International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(6), 505-511.

Analyzing the Interplay of Industrial Growth, Energy Use, and Employment in Turkiye: A Least Squares Approach

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Received: 24 May 2025 **Accepted:** 22 September 2025 **DOI:** https://doi.org/10.32479/ijeep.20918

ABSTRACT

The aim of this study is to examine the relationship between the development of the industrial sector, employment rates and energy consumption in Turkiye. The annual data series between 2001 and 2020 is used in the research. According to the LCC regression results, the F test is significant and the significance coefficient R^2 has a value of 0.3698. These two results show that the independent variables used in the model together are statistically significant in explaining the dependent variable, and the model explains about 36% of the increase and decrease in employment rates, which is the dependent variable. According to the results of the t-test, which shows whether the coefficients obtained for the independent variables are statistically significant, while the coefficients calculated for energy consumption are significant from the 95% confidence interval, the coefficient calculated for the industrial sector growth is meaningless

Keywords: Industrial Sector, Energy Consumption, Employment, Least Squares Method, Türkiye
JEL Classifications: L60, O14, Q43, E24, O11

1. INTRODUCTION

Energy consumption is rising in the modern world as a result of urbanization and population growth. This is essential if you want to stay up with the rapid changes and turmoil in the world economy. Human existence and the social, economic, and environmental development of the global economy are both fundamentally reliant on energy. It is presumably challenging to create, distribute, or utilize common commodities without using energy (Li et al., 2023). Production in the manufacturing sector is becoming more significant in the global supply chain as a result of globalization (Haraguchi et al., 2017). This industry has a higher need for capital and investment than other industries do. Due to the need, there are more employment, investments, and innovative ideas.

Energy usage may be significantly impacted by a variety of factors. The issue of energy consumption has been studied in the literature across a range of subjects. He has recently examined how much energy Bitcoin uses in a number of academic articles (O'Dwyer and Malone, 2014; Stoll et al., 2019). The presence of unidirectional causation or neutrality from GDP to energy, supposing that energy consumption and output are positively associated, suggests that energy conservation programs may be implemented without negatively impacting economic growth. Energy conservation strategies that limit energy usage will slow economic development because there is unidirectional causation between energy and GDP or feedback between energy and GDP (Sadorsky, 2012).

The exploration of numerous potentials by sustainable economies also includes concerns about energy use (Sadiq et al., 2023). In order to plan energy distribution, personalize services, and create demand response programs, utilities often measure energy consumption, comprehend the geographical distribution and

fluctuation of consumption over time, and investigate customer groups (Wu et al., 2023). Resource economists have created models that consider how resources, particularly energy, contribute to economic development. In the area of resource economics, however, these concepts are unique. Energy often has a major influence in economic development, according to ecological economists (Stern, 2011). In this regard, energy is seen as a crucial engine for the expansion and advancement of the economy.

Industrial employment is increasing or constitutes a significant part of employment at a constant level in developing countries (World Bank, 2019). Within the scope of the 2022 Labor Market Research in Turkiye, data were compiled for 255 thousand 22 workplaces in the manufacturing sector, and a total of 4 million 513 thousand 318 employees were identified in these workplaces. 76.2% of the workplaces operating in this sector consist of workplaces with 2-9 employees, 10.6% of workplaces with 10-19 employees, and 13.2% of workplaces with 20 or more employees. The manufacturing sector is the fifth sector with the highest increase in net employment change rate. The sector is above the average of Turkiye in proportional net employment change with 5.2% (İŞKUR, 2022).

There are numerous academic articles on energy and economics in Turkiye (Huseynli, 2023a; Kandemir Comoğlu and Huseynli, 2025). This article focuses on energy and employment in the industrial sector in Turkiye. The link between energy and income is the primary focus of the energy consumption debate at both the micro and macro levels. Energy usage has a micro level relationship with consumer behavior and a macro level relationship with family income. At the national level, GDP and energy use are linked. The manufacturing sector, however, is what really propels the economy of the nation. One of the key elements influencing the industrial sector is energy. From this point of view, the aim of this study is to examine the relationship between the development of the industrial sector, employment rates and energy consumption in Turkiye in the 2001-2020 period.

2. LITERATURE REVIEW

2.1. Industry Sector

The manufacturing sector in industrialized countries has the potential to stimulate trade, innovation, and productivity development. Also, this industry is crucial for lowering resource and energy usage as well as greenhouse gas emissions (Herman, 2016). The energy element is, in general, a highly significant aspect in industry.

For all nations, energy is a critical component of production. Conventional energy sources like coal, natural gas, and oil are seen to be the best economic development generators (Ellabban et al., 2014). The demand for conventional energy sources has significantly expanded as a result of social and economic changes during the last 50 years (Aslan et al., 2014). On the other hand, a fresh debate concerning the role of renewable energy sources in sustainable development has been sparked by the developing trend in the global energy industry (Sadorsky, 2012; Lund, 2007). Non-renewable energy sources continue to have a significant impact on the energy mix. This illustrates how both renewable and non-renewable energy sources may be used for a long time to come (Li et al., 2023). By needing significant expenditures in fossil fuels, enormous capacities, and decreased imports and investments, the sector for renewable energy resources provides employment (Lehr et al., 2008). At the global, national, regional, and local levels, energy is a key environmental issue that affects sustainable development. Renewable energy sources, however, may act as a catalyst for regional growth (Del Rio and Burguillo, 2009; Maria and Tsoutsos, 2004).

Inputs that are not directly employed in production are referred to as primary factors of production. These inputs might deteriorate over time or accumulate from one period to the next. Intermediate inputs are those that are produced throughout the production period. Mainstream economics often consider products (such as fuels and materials) to be intermediate inputs and capital, labor, and land to be the basic components of production. Prices paid for different intermediate inputs are ultimately seen as payments made to main input owners for services that were either directly rendered or included in the production of intermediate inputs. This strategy has caused mainstream growth theory to concentrate on primary inputs, particularly capital and labor (Stern, 2011).

Rapid technical progress, economies of scale, and simple integration into the national production network are hallmarks of the manufacturing sector (Su and Yao, 2017). The transition from wood and waterpower to coal, oil, natural gas, and primary electricity has been driven by the long-term paradigm of energy usage in industrial economies (Hall et al., 1986; Smil, 1991).

The primary reasons of climate change, according to researchers, are the acceleration of human activity because of the expansion of industry, the rise in world population, and the necessity to deal with these transitions. Even though industrialization helped nations expand economically by producing more goods and services, transforming society, and enhancing life, it has also left them with the issue of rising greenhouse gas emissions (Li et al., 2023).

In Turkiye, the industrial sector is also quite significant. Based on workplace and current employment statistics, the manufacturing industry accounts for 28.5% of employment in Turkiye, considering the country's overall condition (İŞKUR, 2022).

2.2. Employment

For the generation of jobs and long-term economic growth, the manufacturing sector is crucial for national economies (Herman, 2016). Industrialization is seen as the primary driver of economic development as a result (Karaca, 2021). The literature on employment in the industrial sector contains research in a variety of topics.

Kurz and Senses (2016) investigated the relationship between the fluctuation in employment and the trade of the firm. However, Afşar et al. (2017) the relationship between economic growth and employment between 2000 and 2016 was examined with VAR analysis, impulse response analysis, variance decomposition

method, Granger causality test. Feenstra et al. (2019) examined the effects of exports and imports on employment in the USA.

On the other hand, Ersin and Ergeç (2018) discovered a one-way causal relationship between total employment across all sectors, employment in the industrial sector, employment in the agricultural sector, and employment in the service sector, and they concluded that there is a bidirectional causal relationship between employment in the construction sector and exports. In the research by Sasahara (2019), it was shown that exports had a favorable impact on employment in the USA, China, and Japan. It was also discovered that this contribution varied by sector, and that it was greatest in industries with high added value.

Exports boost employment, according to Whang (2019), although the amount they boost depends on the export sector's size and manufacturing method. Additionally, out of the regions created by the Turkish Statistical Institute at three different levels in accordance with Turkiye's harmonization process with the European Union, it was investigated in the study conducted by Karaca (2021) how the indicators of the manufacturing industry affect employment in 26 sub-regions, which are located at the second level. Nonetheless, Turkiye's export and employment link in the industrial sector was experimentally evaluated over the years 1991-2019 in the research undertaken by Gerçeker (2021).

Exports do, according to Aydiner-Avşar and Onaran (2010), favorably impact employment in Turkiye, although their impact is modest. Similarly, exports do not significantly affect employment, according to Polat et al. (2011). Moreover, Kızılırmak (2012) discovered that exports had a short-term negative impact on employment but a long-term favorable impact.

The impact of variations in oil prices on Turkiye's manufacturing economy and employment are looked at in the research undertaken by Azazi and Topkaya (2017). Like this, Altuntepe (2018) found that exports had a short-term but not long-term favorable impact on employment.

According to Greenway et al. (1999), exports have a detrimental impact on employment. In their study on Germany, Görg and Görlich (2011) discovered a negative correlation between employment and service sector exports.

2.3. Energy Use

In reaction to the shocks caused by the rise in oil prices in the 1970s, research was conducted to determine the link between energy use and GDP (Sadorsky, 2012). Also, a country's social life and the functioning of the economy in a number of areas, including transportation, suffer from a lack of energy (Yildirim, 2017). Nonetheless, it is said that families may lower their energy usage by roughly 30% by altering the technology they choose and use for their homes and cars without having to wait for new ones, make significant financial sacrifices, or lose their feeling of wellbeing (Gardner and Stern, 2008).

According to Cheng's (1997) research, there is a clear link between Brazil's real GDP and the country's energy use. Similar to this, Soytas and Sari (2003) analysis of 12 G7 and emerging market nations revealed a bidirectional causal relationship between Argentina's energy use and GDP per capita.

Unidirectional causation from energy consumption to real GDP has been shown in research by Lee (2005) based on a panel analysis of 18 developing nations, including Argentina, Chile, Colombia, Peru, and Venezuela. It was discovered that for Argentina and Venezuela, there is a bidirectional causal relationship between energy consumption per capita and real GDP per capita in research by Mahadevan and Asafu-Adjaye (2007) on net energy exporting emerging nations.

By reducing vehicle idling and switching to compact fluorescent bulbs instead of incandescent ones, for example, Vandenbergh et al. (2007) identified seven actions that have the potential to result in significant emissions reductions at a low cost to the government and net savings for individuals (CFLs). Nonetheless, it was shown in research by Squalli (2007) that there is a single direction of correlation between Venezuela's real GDP per capita and its per capita power consumption.

No correlation between energy consumption and real GDP per capita for the low-income panel was discovered by Huang et al. (2008) based on data from 82 countries, including Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, and Venezuela. While establishing a link between real GDPs per capita and energy use for middle- and high-income panels. Attari et al. (2010) used information gathered from 505 participants in an online survey in the USA to assess perceptions of energy use and savings for different home, transportation, and recycling activities. Contrary to professional advice, the majority of respondents named energy reductions (such as installing more energy-efficient light bulbs and appliances) rather than efficiency increases (such as turning off lights, driving less).

Using a data set spanning the years 1997-2021, Huseynli (2023b) examined the connection between energy use in the Italian service sector and the variables influencing exports of products and services. According to the data, 86% of Italy's commercial service exports may be explained by a 1% growth in the country's exports of products and services. Additionally, almost 27% of Italy's exports of commercial services may be explained by a 1% rise in energy use.

According to Ajmi et al. (2015), it has been shown that implementing the energy plan would lessen reliance on non-renewable energy sources. Singh and Yassine (2018) utilized data mining and visual analysis techniques to analyze time series data related to energy use. Moreover, Pegkas (2020) looked at the impact of economic growth, non-renewable energy use, and renewable energy with a focus on the combined effect of renewable energy consumption in Greece. Using panel cointegration analysis, Huseynli (2024) investigated the connection between Greece's economic development, energy consumption, and renewable energy sources from 1997 to 2015. According to the research, energy consumption would rise by almost 15% for every 1% increase in economic development.

3. RESEARCH METHODOLOGY

3.1. Purpose and Data Set

The aim of this study is to examine the relationship between the development of the industrial sector, employment rates and energy consumption in the period of 2001-2020 in Turkiye. The least squares method was used in the study. The data were subjected to panel analysis method. The data set used in the study was obtained from the World Bank database.

3.2. Analyses Method

In a study conducted by Lee and Chiu (2013) on 24 OECD countries, a panel data set was used as well as the most appropriate econometric model to determine whether energy consumption is affected by GDP per capita. Baltagi (2005) pointed out that the advantages of panel data are "more informative data, more variability, less linearity between variables, more degrees of freedom, and greater efficiency."

In regression analyzes based on panel data, Ordinary Least Squares (OLS) Regression has two different methods, constrained and unconstrained. Unlike the constrained OLS method, there are three basic models of the unconstrained OLS method. These are pooled (POLS), fixed-effects (FE) and random-effects (RE) models, respectively. In terms of our subject, the least squares model will be emphasized in the sub-titles. However, before these models, it is necessary to briefly talk about the content of the panel data regression model.

The panel regression model with dependent variable Y and independent variable X with two sub-indexes i for units and t for time period can be specified as in Eq. (1).

$$Y_{it} = \alpha_{1t} + \sum_{i=1}^{k} \beta_k X_{kit} + \mu_{it} \quad (1)$$

According to the equation, according to the panel regression model with "k" variables, β_{kit} refers to the constant term, slope coefficients from β_{kit} to β_{xit} are unknown response coefficients, and εit refers to the error term.

In this study, since only an analysis will be made on the Turkish economy, a time series analysis will be made, which shows the changes of the variables according to time while the space is fixed (2013). Another advantage of time series analysis is that it helps to analyze changes (2007).

One of the most important assumptions of the EKK technique is the constant variance assumption (Tarı, 2006; Orhunbilge, 2000). The EKK technique assumes that the variance of the unit values of the dependent variable will remain constant while the unit values of the independent variables change, and this assumption is called homoscedasticity in the statistical literature (Tarı, 2006; Orhunbilge, 2000; Yamak and Köseoğlu, 2006). In other words, the error term variance remains the same without being affected by the changes in the independent variables.

If the variance of the error term is different, it is called heteroscedasticity and shows the undesirable situation in the regression analysis. In this case, the variance of the errors of the regression model does not remain constant, but may change by showing an increasing, decreasing or both increasing and decreasing distribution.

Due to the aforementioned reasons and the use of more than one independent variable in the study, multiple regression model will be used, and the parameters will be estimated by the EKK method. EKK method, which is one of the most common methods used for the estimation of fixed and slope parameters, has been preferred in this study because it gives reliable estimates if it has some assumptions in the econometric analysis to be made in the later parts of the study. The employment rate of the regression model in which the EKK method is used is dependent; the other two variables are independent.

4. ANALYSES AND RESULTS

Before the analysis, the summary statistics table was examined on the data set to be used in the study. After no problem was found in the length relationship between the data sets, the transition to model building was made. The model required for the analysis, employment rates are considered as dependent, energy consumption and industry sector as independent variables. The model estimation of the study is explained as in the Eq. (2).

$$Lemployment = \beta_0 + \beta_1 \, Lindustrial\ sector + \beta_2 \, Lenergy\ use + \mu \quad (2)$$

The logarithm of the data set regarding the energy consumption and the growth in the industry was included in the analysis. The analysis was carried out using the panel data method. Panel data analysis countries, regions, companies, etc. It is a method of analyzing cross-section observations such as time series observations together. In panel data analysis, it is first necessary to decide which of the classical model, random effects and fixed effects models will be chosen. Against the null hypothesis that there is no unit effect, the model is tested with F, LM and LR tests. The LR test is called the most likelihood test and allows the classical model to be tested against the random effects model. The LR test estimates random effects and classical effects models using the maximum likelihood method (Yerdelen Tatoğlu, 2013). As a result of the rejection of the basic hypothesis, it is understood that one of the fixed and random effects models is valid. The results of the study-specific odds ratio test (LR) are presented in Table 1.

As a result of the test, it is concluded that the study complies with the classical model. There is no unitary and temporal effect among the data established in the study. In the study, White's Test was used for varying variance (heteroskedastic) testing. According to the White Test result seen in Table 2, the hypothesis claiming that there is constant variance in the model is accepted, and accordingly, there is no heteroscedasticity problem in the model.

For the autocorrelation test, the Wooldridge Test, which is valid for the least square's method, was used in the study. According to the result of the Wooldridge Test, the hypothesis claiming that there is no first-order autocorrelation in the model is rejected,

and accordingly, there is an autocorrelation problem in the model (Table 3).

VIF (Variance Inflation Factor) test was performed to test the existence of multicollinearity problem between independent variables. When the VIF test results in Table 4 are examined, it is seen that the VIF statistical values among the independent variables are within acceptable limits. It shows that there is no multicollinearity problem between the independent variables (Fogarty, 2018).

When all these results are considered, it becomes clear that the Drisc/Kraay Estimator, which is resistant to the autocorrelation problem, should be used in order to perform the Panel Data Analysis, which will be applied with the Classical Pooled Least Squares Model in this study (Hoechle, 2007). In this way, the panel data analysis regression results using the Drisc/Kraay estimator are shown in Table 5.

According to the LCC regression results seen in Table 5, the F Test is significant and the significance coefficient R^2 has a value of 0.3698. These two results show that the independent variables used in the model together are statistically significant in explaining the dependent variable, and the model explains about 36% of the increase and decrease in employment rates, which is the dependent variable. According to the results of the t-Test, which shows whether the coefficients obtained for the independent variables are statistically significant; While the coefficients calculated for energy consumption are significant from the 95% confidence interval, the coefficient calculated for the industrial sector growth is meaningless. Since the energy consumption and industrial sector growth variables used in the model are included in the model by taking their natural logarithms, the coefficients calculated for these variables express the increase and decrease in the dependent variable as percentages.

Table 1: Likelihood ratio (LR) test results

Statistics	LR statistics	Probability value
Unit and time impact	0.00	1.0000
Unit impact	0.00	1.0000
Time effect	0.00	1.0000

Table 2: White's test results

Test statistic	Probability value
4.9051	0.4276

Table 3: Wooldridge's test results

Test statistic	Probability value
22.075	0.0178

Table 4: VIF criteria results

Variable	VIF	1/VIF
Industry sector	1.17	0.855056
Energy use	1.17	0.855056
Mean VIF	1.17	

Table 5: Least squares estimation test result

R^2	Number of observations		Prob	
0.3698	20		prob>0.0089	
Employment	**Coefficient Values**	**Drisc/Kraay Resistive Standard Errors**	**T statistics**	**P>|t|**
Industry sector	0.0210891	0.022575	0.93	0.363
Energy use	4.323436	1.800855	2.40	0.028
Fixed coefficient	18.5014	5.816685	3.18	0.005

5. DISCUSSION AND CONCLUSION

The findings of the research done by Afşar et al. (2017) indicate that economic expansion benefits employment. Feenstra et al. (2019), however, found that although imports reduce employment, exporters enhance employment because of the research carried out in the USA. The findings of the research by Kurz and Senses (2016) show that companies with higher levels of exports see less variations in employment than companies with lower levels of exports.

According to the research done by Azazi and Topkaya (2017), the manufacturing sector was directly impacted by oil prices, but employment in the sector was not affected in the same way. Similar to this, the findings of a research by Karaca (2021) show that although an increase in exports, GDP, and a reduction in imports all have a positive impact on employment, an increase in the number of businesses has a negative impact. Employment is not statistically significantly impacted by production.

The investigation carried out by Gerceker (2021) led to the rejection of the hypothesis that "positive export-related shocks are not the source of positive shocks in employment" and "negative export-related shocks are not the cause of negative shocks in employment." Hence, changes in exports—whether positive or negative—are considered as the cause of the same-sided changes in employment.

In this study, which aims to investigate the effects of growth and energy consumption in the industrial sector on employment rates, panel data analysis was carried out using Turkiye's 2001-2020 period data. As a result of the tests required for this analysis, it was determined that the study was suitable for the classical pooled least squares model and the regression analysis should be done using the Drisc/Kraay estimator. According to the panel data analysis made in this way; It has been determined that energy consumption positively affects employment rates in Turkiye and is statistically significant with employment rates.

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