability (P(M|data)) of 0.271 and the highest Bayes factor (BF10) of 1.000. These predictors explain 91.9% of the variance in CO2 emissions (R^2 = 0.919), emphasizing the critical role that energy efficiency, private sector investment, and renewable energy play in determining carbon emissions. The high explanatory power of these variables highlights their interconnected impact on mitigating emissions in various economies.

When looking at a more simplified set of predictors - energy intensity and Private energy investment - there is still significant explanatory power with a posterior probability of 0.164 and an R^2 value of 0.823. However, the slight reduction in explained variance suggests that renewable energy consumption is critical in further reducing CO2 emissions. The absence of renewable energy consumption in this set of predictors reduces the model's overall fit, reinforcing the importance of integrating renewable sources into energy policies.

The Null predictor, which assumes no relationship between the chosen factors and CO2 emissions, has a very low posterior probability (P(M|data) = 0.061) and explains none of the variance (R^2 = 0.000). This provides strong evidence that the selected economic and energy-related predictors significantly contribute to CO2 emissions, unlike a scenario where no variables are considered.

Additional predictors, such as Total natural resources rents and Ores and metals exports, offer modest improvements in explanatory power but do not outperform the combination of renewable energy, energy intensity, and private investment. For instance, including Total natural resources rents along with the primary predictors raises the R^2 slightly to 0.923. Still, the posterior probability (P(M|data)) decreases to 0.036, indicating that adding natural resource rents contributes little to improving the overall explanatory power.

Likewise, adding Fuel exports to the primary predictors produces a slightly lower posterior probability of 0.030 and an R^2 of 0.919. This outcome indicates that fuel exports have a minimal impact on CO2 emissions compared to energy efficiency, renewable energy, and private investment. Similarly, incorporating Ores and metals exports into the analysis shows limited influence on the variance explained.

To sum up, energy-related variables - energy efficiency, renewable energy consumption, and private sector investment - emerge as the strongest predictors of CO2 emissions. Additional factors like natural resource rents and exports of fuel or ores contribute some explanatory power but do not significantly improve emissions prediction..

In Table 3, the results of the regression analysis for model 2 are presented.

TABLE 3. Regression analysis -model 2

Model 2	**P(M)**	**P(M|data)**	**BF_M**	**BF_{10}**	**R^2**
Energy_intensity_MJ_PPP_GDP + Energy_investment_private_USD	0.009	0.517	116.734	1.000	0.899
Renewable_energy_cons% + Energy_intensity_ MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.099	35.958	0.572	0.924
Total natural resources rents% + Energy_intensity_ MJ_PPP_GDP + Energy_investment_private_USD	0.003	0.068	24.159	0.397	0.916
Energy_intensity_MJ_PPP_GDP	0.045	0.047	1.035	0.018	0.643

Energy_intensity_MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.003	0.046	15.769	0.265	0.907
Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.003	0.039	13.226	0.224	0.902
Null model	0.500	0.018	0.018	6.238 ×10-4	0.000
Renewable_energy_cons% + Total natural resources rents% + Energy_intensity_MJ_ PPP_GDP + Energy_investment_private_USD	0.002	0.018	11.835	0.205	0.935
Renewable_energy_cons% + Energy_intensity_ MJ_PPP_GDP + Ores_metals_exports% + Energy_investment_private_USD	0.002	0.014	9.145	0.159	0.930
Total natural resources rents% + Energy_intensity_MJ_PPP_GDP + Fuel_exports% + Energy_investment_private_USD	0.002	0.013	8.411	0.146	0.928

Note: complied by authors based on calculations

The comparison of predictors in the second model emphasizes the strength of the combination of Energy intensity (MJ/$2017 PPP GDP) and Private energy investment (USD), which emerges as the most robust set of predictors with a posterior probability (P(M|data)) of 0.517 and a Bayes factor (BF10) of 1.000. This combination explains 89.9% of the variance in the dependent variable (R^2 = 0.899), highlighting the significant roles of energy efficiency and private sector investments in energy infrastructure in influencing CO_2 emissions. The high explanatory power underscores the central importance of these predictors in understanding the emissions dynamics across economies.

Adding Renewable energy consumption (% of total energy consumption) to the combination of energy intensity and private investments slightly improves the explained variance to 92.4% (R^2 = 0.924). However, the posterior probability decreases to 0.099, indicating that renewable energy consumption positively contributes to the explanatory model. However, its overall effect is less significant than the core combination of energy intensity and private investment. Therefore, renewable energy variables, though necessary, might play a complementary role in reducing emissions rather than being a primary driver.

The inclusion of Total natural resources rents alongside Energy intensity and Private investment in energy yields a similar pattern, with an R^2 of 0.916 and a lower posterior probability of 0.068. This indicates that natural resource rents contribute moderately to explaining emissions but are less effective than the primary predictors. While relevant, the impact of resource rents seems to be overshadowed by the more direct influence of energy efficiency and investments.

Other predictor combinations, such as those incorporating Ores and metals exports or Fuel exports alongside Energy intensity and Private energy investment, show lower posterior probabilities and reduced explanatory power. For instance, including Ores and metals exports results in an R^2 of 0.907, with a posterior probability of 0.046, while adding Fuel exports leads to an R^2 of 0.902 and a posterior probability of 0.039. These results indicate that export-related variables while contributing some explanatory power, do not significantly enhance the model's ability to explain CO_2 emissions.

The null model, which assumes no relationship between the variables and emissions, shows a negligible posterior probability (P(M|data) = 0.018) and explains none of the variance (R^2 = 0.000). The extremely low Bayes factor (BF10 = 6.238×10^{-4}) confirms the necessity of including key predictors to explain emissions meaningfully.

More complex combinations, such as those involving Renewable energy consumption, Total natural resources rents, and various export-related variables alongside Energy intensity and Private energy investment, slightly improve the explained variance. For instance, including Renewable energy consumption and Total natural resources rents increases R^2 to 0.935, but the posterior probability remains low at 0.018, indicating limited added value from these variables. Similarly, combinations involving Ores and metals or Fuel exports yield higher R^2 values (0.930 and 0.928, respectively). Although additional variables such as renewable energy consumption, natural resources rents, or export-related variables are included in the model, they contribute very little to improving the model's ability to explain the variation in CO2 emissions when compared to the main predictors - energy efficiency (Energy intensity) and private energy investment.

In summary, Energy intensity and Private energy investment are the strongest predictors, with additional variables like Renewable energy consumption, Natural resources rents, and export-related indicators providing some improvements but not significantly altering the core explanatory framework. The findings reinforce the importance of energy efficiency and targeted investments in reducing emissions, while other factors play more supporting roles in shaping the emissions profile.

The analysis of CO2 emissions per capita and total greenhouse gas emissions confirmed the significance of critical factors such as energy intensity and private energy investment. These predictors emerged as the primary drivers explaining variations in CO2 emissions per capita and overall greenhouse gas emissions. Improving energy efficiency and attracting private investments in the energy sector have the most substantial impacts on reducing emissions.

Renewable energy consumption also reduces CO2 emissions, though its effect is less significant than energy efficiency and investments. This indicates that while renewable energy plays an important role, its influence is more pronounced when combined with broader measures to enhance energy efficiency and encourage private-sector investments.

Factors such as fuel and metal exports had a minimal impact and contributed little to explaining emissions. This highlights that strategies focused on improving energy efficiency and expanding private sector involvement in energy are far more crucial for reducing CO2 and greenhouse gas emissions than regulating export activities.

The following results were obtained:

Hypothesis 1. CO2 emissions per capita significantly depend on energy intensity, private energy investment, and renewable energy consumption - *accepted (with a partial influence of renewable energy consumption, as its contribution to reducing emissions is evident but not as significant as the effects of energy efficiency and private investments).*

Hypothesis 2. GHG emissions (kt of CO2 equivalent) are significantly influenced by energy intensity, private investment in energy, and exports of fuel and metals - *partially accepted (fuel and metal exports were found to have minimal impact on overall emissions, suggesting that energy efficiency and investments remain the dominant factors, while export-related variables play a less substantial role).*

5. CONCLUSIONS

The overall objective of this study was to analyze the key factors influencing carbon dioxide (CO2) emissions per capita and total greenhouse gas (GHG) emissions in kilotons of carbon dioxide equivalent, focusing on the roles of energy intensity, private investment in energy, renewable energy consumption, and export-related variables. The analysis confirmed that energy intensity and private energy investment are the most significant predictors of emissions, supporting the first hypothesis that these factors, along with renewable energy consumption, substantially affect CO_2 emissions per capita. The second hypothesis, regarding the influence of fuel and metal exports on GHG emissions, was only partially supported, as export-related variables showed a minimal impact compared to the more potent effects of energy efficiency and investments.

The striking findings revealed that improvements in energy efficiency and increased private investment in clean energy technologies are the most effective strategies for reducing CO_2 emissions per capita and GHG emissions. While renewable energy consumption contributes to emissions reductions, its influence is secondary compared to the more impactful factors of energy efficiency and private sector investment. The limited effect of fuel and metal exports suggests that export activity is not a critical driver of emissions, emphasizing the need to focus on domestic energy policies and investment strategies.

For future research, further exploration into sector-specific energy efficiency measures and investment incentives is recommended, along with studies that assess the long-term impact of such measures on emission reductions. Investigating the role of different types of renewable energy sources, such as solar and wind, combined with broader energy efficiency strategies, would provide deeper insights. Longitudinal studies focusing on how changes in energy policy and investment patterns affect emissions over time could also enhance understanding of sustainable development strategies.

From an economic and policy perspective, policymakers must prioritize energy efficiency improvements and create incentives for private investments in renewable energy projects. Developing targeted fiscal policies and frameworks that encourage the adoption of low-carbon technologies, along with a regulatory environment that supports private sector engagement, would be critical steps toward reducing emissions. Aligning national energy policies with sustainability goals will help mitigate environmental impacts while ensuring economic growth remains strong and resilient.

AUTHOR CONTRIBUTION

Writing – original draft: Aizhan M. Baimukhamedova.
Conceptualization: Aizhan M. Baimukhamedova.
Formal analysis and investigation: Aizhan M. Baimukhamedova.
Funding acquisition and research administration: Aizhan M. Baimukhamedova.
Development of research methodology: Aizhan M. Baimukhamedova.
Resources: Aizhan M. Baimukhamedova..
Software and supervisions: Aizhan M. Baimukhamedova.
Data collection, analysis and interpretation: Aizhan M. Baimukhamedova.
Visualization: Aizhan M. Baimukhamedova.
Writing review and editing research: Aizhan M. Baimukhamedova

REFERENCES

Caiado, R. G. G., de Freitas Dias, R., Mattos, L. V., Quelhas, O. L. G., & Leal Filho, W. (2017). Towards sustainable development through the perspective of eco-efficiency-A systematic literature review. *Journal of Cleaner Production*, *165*, 890-904. https://doi.org/10.1016/j.jclepro.2017.07.166

Cantarero, M. M. V. (2020). Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries. *Energy Research & Social Science, 70,* 101716. https://doi.org/10.1016/j.erss.2020.101716

Celik, A. N., & Özgür, E. (2020). Review of Turkey's photovoltaic energy status: Legal structure, existing installed power and comparative analysis. *Renewable and Sustainable Energy Reviews, 134,* 110344. https://doi.org/10.1016/j.rser.2020.110344

Ertimi, B., Sarmidi, T., Khalid, N., & Helmi Ali, M. (2021). The policy framework of natural resource management in oil-dependence countries. *Economies*, *9*(1), 25. https://doi.org/10.3390/economies9010025
Fadly, D. (2019). Low-carbon transition: Private sector investment in renewable energy projects in developing countries. *World Development*, *122*, 552-569.
Holechek, J. L., Geli, H. M., Sawalhah, M. N., & Valdez, R. (2022). A global assessment: can renewable energy replace fossil fuels by 2050? *Sustainability*, *14*(8), 4792. https://doi.org/10.3390/su14084792
Huang, S. Z., Sadiq, M., & Chien, F. (2021). The impact of natural resource rent, financial development, and urbanization on carbon emission. *Environmental Science and Pollution Research*, 1-13. https://doi.org/10.1007/s11356-021-16818-7
Isah, A., Dioha, M. O., Debnath, R., Abraham-Dukuma, M. C., & Butu, H. M. (2023). Financing renewable energy: policy insights from Brazil and Nigeria. *Energy, Sustainability and Society*, *13*(1), 2. https://doi.org/10.1186/s13705-022-00379-9
Liu, W., McKibbin, W. J., Morris, A. C., & Wilcoxen, P. J. (2020). Global economic and environmental outcomes of the Paris Agreement. *Energy Economics*, *90*, 104838. https://doi.org/10.1016/j.eneco.2020.104838
Malik, K., Rahman, S. M., Khondaker, A. N., Abubakar, I. R., Aina, Y. A., & Hasan, M. A. (2019). Renewable energy utilization to promote sustainability in GCC countries: policies, drivers, and barriers. *Environmental Science and Pollution Research*, *26*, 20798-20814. https://doi.org/10.1007/s11356-019-05337-1
Østergaard, P. A., Duic, N., Noorollahi, Y., Mikulcic, H., & Kalogirou, S. (2020). Sustainable development using renewable energy technology. *Renewable energy, 146*, 2430-2437. https://doi.org/10.1016/j.renene.2019.08.094
Qadir, S. A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Energy Reports*, *7*, 3590-3606. https://doi.org/10.1016/j.egyr.2021.06.041
Ruggerio, C. A. (2021). Sustainability and sustainable development: A review of principles and definitions. *Science of the Total Environment*, *786*, 147481. https://doi.org/10.1016/j.scitotenv.2021.147481
Spaiser, V., Ranganathan, S., Swain, R. B., & Sumpter, D. J. (2017). The sustainable development oxymoron: quantifying and modelling the incompatibility of sustainable development goals. *International Journal of Sustainable Development & World Ecology*, *24*(6), 457-470. https://doi.org/10.1080/13504509.2016.1235624
Saqib, N., Duran, I., & Hashmi, N. I. (2022). Impact of financial deepening, energy consumption and total natural resource rent on CO2 emission in the GCC countries: evidence from advanced panel data simulation. *International Journal of Energy Economics and Policy*, *12*(2), 400-409. https://ssrn.com/abstract=4074051
Sen, S., & Ganguly, S. (2017). Opportunities, barriers and issues with renewable energy development–A discussion. *Renewable and sustainable energy reviews*, *69*, 1170-1181. https://doi.org/10.1016/j.rser.2016.09.137
Yan, H., Qamruzzaman, M., & Kor, S. (2023). Nexus between green investment, fiscal policy, environmental tax, energy price, natural resources, and clean energy - a step towards sustainable development by fostering clean energy inclusion. *Sustainability*, *15*(18), 13591. https://doi.org/10.3390/su151813591
Yildizhan, H., Yıldırım, C., Gorjian, S., & Ameen, A. (2023). How May New Energy Investments Change the Sustainability of the Turkish Industrial Sector? *Sustainability*, *15*(2), 1734. https://doi.org/10.3390/su15021734

AUTHOR BIOGRAPHIES

***Aizhan M. Baimukhamedova** – DBA, Associated Professor, Gazi University, Department of Industrial Engineering, Ankara, Turkey, Email: djanin65@gmail.com, ORCID ID: https://orcid.org/0000-0002-3926-7867