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Estimation of the Factors Influencing Changes in Energy Efficiency in Algeria

Dr. Nour El-Houda LAYADI [1] , Dr. Benabbou SENOUCI [2]

[1] Oran Graduate School of Economics, Algeria. Email: layadi.nourelhouda.95@gmail.com

[2] Oran Graduate School of Economics, Algeria. Email: senouci.ben@gmail.com

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Abstract:

In light of the criticisms regarding energy intensity (EI) as an unreliable indicator of energy efficiency (EE), this study relies on true EE data derived from a previous index decomposition analysis (IDA) (Layadi N.;Senouci B., 2022), which revealed significant variations in EE over 1990–2020. Based on these results, we employ a partial adjustment model (PAM) to investigate the influence of fundamental factors on the true EE variation during 1990–2019, in both the short and long run.

The findings show that energy and capital are substitutable, suggesting that investments in energy-saving technologies and the adoption of efficiency practices can substantially improve the country's energy performance. Furthermore, the development of appropriate infrastructures to meet demographic growth, alongside energy price adjustments, is identified as essential. Conversely, temperature variations appear to have no significant effect on EE. These effects strengthen over the long run.

Keywords: Energy intensity; Energy efficiency; Decomposition; Determinants; Algeria;

Classification JEL: Q480

1. Introduction

The global degradation of environmental quality, the depletion of resources, and the energy issue are closely linked. Consequently, this issue today represents one of the most significant challenges for the global economy. Likewise, the use of fossil fuels generates a flow of environmental externalities, particularly greenhouse gas emissions. Moreover, global CO_2 emissions from fossil fuels are increasing year after year. It is important to note that in 2022, after two years largely influenced by the impacts of the Covid-19 pandemic, an increase of 0.9%, representing a growth of 321 Mt CO_2, was recorded. This led to a new peak in emissions, exceeding 36.8 Gt. Despite a less pronounced increase between 2021 and 2022, CO_2 emissions remain on a trajectory that is not compatible with the objectives set by the Paris Agreement. This highlights the need to adopt stronger measures to accelerate efforts to reduce the ecological footprint (IEA, 2022).

Therefore, the growing interest in an energy transition is of great importance today. In this regard, finding ways to reduce energy consumption represents a fundamental challenge for policymakers, and energy and environmental economists. To achieve this, they tend to improve the energy mix by increasing the share of renewable and alternative energies — this concerns the energy production side (energy supply) (Tajudeen, 2017). Moreover, on the energy demand side, and with the aim of addressing the consequences of the increasing energy needs (resulting from population growth and improved living standards driven by strong economic growth), specialists focus on regulating energy consumption (Hauet, 2014). The main goal is to reduce the amount of energy used without constraining economic growth. In this respect, to apply the precautionary principle judiciously, it is recommended to pay greater attention to energy efficiency.

Improving energy efficiency represents one of the key solutions in managing energy demand. It is widely recognized as one of the most preferred, accessible, cost-effective, and less costly options to address numerous issues related to energy and climate change (IEA, 2012, 2014; Mehmood Mirza et al., 2022). It is commonly defined as the reduction in the amount of energy actually used to produce an energy service or a certain level of output. Therefore, it is the element that should be optimized (Farla & Blok, 2000; Hauet, 2014; N. Liu, 2006; Tajudeen, 2017).

Thus, a decomposition analysis (IDA) of energy intensity in Algeria over the period 1990–2020 (Layadi N., Senouci B., 2022) was used to estimate trends and the true level of energy efficiency at the economy-wide scale, given that energy intensity, as a simple energy-to-GDP ratio (a rough measure of energy efficiency), is likely to be too simplistic. Consequently, energy intensity is not necessarily a good indicator of energy efficiency (Filippini & Hunt, 2011), since changes in energy intensity depend on several factors such as energy efficiency and the economic structure (IEA, 1995, 2007, 2009).

Their results showed that the deterioration of the real energy efficiency index presents considerable variation. Nevertheless, although this decomposition analysis of energy intensity provides the true level of energy efficiency, it does not explain the role of the fundamental factors underlying these variations that stimulate (or hinder) energy efficiency. Hence, the question arises: ***What are the determinants of these changes in energy efficiency in Algeria?***

We follow the researchers who used a two-step method. The first step, already carried out, consists of separating the effect of the economic structure from the effect of energy efficiency (efficiency index) through an index decomposition approach, thereby deriving what is often called by some authors the real, true, or sectoral energy efficiency, which represents the actual energy consumption per unit of economic output (Tajudeen, 2017), citing (Choi and Ang, 2003; Boyd and Roop, 2004; Inglesi-Lotz and Pouris, 2012; and Zhao et al., 2010). In the present study, we plan to carry out the second step using a regression analysis, which will consist of estimating the impact of the key factors influencing these changes in the previously estimated real energy efficiency index.

2. Literature Review

A strong upward trend in global energy consumption has been observed since the 1970s, along with an acceleration of greenhouse gas (GHG) emissions due to the continuous growth of the global economy, population increase, and the high energy demand (Hui, 2017). In this regard, several factors recognized as contributors influencing variations in energy consumption, and consequently in emissions, including energy efficiency, must be the subject of national policy measures by identifying and quantifying their impact. Therefore, monitoring developments and trends in energy efficiency at the economy-wide level has become a crucial component of energy strategies in many countries (B. W. Ang, 2006; Hui, 2017).

Energy intensity and the factors explaining its evolution, as well as the driving factors of energy efficiency, have attracted significant attention in the literature.

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Table 1. *Summary of some general observations from recent empirical studies on the decomposition of energy intensity and its main drivers.*

Author	Country and period	Methodology	Main findings
(Aljahdali & Elimam, 2020)	Saudi Arabia, 1971–2015	ARDL and a version of the Granger causality test	There is a negative effect of GDP and energy prices on EI, unlike other variables. The urban environment must be improved to enhance EE. The authors also emphasize the need to reduce pressure on fossil energy sources and invest in alternative energies.
(D. Zhang et al., 2016)	China, 2001–2010 (30 provinces)	Bayesian averaging approach	Fiscal expenditures plays an important role. Investment in fixed assets and infrastructure, as well as the economic structure, are robust and relatively significant factors that policies should focus on.
(Tachega et al., 2021)	14 oil-producing African countries, 2010–2017	Random effect model	Population and trade liberalization have a major impact on EE. Economic growthhas a positive and statistically significant effect. However, the economic structure and the capital–labor had an insignificant effect.
(Song & Zheng, 2012)	Provincial level in China, 1995–2009	Econometric panel data analysis	Rising income has a significant impact on improving EI, while the effect of energy prices is relatively limited. The study stresses the urgency of accelerating energy price reform to establish a market-oriented regulatory system to reduce EI.
(Jimenez & Mercado, 2014)	Latin American countries, 75-country , 1971–2010	Panel data regression techniques	Per capita income, oil prices, energy mix, and GDP growth are the main determinants of EI and EE during the analyzed period.
(Moshiri & Duah, 2016)	10 Canadian provinces, 1981–2008	Panel data estimation methods (PAM)	EI is lower in provinces with higher energy prices and investment. However, in provinces with faster population growth, higher average income, and a colder climate, EI is higher. Moreover, rising energy prices have driven economic structure away from energy-intensive activities. Investment and technological advances are the main economic forces that improve efficiency and reduce intensity.
(Wu, 2012)	China, 1997–2007 (27 regions)	Regression (PAM)	During 1997–2007, some regions recorded a significant decrease in EI, while others experienced moderate growth. Rising income leads to lower intensity, which is also sensitive to energy prices (in both the short and long term). There is also a nonlinear relationship between intensity and the capital–labor ratio, as well as with capital stock growth.

(Oseni, 2011)	16 OECD countries, 1975–2007	Dynamic panel analysis (ARDL)	In these countries, higher energy prices and incomes lead to a decrease in EI, while countries with faster population growth show higher intensity.
(Tajudeen, 2017)	32 OECD countries, 1980–2013	Static and dynamic panel modeling, considering possible asymmetric price effects	No significant evidence of asymmetric effects was found for total energy prices, but asymmetry exists for specific energy prices. Thus, using energy-specific prices is more appropriate. In both the short and long term, industrial value added and foreign direct investment have a positive effect on efficiency, while a greater economic openness enhances long-term efficiency. However, land area has a negative impact.
(Metcalf, 2008)	United States, 1970–2001	Econometric modeling: static and dynamic (PAM)	Increases in per capita income and energy prices have played a significant role in reducing EI through improvements in efficiency.
(Robaina et al., 2019)	Portugal, 1995–2015	BVAR model	An increase in energy prices reduces EI, while GDP also has a negative impact. In contrast, industrial value added has a positive effect.
(Nugraha, 2019)	Indonesia, 1984–2015	FMOLS	Economic growth leads to a decrease in EI, and energy prices also have a negative effect. Conversely, the energy mix exerts a positive effect, as does industrialization.
(Jain & Goswami, 2021a)	South Asian countries, 1990–2014	Panel regression model estimation	The following variables significantly influence and promote EE : rising energy prices, population density, and per capita income. Countries with abundant energy resources and higher renewable energy production tend to be less efficient in energy use.
(Tenaw, 2021)	Ethiopia, 1990–2017	ARDL, FMOLS, and DOLS	In the long term, real GDP per capita, higher share of modern renewable energies, and institutional quality have a negative effect on intensity. However, FDI stock and industrialization deteriorate efficiency.
(Samargandi, 2019)	OPEC countries, 1990–2016	ARDL	Trade openness plays the main role in reducing intensity in both the short and long term, while technological innovation remains insufficiently developed to significantly reduce energy intensity.
(Louafi & Bellara, 2019)	Algeria, 1970–2016	Econometric study	The need to advance EE policies based on the most effective determinants (increasing trade openness, encouraging foreign direct investment, promoting energy conservation policies, and shifting economic structure toward less energy-intensive sectors), due to the slow progress of energy intensity reduction.

Source: Prepared by the authors

As shown in the table above (Table 1), the factors affecting energy efficiency have been analyzed in various ways using different econometric methods. In this context, three groups of research can be distinguished:

A first group of analysts is based on the traditional measurement of energy efficiency at the macroeconomic level, using energy intensity as a proxy for energy efficiency (that is, the ratio of energy consumption to GDP) to study the impact of key factors on energy intensity. A reduction in the energy intensity indicator reflects an improvement in energy efficiency. In other words, if a causal factor has a negative effect on energy intensity, it is considered a driver of energy efficiency improvement. To this end, this group of authors, such as Adom & Kwakwa (2014), Aljahdali & Elimam (2020), and D. Zhang et al. (2016), employ various estimation methods such as FM-OLS, ARDL, and others.

In analyzing the drivers of energy efficiency, and considering the limitations of the energy intensity indicator as highlighted by the IEA and several authors, a second group of researchers adopts an innovative approach to address this gap and better analyze the drivers of energy efficiency. This involves going further in the analysis by introducing an additional step prior to econometric estimation.

A common practice, therefore, consists in combining two analytical methods (IDA and econometric estimation). In this framework, the authors decompose the variations in energy intensity into several predefined components, including the real change in energy efficiency. They then examine the drivers of these energy indices using regression techniques.

To this end, the researchers take into account several socio-economic and climatic explanatory variables that influence changes in energy efficiency. Which most often include: Energy prices (whose approximation differs across authors and countries, depending on the data available), Per capita income, Population growth, Trade openness, Climate variables, and the capital-labor ratio (Jimenez & Mercado, 2014; Löschel et al., 2015; Moshiri & Duah, 2016; Oseni, 2011; Song & Zheng, 2012; Tajudeen, 2017; Wu, 2012). In order to analyze their impacts on the studied index, which represents the dependent variable (the sectoral intensity index, in our case).

This has not prevented some authors from using both methods (a decomposition analysis and an econometric estimation) separately within the same study to obtain diverse results when analyzing the overall energy intensity of a country, for example, in the cases of Ethiopia (Tenaw, 2021), Portugal (Robaina et al., 2019), and Indonesia (Nugraha, 2019). Or across several countries such as South Asian nations (Jain & Goswami, 2021a).

3. Materials and Methods

3.1. Data and variables

Based on the literature review, we analyze the role of selected macroeconomic variables to explain the changes or variations in the dependent variable (the energy efficiency index (Eff)) in order to identify the key factors that significantly influence energy efficiency. Annual time-series data covering the period **1990–2019** were used for this study. The variables include energy price (P), GDP per capita (Incm), the capital-labor ratio (K/L), population (Pop), and a climate variable represented by average temperature (T).

- **Dependent variable:** The variable to be explained is the energy efficiency index (Eff). The decomposition analysis provided a time-series dataset, between 1990 and 2020, for the aggregate intensity index, the structural index, and the efficiency index (Eff) that represents the estimated level of energy efficiency at the national level (Layadi N., Senouci B.).

- **Explanatory variables:** The explanatory variables include energy price (P), GDP per capita (Incm), capital-labor ratio (K/L), population (Pop), and average temperature (T). As the objective is to examine the drivers of energy efficiency through a decomposition method, the reviewed literature indicates that these variables are generally considered as contributors to variations in energy efficiency.

Theoretical expectations regarding their relationship with the energy intensity index can be summarized as follows:

- **Energy Price (P):** Theoretically, higher energy prices should reduce energy intensity by encouraging more efficient energy use and a shift toward less energy-intensive sectors (structural adjustment), this will be achieved if the market operate properly, driven by reduced consumption (Moshiri & Duah, 2016; Song & Zheng, 2012). However, several studies (e.g., Song & Zheng, 2012; He & Wang, 2007) found weak or even positive relationships between energy prices and intensity, attributing this to limited price deregulation or low energy prices that fail to incentivize efficiency improvements.

In this study, the energy price proxy is calculated as a weighted average energy price combining electricity, gas, LPG, and fuel prices (2015 = 100).

- **Population (Pop):** The variable is included to capture the influence of changes in population growth on energy efficiency.

  In the context of demographic expansion, rapid population growth can have contradictory effects on energy efficiency. Two main perspectives are often highlighted in this regard.

On the one hand, faster population growth may generate economies of scale, leading to a more efficient use of energy resources. On the other hand, if infrastructure fails to keep pace with the growing population and its increasing needs, several problems may arise. For instance, traffic congestion—a typical outcome of population growth combined with insufficient infrastructure—can increase fossil fuel consumption per unit of distance traveled.

Therefore, the overall impact of population growth on energy intensity depends largely on the ability of infrastructure development to match the rising demands of a growing population (Jimenez & Mercado, 2014).

In the same line of thought, Metcalf (2008) emphasized that, compared to countries with slow population growth, those experiencing rapid demographic expansion are more likely to adopt energy-efficient infrastructure in order to optimize their energy consumption. However, these same countries may also exhibit lower energy efficiency if capital investments fail to keep pace with the rate of population growth.

Income (Incm): The level of energy efficiency and intensity may vary according to the degree of economic development. Consequently, the impact of income on the efficiency index remains a subject of empirical debate (Metcalf, 2008).

An increase in income may lead to the adoption of more energy-intensive lifestyles, resulting in higher energy demand and, consequently, greater energy intensity. Conversely, higher income levels can also make individuals more aware of environmental and resource depletion issues, encouraging them to adopt energy-saving technologies.

In this case, a positive correlation is expected between income and the degree of energy efficiency, leading to a reduction in energy intensity. Overall, since income is generally associated with the level of development, its effect on energy efficiency may depend on whether economic growth translates into greater energy consumption or enhanced technological efficiency.

- **Capital-Labor Ratio (K/L):** We include the capital–labor ratio as an explanatory variable in our model in order to account for the theoretical premise suggesting that capital and energy are likely to be substitutes in the production process, as emphasized by Thompson and Taylor (1995).
  Building on this theoretical insight, several authors have incorporated this variable to capture differences in capital intensity, which may influence overall energy intensity.

The relationship between energy intensity and the capital–labor ratio thus depends on the degree of complementarity or substitutability between capital and energy. This issue has long been the subject of academic debate, with empirical evidence supporting both perspectives (Song & Zheng, 2012).

When capital and energy act as complements, energy intensity is expected to increase, whereas in the case of substitution, energy intensity is likely to decrease.

- **Temperature (T**): The variable is introduced to control for the effect of climate on energy efficiency. It represents climatic data that account for variations in energy demand associated with cooling and heating needs (Metcalf, 2008).

We summarize the **definition and data sources** for the variables described above in the following table (Table 2)

Table 2. *Definitions and Sources of the Study Variables*

Variables	Definition	Source
Dependent Variable:		
Eff	Energy Efficiency Index (variation in energy intensity)	Table 1 of (Layadi N., Senouci B., 2022).
Independent Variables:		
P	Energy Price (at constant national currency 2015 DZA / Toe)	APRUE (National Agency for the Promotion and Rationalization of Energy Use).
Incm	GDP per capita (at constant prices in DZD, with 2015 as the base year)	Economic accounts published by the National Statistics Office (ONS) and the Ministry of Finance
K / L	Capital-Labor Ratio (K/L) in DZD *K in mil 2017 DZD, L in millions*	Penn World Table (PWT) Version 10.0

Pop	Algerian Population	ONS
Tmprtr	Annual Average Temperature for Algeria (°C)	World Bank – Climate Change Knowledge Portal

Source: Prepared by the authors.

3.2. Research methodology

The model of this research is developed based on relevant literature. It consists of a regression analysis of the estimated level of energy efficiency on several factors (economic and climatic) that influence its variation, following the studies of Basuki (2015), Bourbonnais (2021), Metcalf (2008), and Mirza & Nishat (2016):

The model is specified as follows:

$$Eff^{*} = a_0 + a_1 x_t + \mu$$

Eff^{*}Representing the desired value of efficiency for the year t.

The desired level of the dependent variable is a function of the set of explanatory variables suggested by the literature, included or grouped in the vector x_t.

Since the desired energy efficiency is not directly observable, we approximate it using the observed value (In other words, we do not have any measurement of $Eff*$; however, we have the observed values of Eff_t and can establish a relationship between them:

$$Eff_t - Eff_{t-1} = \partial\,(Eff^{*}_t - Eff_{t-1})$$

Where :

$0 < \partial < 1$ represents the adjustment coefficient or the adjustment speed toward the long-run equilibrium.

Thus, in order to reach a desired level of energy efficiency, the economy undergoes partial adjustments. The formulation of the partial-adjustment hypothesis, which operates between the desired value and the observed value, i.e., the adjustment process linking actual energy efficiency to its desired level, is represented by the relationship in the final equation.

By substitution, we obtain:

$$Eff_t = \partial\, a_0 + \partial\, a_1 x_t + (1-\partial) Eff_{t-1} + \partial\, \mu_t$$

Thus:

$$Eff_t = \beta_0 + \beta_1 x_t + \beta_2\, Eff_{t-1} + \Pi_t$$

With:

$$\partial\, a_0 = \beta_0\,,\ \partial\, a_1 = \beta_1\,,\ (1-\partial) = \beta_2$$

This last equation is called the PAM.

At this stage, we can estimate the parameters of the equation, the short-term effects of the independent variables on the dependent variable, through the coefficients of this equation. The long-term coefficients can then be obtained by taking into account the adjustment coefficient ∂.

The first equation assumes an instantaneous reaction of energy efficiency to changes in the explanatory variables. However, it is possible that these variables influence energy intensity, and therefore efficiency, with a certain delay, requiring some adjustment time. Consequently, and in accordance with the work developed by several authors, notably Metcalf (2008), this part of the research is based on a dynamic specification of time series data to analyze the impact of certain factors on one of the energy indices, namely the energy efficiency index.

This approach takes into account the necessary time adjustment for variations in efficiency, given that these indices may exhibit a slow response to changes in explanatory variables, by using a Partial Adjustment Model (PAM) and including the lagged dependent variable.

Thus, by including the lagged dependent variable, we are able to estimate both short-term and long-term elasticities or coefficients, as previously demonstrated.

In addition, the Partial Adjustment Model can be used in this situation whether the variables are stationary or non-stationary (Mirza & Bergland, 2012; Mirza & Nishat, 2016; Qin & Lu, 1998).

The regression model used is a PAM with a double-log specification, in order to obtain direct elasticity (percentage) estimates.

4. Results and Discussion

The table below presents the regression results of the efficiency index as a function of the variables described earlier.

For a clearer understanding of the results and their interpretation, it should be recalled that the dependent variable is the energy efficiency index based on the IDA. It is essential to emphasize that a decrease in the EE index is interpreted as an improvement. Therefore, a variable with a negative coefficient contributes to improving EE, and vice versa (Tajudeen, 2017). This efficiency index or efficiency component (also called pure energy intensity index, real efficiency index, or sectoral energy intensity effect) (Tenaw, 2021) refers to the variations in real intensity linked to changes in the efficiency of energy use; it is represented and calculated as the ratio of Energy consumed-GDP.

In the first column, a positive association is observed between the energy price and the efficiency index. A 1% increase in the energy price leads to a 0.109% increase in the pure intensity or efficiency index (i.e., a deterioration in energy efficiency), and this relationship is significant at the 5% level. Similarly, population growth shows a positive effect on the efficiency index, at a 1% significance level; a 1% increase in population implies a 2.0505% increase in energy inefficiencies.

On the other hand, there is a negative relationship between the per capita income variable and the efficiency index. A 1% increase in per capita income decreases the index by -0.864%, which leads to improvements in energy efficiency, at a 1% level of significance. Likewise, the negative coefficient of the capital-labor ratio reveals that energy and capital are substitutable; a 1% increase in the capital-labor ratio results in a 0.119% decrease in the index, and this coefficient is significant at the 5% significance level. However, we note that the efficiency index does not react to temperature variations in Algeria according to the results of the static model.

Table 3. *Regression results and short-term coefficients*

	Efficiency Index	
Variable	(1)	(2)
C	-21.59381*	-11.47471*

LOG(TMPRTR)	-0.603227	0.212888
LOG(PRICE_DZA_TEP)	0.109812**	0.056461
LOG(POP)	2.050536*	0.947074*
LOG(K_L_DZA)	-0.119925**	-0.074973***
LOG(INCOME_DZA)	-0.864881*	-0.383341**
Adjustment parameter	-	0. 382142*

Source: Prepared by the authors.

Remarks: Column 1 represents the coefficients of the static model, while Column 2 represents the results of the dynamic model.
*indicates a significance level of 1%
**indicates a significance level of 5%
*** indicates a significance level of 10%

The results in column 1 highlight that all variables in our efficiency index model are significant, except for the variable related to temperature. However, the price variable also becomes insignificant, in addition to the temperature variable, when considering the model whose resulting coefficients are shown in column 2 — developed within the framework of improving results using a dynamic model. The estimations in this column are based on the Partial Adjustment Model (PAM).

These results are considered more realistic than those of the static model because they take into account the fact that energy indices (the efficiency index in our case) do not react immediately to changes in economic and climatic variables. Thus, the estimated coefficients are relatively smaller in this model.

First, our estimations show the existence of a positive but weaker relationship than the previous one between energy prices and the efficiency index, but we do not have sufficient evidence to say that this relationship is statistically significant: the significance level is 14% (which is even higher than 10%). This surprising positive effect has been found by some authors in similar studies, as we have already noted. However, in the case of Algeria, this result was not expected from a theoretical standpoint. Economic theory generally suggests that increases in energy prices should enhance energy efficiency. In contrast, energy prices in Algeria remain low, strongly regulated, and subsidized (even below their actual costs).

This result means that the impact of energy prices does not significantly contribute to reducing energy intensity and highlights the insufficiency of the pricing system to stimulate energy efficiency. It may also indicate that energy prices remain too low given the massive demand.

This underscores the importance of deregulating prices or reforming the pricing system and steering the evolution of the energy sector toward a competitive market.

It is also observed that a 1% increase in population leads to a 0.9470% increase in the efficiency index at the same 1% significance level. According to theory, this result indicates that infrastructure development has not kept pace with population growth, thereby limiting its ability to meet the population's growing needs.

Meanwhile, at higher significance levels (10% and 5% respectively), the capital–labor ratio and per capita income continue to exhibit a negative relationship and a negative impact on the efficiency index. The estimation of the capital–labor ratio confirms that capital and energy are substitutes, thus improving energy efficiency by 0.074973 percentage points.

Furthermore, an increase in per capita income reduces the efficiency index by 0.383341 percentage points. The income effect leads to an improvement in energy efficiency. This result suggests that rising income encourages individuals to adopt energy-saving technologies.

Regarding temperature, no reaction of the index to temperature variations is observed, even at the 10% significance level.

Thus, the result of the regression equation (PAM) is as follows:

$$\log \log (Eff) = 0.212888 \log \log (tmprtr) + 0.056461 \log \log (P) + 0.947074 *\log \log (Pop) - 0.074973 ***\log \log \left(\frac{K}{L}\right) - 0.383341 **\log \log (incm) + 0.617858 * \log \log \big(eff(-1)\big) - 11.47471 *$$

The coefficients obtained from the previous PAM regression equation, as well as the conducted analysis, are dedicated to the estimation for the short-term period (ST). In contrast, the long-term (LT) coefficient is obtained by dividing the short-term coefficient by the adjustment coefficient as follows:

The long-term PAM model:

We have:

Long run coefficient = Short run coefficient / (∂)

Table 4. *Long-Term Estimates*

	Coefficient	
Variables	CT	LT
LOG(TMPRTR)	0,212888	0,5570913
LOG(PRICE_DZA_TEP)	0,056461	0,1477487
LOG(POP)	0,947074*	2,47833*
LOG(K_L_DZA)	-0,074973**	-0,196191**
LOG(INCOME_DZA)	-0,383341**	-1,003138**
LOG(EFF(-1))	0,617858*	
C	-11,47471*	-30,02735*
Adjustment coefficient		0,382142

Source: Calculated by the authors using EViews 12.

Thus, the equation with the long-term coefficients will be:

$$\log \log (Eff) = 0.5570913 \log \log (tmprtr) + 0.1477487 \log \log (P) + 2.47833 *\log \log (Pop) - 0.196191 ** \log \left(\frac{K}{L}\right) - 1.003138 **\log \log (incm) - 30.02735 *$$

Table 4 presents the short-term and long-term coefficients calculated from the partial adjustment model (PAM) regression, as discussed previously. The estimation shows that the impact of energy prices is positive, statistically insignificant, and very small compared to the other coefficients — with values of 0.05 % in the short term and 0.14 % in the long term.

Moreover, energy efficiency improves with the increase in per capita income and the capital-labor ratio, with coefficients of −0.383341 and −0.074973 in the short term, −1.003138 and −0.196191 in the long term, respectively. It should be noted *that*, after the energy price, the impact of the capital-labor ratio on efficiency remains relatively limited compared to the other coefficients in both the short and long term.

However, population growth contributes more significantly to the reduction of energy efficiency in the long term: a 1 % increase in population leads to a 0.94 % rise in the short term and a 2.47833 % rise in the long term of the energy intensity index.

Furthermore, the efficiency index remains insignificantly affected by variations in average temperature in the long term.

These results indicate that, considering a 5 % significance level, the effect of each variable intensifies over time (from the short to the long term). Thus, the most significant and negative effect is that of per capita income (from −0.38 in ST to −1.003 in LT), which can be considered the main factor driving improvements in energy efficiency in Algeria, followed by the capital-labor ratio, whose effect also becomes more pronounced in the long term (from −0.075 to −0.19).

Conversely, population growth deteriorates energy efficiency both in the short and long term, with a significant impact that rises from 0.95 to 2.48, thereby worsening national energy efficiency.

5. Conclusion

The real level of energy efficiency, determined from the decomposition of aggregate energy intensity (EI) in Algeria (Layadi N, Senouci B, 2022), shows considerable variation during the study period from 1990 to 2020. To better explain the trends and variations in the evolution of the efficiency index resulting from the decomposition analysis, we applied a regression analysis or a dynamic specification of time series data to analyze the determinants of energy efficiency using a Partial Adjustment Model (PAM). This approach allows us to account for the fact that the efficiency index may react slowly to changes in the explanatory variables and thus estimate both short-term and long-term impacts, by including the lagged dependent variable.

The model was used to study the fundamental underlying factors driving changes in energy efficiency, examining their impacts on its variation over the study period (1990–2019).

Based on the results previously presented and interpreted, and considering a 5% significance level, the effect of each variable intensifies over time (from the short term to the long term). Thus, we can observe that the impact of energy prices on energy efficiency is practically statistically insignificant, very weak, and positive. An increase in energy prices leads to a non-significant increase in the efficiency index (that is, a deterioration of energy efficiency). This is a surprising result, as it appears to contradict the theoretical expectation. Nevertheless, in Algeria, where energy prices are highly regulated and subsidized, an increase in prices does not lead to a significant improvement in energy efficiency. This finding suggests a limited and statistically insignificant impact of energy prices on energy efficiency and may indicate that the current pricing system is not sufficiently incentivizing to encourage the adoption of energy-efficient practices.

Similarly, temperature variations have no significant effect on energy efficiency. However, another positive and highly significant effect is observed: the impact of population growth on the efficiency index. This indicates that the infrastructure fails to keep up with the pace of population growth, leading to an increase in energy intensity, that is a deterioration in energy efficiency.

Conversely, we observe a negative and significant impact of the capital-labor ratio (whose effect is relatively small) and per capita income (whose effect is strong) on the efficiency index. This reveals that energy and capital are substitutable, and demonstrates that investments in energy-efficient technologies and the adoption of energy-saving practices can significantly improve the country's energy performance.

These results provide valuable insights for developing reliable policies aimed at improving energy efficiency. They suggest that higher economic growth could serve as a powerful driver encouraging the country to increase investments in energy-efficient technologies and improve its energy intensity profile. Moreover, these conclusions reinforce the notion of the ineffectiveness of the current pricing system in stimulating energy efficiency and promoting energy-conscious practices. They also highlight the need to adapt infrastructure capacity to keep pace with population growth, ensuring that the increasing demand and needs of the population can be met more efficiently.

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Author contributions

The author, Dr. Benabbou SENOUCI, worked on the literature review and contributed to the theoretical part of the research; the author, Dr. Nour El-Houda LAYADI, worked on the remaining parts and wrote this manuscript.

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Data availability

No datasets were generated or analyzed during the current study.

Declarations

Consent for publication

Yes.

Competing interests

The authors declare no competing interests.

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