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The Nexus among Energy Intensity, Energy Mix and Economic Performance in Europe: A Decomposition Analysis

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ABSTRACT

Using a versatile piecewise linear regression model, this study revisits the connection between energy intensity, energy mix, macroeconomic variables, and economic performance. The analysis determines a threshold effect of income growth on changes in energy intensity based on dynamic panel data for a collection of European economies from 1990 to 2020. The study builds on the three specifications: The Skelton model (M1), the human capital model (M2), and the policy model (M3). The Skelton model is a fundamental model that explains the energy economic relationship with energy use in many economic sectors and with various energies. Additionally, in M2, achieve basic and secondary education as human capital, investment, and commerce as models for policies (M3). Numerous diagnostic procedures are carried out to examine serial correlation, heteroscacity, and cross-sectional dependence. In order to evaluate the robustness of the results, the specification of the dynamic panel is put through the Generalized Method of Movement (GMM) regression framework. Although energy intensity and income growth are negatively correlated for the entire sample and study period, the rate of decline significantly slows after the level of per capita income reaches $5,000, by more than 30%. According to the analysis's findings based on index decomposition, structural change is crucial for intensity levels across all nations. Additionally, moving from fossil fuels to renewable energy sources has a positive correlation with economic success in terms of energy intensity. While increasing energy intensity spurs global growth because of the current state of environmentally friendly technological innovation.

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1. Introduction

The economic energy intensity of a country is defined as the ratio stuck between energy intake and gross domestic product (GDP), and it is frequently used as a measure of economic success and applied to sustainability studies. Energy intensity is a component of energy usage since energy use and economic output are positively associated, yet energy intensity has decreased over time.

Although, in general, the energy intensity of prosperous countries is lower than that of underdeveloped nations. A number of factors influence the economy's energy intensity, while energy efficiency is the most important component of economic growth. Due to the rebound effect, gains in energy efficiency will be reduced, while energy efficiency is the utmost imperative component of economic progress. The intensity of energy was possibly limited. According to natural science, energy is essential to economic development, although some ecological economists and economic historians disagree that energy availability is the primary engine of expansion.

However, the majority of orthodox economic and social development theories, according to prior literature, underestimate the effect of energy in the production process. These estimates likely evolve over time due to the scarcity of energy resources in the past, which placed limitations on growth. On the other hand, the increased accessibility of contemporary energy sources has diminished the significance of energy (as a driver of growth). It's questionable whether empirical studies clearly elaborate that energy causes growth or vice-versa.

Several authors have highlighted the significance of examining the association among energy and economic progression, even though production function stresses the importance of capital-energy complementarity. Atkeson and Kehoe (1999), as well as Dıaz, Puch, and Guilló (2004), present their work to demonstrate the consequences of short-term capital and energy substitution, as well as the impact on production. In spite of fact that their findings provide theoretical provision that large variances in energy costs among states neither indicate a significant fissure in macroeconomic performance, it’s all because there is a reason that production technology represents frequencies that, the investment in innovative efficient energy units adjusts to energy price shocks. Nonetheless, the growth models of Schumpeterian support a capital replacement mechanism to reunite long-run growth with massive fluctuations in energy prices, as presented in slog by Ferraro and Peretto (2018).

According to the most recent work of Díaz and Puch (2018) fused technological progress in various aggregate models, make their differences by means of imperfect substitution among energy and capital. As a result, our primary goal is to assess the robustness that fluctuations in energy intensity, as well as variations in share of the energies, may affect economic growth or performance.

From previous empirical literature, it can be observed that energy intensity and economic performance are intern link to each other and having impacting values to each other. These variables are co-related to each other. It’s also worth noticing that economic growth is a widely used indicator of economic performance, and the economic growth variable is measured as gross domestic product (GDP). The analysis is also restricted to the effects of the energy mix (as energy sources are renewable and non-renewable) on countries’ economies.

In this study focused study area is Europe. The European Union's real GDP growth rate at averaged 1.57 percent from 1996 to 2021, with a high of 13.80 percent in the 2020.Based on purchasing power parity, in 2019, the European Union's share of world gross domestic product was predicted to be 15.4%. In 2019, the EU's GDP was 13.97 trillion euros.

Energy consumption in Europe is lower than it was ten years ago, attributable to improvements in energy efficiency. Due to energy savings and a faster-than-expected adoption of renewable energy, Europe is also relying less on fossil fuels. Renewable energy usage in the EU nearly doubled between 2005 and 2015, from 9% to nearly 17%. Some industries and governments are pioneering the transition to renewable energy.

However, despite their diminishing market share, fossil fuels remain Europe's primary energy source. But to improvements in energy efficiency due to energy savings and a faster-than-expected adoption of renewable energy, Europe is also relying less on fossil fuels. Renewable energy usage in the EU nearly doubled between 2005 and 2015, from 9% to nearly 17%. Some industries and governments are pioneering the transition to renewable energy. However, despite their diminishing market share, fossil fuels remain Europe's primary energy source.

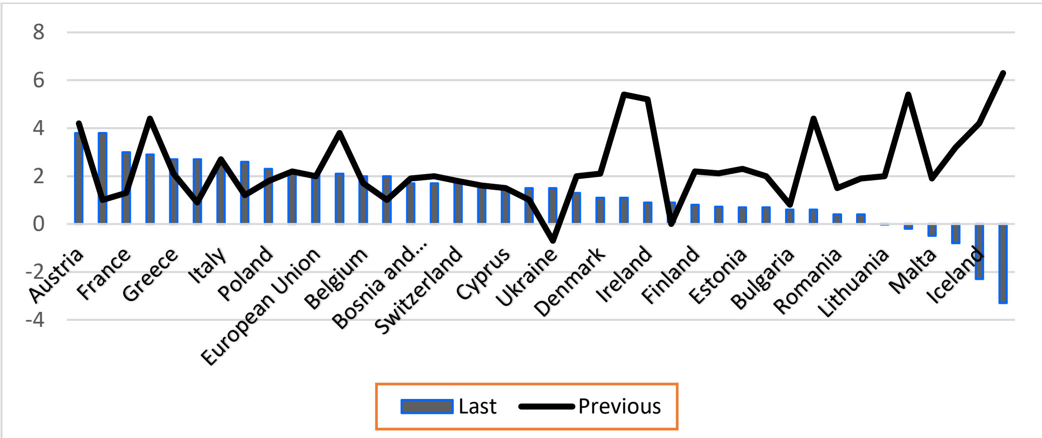

Figure 1: GDP Growth Rate by Country in Europe
Source: Self-generated

Here explain the descriptive values of concerned study area to support further empirical findings. Countries with negative growth rates in our data set include Lithuania (-0.03%), Croatia (-0.2%), Malta (-0.5%), and Iceland (-2.3), as well as countries with highly positive growth rates such as Norway, and Austria (3.8%). As explained in figure1, the figure shows the GDP growth rate for a list of countries in Europe. These values indicate that GDP growth have fluctuated rate in Europe.

Further the average energy intensity is currently shrinking in almost all European Union member countries and countries like Ireland (4.5%) and Malta (-4.9%). It's all responsible of alterations in their economic structures. Average rate of EI also decreased in countries in eastern and central European regions, like Slovakia, Romania, and Lithuania. But statistics show that after the period of 2014, gross energy intake is again beginning toward upsurge and improvements in energy intensity are experiencing a slowdown (EEA,2021).

These descriptive statistics are explained by Figure 2. These specific reasons are improvements in energy efficiency, moving toward conventional and frontier energy sources (as using energy from wind, hydro, photovoltaic (PV) power) and solar, and focusing on climate change conditions and the economic recession.

At aggregate level the primary energy share in EU, the available energy mix range 70% of the production of energy accounts from fossil fuel[1] sources as petroleum products including crude oil is 36%, and the 22% share of natural gas, 15% of renewable sources, nuclear and fossil fuels both 13%. Share of energy mix in different sources is given in figure 3. This explain that share renewables in energy mix is increasing but still petroleum product is at highest rate in Europe.

[1] A fossil fuel containing hydrocarbon material. These resources are created from past underground dead plants and animals and after a long time period that utilizes by people as energy sources. Mainly most common fossil fuels are Coal, petroleum, and natural gas.

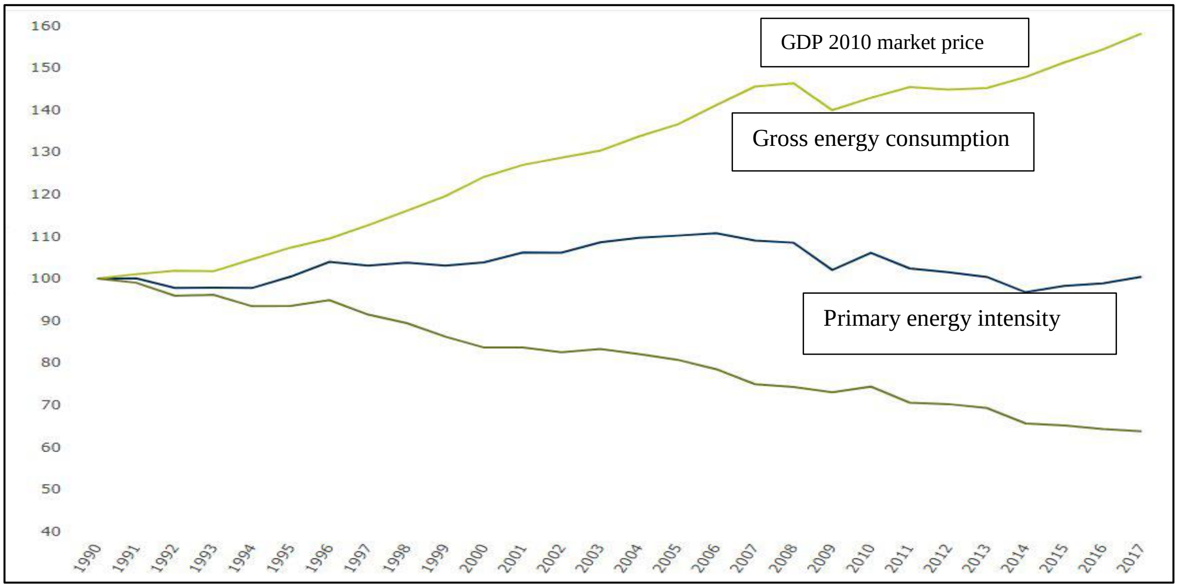

Figure 2: Energy Intensity, Gross Domestic Product, and Gross Inland Energy Consumption trends
Source: Eurostat/statistics

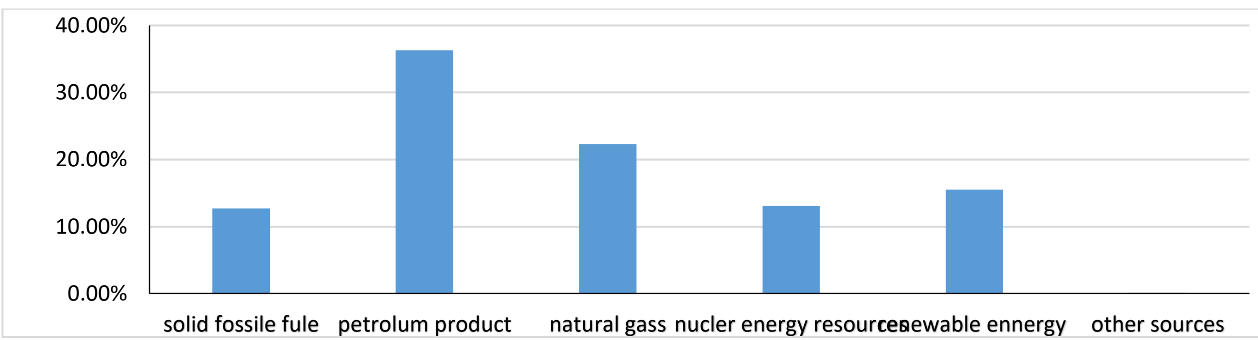

Figure 3: Average Energy mix for the European countries
Source: Self-generated

While sectoral share with respect to energy consumption varies sector to sector as transport sector at their higher level. Second is industrial sector and then leading this consumption rate is household sector. This sectoral consumption of energy total based on tones oil in EUR is presented in figure 4.

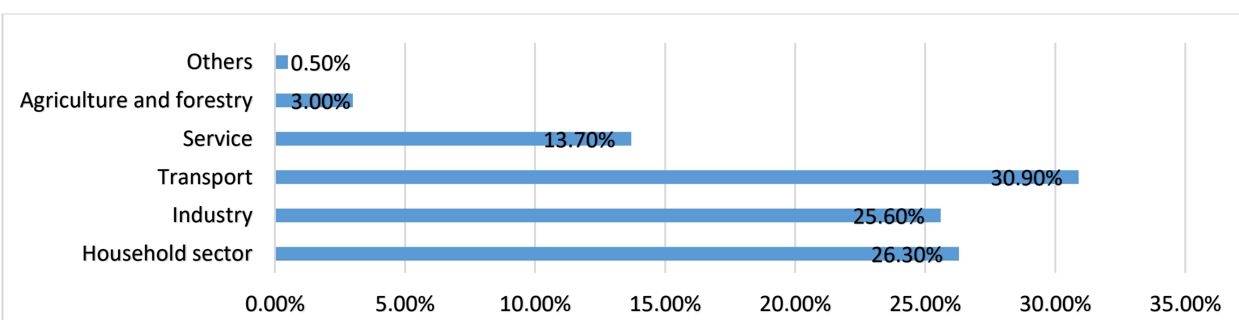

Figure 4: Final energy consumption by sector, EUR 2019 % of total based on tones oil equivalent
Source: Self-generated

Therefore, our primary goal is to assess the vigor that how deviation in energy intensity, along with alterations in the share of energies (as renewable and non-renewable) can distress performance of economy. The further determination would be to ascertain whether these energy features are strategic elements to boost economic performance. Furthermore, an integrated and comprehensive logical inference from the reviewed studies is that there is no clear evidence in the literature indicating the direction or existence of causation among intensity level of energy and economic performance.

This study adds to earlier research in various ways. The analysis in this study is based on larger data sets. Second, the study employs a multivariate framework in the analytical section. This research seeks to isolate energy growth relationships with various energy mixes across different areas and time patterns. The current panel methodologies used in this work allow for cross-sectional dependence and heterogeneous unobserved factors. This research also included a set of control variables relating to socioeconomic situations, institutions, policies, and human and physical capital. The following outline will be used to establish the rest of this paper: Section 2 serves as a review of the literature. Section 3 describes the theoretical approach, whereas Section 4 describes the empirical model and data used in this study. Section 5 contains the completed results and discussion. In last section 6 is constravted as conclusion.

2. Literature Review

For several reasons in today’s world energy is the most imperative issue of economies because of several reasons. For different economic activities and human deeds energy plays an important role and act as a scale of social and economic development. For that reason, energy consumption per capita of a country is considered as an essential indicator of economic development. Now a day, energy is not even use as an input of production but it’s a strategic commodity for international relations between the economies. So energy set up as one of the main indicators of basic economic variables. Although in the absence of energy, it seems impossible to do production process for goods and services and offer these produce valuables to consumer (IAEA, 2009).

The International Energy Agency (IEA) (2009) reports that, the first time since 1981 the over-all energy usage is probable to drop pointedly. Yet, once economic recovery gathers pace. The energy demand would be up trend. From 1971 to 2015, for production deeds the worldwide energy demand had increased 150%.

According to Liddle (2010) indicator of energy intensity are different in different regions and countries. There are four main factors that explain nature of energy intensity (EI) in different economies is different. Firstly, it can be different because of economic structure (total share of energy intensive industries), secondly, use of energy in many segment or sectoral of economy. (shares of energy for different means of uses like transport, buildings and transport), third, efficiency in the end-use energy conversion and fuel mix. For making distinction between the non-goods imported and goods imported economies the study of efficient energy intensity (EEI) would require that help analysis to elaborate more. The empirical evidence is varied across different countries because of country’s energy efficiency polices, uses of energy resources, energy consumption patterns and research and development path of country. So empirical results are different in different regions as is unidirectional, bi-directional causality to no causality. In ongoing literature discussion on relation between energy consumption and economic growth have prodigious importance.

Emir and Bekun (2019), given the contradictory data in the literature between 1990 and 2014 on a quarterly basis, this study empirically investigates the link among energy intensity, carbon emissions, renewable energy consumption, and economic growth for the instance of Romania. To do this, this study uses the Toda-Yamamoto model to determine direction of causality while cointegration is accomplished using an autoregressive distributive lag (ARDL) model. The variables under study exhibit cointegration, according to empirical evidence. According to the results of the causality analysis, there is a feedback relationship between energy intensity and economic growth, however there is a one-way relationship between economic growth and the consumption of renewable energy. The energy-led growth hypothesis is therefore supported by this study. Our research supports the present success story of Romania achieving its energy goals in less than 20 years. However, she must continue to diversify her energy sources by adding to her portfolio in order to keep this milestone.

Mahmood and Ahmad (2018) in their study, the effect of economic expansion on energy intensity in European nations is examined. The study excludes the effects of technical changes in the usage of energy as reflected by trend while assessing the energy-growth link since energy intensity may decrease with economic expansion due to technical advances accompanying growth. It is asserted that the inverse link need not be explained by a decreasing trend in energy intensity. Even when economic growth is de-trended, the empirical study demonstrates that energy intensity is greatly lowered in reaction to it. The influence of economic expansion on energy intensity in European countries is investigated in this study. While assessing the energy-growth link, the study ignores the effects of technical changes in energy usage as reflected by trend, because energy intensity may decrease with economic expansion due to technological advances accompanying growth. It is claimed that the inverse relationship does not have to be explained by a declining trend in energy intensity. Even though economic growth is de-trended, the empirical analysis shows that energy intensity falls dramatically in response to it.

Díaz, Marrero, Puch, and Rodríguez (2019) investigates how changes in energy intensity and a shift to renewable energy can increase economic growth. To accomplish this, we employ a dynamic panel data technique on a sample of 134 nations from 1960 to 2010. Here include a set of control variables from the literature on economic growth that are connected to human and physical capital, socioeconomic conditions, policies, and institutions. Given the current state of technology, increasing energy intensity boosts global growth. Moving from fossil energy to emerging renewables (wind, solar, wave, or geothermic) is likewise favorably connected with growth, depending on energy intensity. Findings are robust to the dynamic panel specification in comparison to alternative methodologies (pooled OLS, within group or system GMM) and specific requirements (accounting for heterogeneity across countries, a set of institutional factors, and other technical aspects).

Stern, Common, and Barbier (1994) for the duration of 1947 to 1990, in US found association among energy and GDP. A multivariate adaptation of the test-vector auto regression (VAR) does permit to test causality. A VAR is estimated for causal relations amongst the variables as GDP, energy use, employment and capital stock and Granger tests are approved. The findings go on to say that there is no evidence that Granger's gross energy use causes GDP.

Iwata, Okada, and Samreth (2011) used panel data from 28 countries and factored in nuclear energy to find evidence in support of the EKC hypothesis. Using the pooled mean group (PMG) estimation method, they found that nuclear energy has a significant negative impact on CO_2 emissions and that there is insufficient evidence to support the EKC hypothesis.

Zeb, Salar, Awan, Zaman, and Shahbaz (2014) used annual data from 1980 to 2008 to examine the association between income and energy use in Romania. The results show the direct relation among real output and energy use in Romania. The study also discovered a positively strong correlation among CO_2 emission and the non-renewable energy consumption.

Lee and Chang (2008) during the 1971–2002 duration establish a long-run causality amongst energy use to economic development in 16 Asian economies. To investigate the causal relationship between these variables panel-based error correction, heterogeneous panel cointegration and panel unit root were used and to includes capital stock and labor input applied a multivariate framework. Results formulate that with heterogeneous country effect there is positive cointegarted relationship among GDP and energy use and find out long run unidirectional causality between both of them. It means that in short run with increase in energy consumption does affect but it would in long run.

Mahmood and Ahmad (2018) described the relationship among energy intensity and economic development. In European countries due to technological changings complementary growth the energy intensity may decreases with economic growth take pace. while analyzing the energy-growth relationship in use of energy this study eradicates the possessions of technical changes and took by trend while analyzing. The observed study indicates that in response to economic growth the energy intensity is significantly reduced even while the former is de-trended. Among economic development and intensity of energy this inverse relation is also proved in previous studies although in the energy-intensity series sluggishness is controlled from side to side taxes in environment, energy consumption and transport.

Bataille, Jaccard, Nyboer, and Rivers (2006) The term "energy efficiency" refers to the well-organized consumption of obtainable energy. It can be defined as the use of primary inputs or valuable and scarce resources in economic activities in a given technology to achieve maximum utility. In a nutshell, energy efficiency refers to getting the most value out of the energy utilised in production or consumption. In this context, energy efficiency refers not only to the process of consuming the required energy, but also to the process of putting energy to its end use with minimal loss and maximum efficiency over a lengthy period of time that encompasses both the distribution and production stages. It is important to note that an energy resource produced in the quickest and cheapest manner feasible without incurring large investment expenses is an energy resource that is used efficiently. The energy's efficient use in the consumption, distribution, and production phases allows for the same amount of work to be done with less energy while maintaining the same level of welfare and production quality and quantity. Thus, the innovative ways that results in the reduction of per unit value added energy input, GDP per unit, or for a new growth that saves energy ensure that current resources of energy are consumed properly in both consumption and production.

Energy consumption per output (level of energy intensity) may reduce during in consumption or production process, when in any economy universal technological take place and new technologies' consumption took place through financial development, these conditions are cross ponding to close association to the efficiency of energy. To measure the efficiency of energy in an economy through technological change, the autonomous energy efficiency index (AEEI) is used. This index tracks technical advancements that lower energy consumption per unit of output while remaining unaffected by price fluctuations in the economy Bataille et al. (2006).

Saunders (1992) explore the efficient use of energy assets rather than decrease energy consumption and should encourage the energy conservation policies and his result would quarry conservation in contrast to environmental goals. In fact, prices of energy goods that required energy in production process (when energy consumption variable is taken as constant) can decreases because of energy efficiency. Gains from energy efficiency can upsurge energy use and directly increasing the economic growth rate. Therefore, the use of energy efficient gains can boost energy demand in the other production factors as capital and labors.

Fiorito (2013) indicator of energy intensity is based on ratio of energy consumption and gross domestic product of country, this indicator has its strong importance because it widely used to measure economic performance of any country. From the period of 1960 and 2010 of 133 countries' EEI or economic energy intensity was examined, this research takes a look at the debate about the utility of the EI indicator and challenges it. In this study for appropriate results with 3 clusters of countries that have same EEI values and having GDP less then <5000 US$. Results indicates that values of EEI similar with selected condition and cluster of economies energy intensity values vary with miscellaneous socio-economic characteristics. It means that at national level EEI does not use for dematerialization.

Mulder and de Groot (2011) find that energy intensity developments through 18 OECD countries and 50 economies sectors, findings explain that in most manufacturing sectors across the countries reductions in energy intensity have driven. The aggregate energy intensity dynamics will increase with variations in the sectoral composition of economy. More by within-sector Structural changes explain a considerable and increasing part of aggregate energy intensity dynamics.

Stern (2000) explore the relationship between different flows of energy and economy involves aggregation. Here review the methods for aggregating energy flows and for aggregation, economic approaches using prices or marginal product. Analysis suggest that economic aggregation with marginal products are superior with respect to energy use because quality of fuels. According to the economic history, in national income, the services sector's share expanded resulting the increase in sector's energy use; however, when expansion rate is less than the GDP growth rate, overall energy intensity of the sector reduces.

Wang (2013) identifies the sources that took change in level of energy intensity all over the world. Data from 1980 to 2010 was used. Problem of Spatial and temporal heterogeneity existed in data. There are five components that have attribute to change in energy intensity across the country. These are specifically as labor–energy ratio second capital–energy ratio, third is technological catch-up, fourth is technological progress and fifth is changes in output structure. Results suggest that decline in energy intensity is contribution of changing in technological progress, capital accumulation and output structure.

Chen, Zhou, Wang, and Li (2018) in recent years, many scholars take attention on relationship between PM2.5 concentrations and socioeconomic development. To analysis this relationship socio economic variables (energy consumption, energy intensity, economic growth, and urbanization) consider as explanatory variables with different level of income in selected countries. Globally countries are paneled in four categories according to different income levels. For econometric estimation balanced panel data was used. Between the selected variables and PM2.5 concentrations presence of cointegration was experience. Results of estimated Vector Error-Correction Model in long run all selected socioeconomic variables increased PM2.5 concentrations. Economic growth is more concerned variable that increase in PM2.5 concentrations but improvement and reduction in energy intensity will decrease it.

Mallick (2009) had used annual data from India during 1970 and 2005 and applied granger causality test to investigate the link between energy consumption and economic growth. Economic development fuels crude oil demand and electricity use, whereas higher coal use fuels economic growth according to the findings. However, VAR results up indicating that power consumption and growth may have two-way relationship.

Overall, the review of the above-mentioned studies revealed that there is a clear and important relationship between economic performance and energy intensity. These relations are investigated with different estimation techniques and methodology patterns with different data sets. But still, there is a need to do more investigation to find this relationship in the border sense.

As a byproduct, the current study adds to literature, through classifying the effects of energy intensity, diverse of energy sources, and sector-based energy consumption on gross domestic product (GDP) in European countries. This study anticipates some essential diagnostic procedures containing cross-sectional dependency and heterogeneity, which will avoid misrepresentative implication and unreliable estimation of selected models.

3. Theoretical Farm Work

Linking economic performance with energy intensity and differentiating the influence of energy mix (renewable vs. nonrenewable) on the economic growth process. This theoretical framework will lend support to the empirical model of concord variables. Here we specified the general aggregate production function and used energy consumption as an explicit factor in the production function. Across countries and for differences in energy technologies, these specifications include two major elements. First in the sprite of Aghion, Caroli, and Garcia-Penalosa (1999) as "learning by doing spillovers" that fused as lagged values of output. Second, in production technology, imperfect substitutes of energy sources of type j are aggregated as a single energy input.

For this group of economists, the revelation of economics was grounded in "neo-liberal policies" and had a specified goal of maximisation of welfare that was recognized with greater opportunities for consumption offered to the largest number of people. The neoclassical theory of growth or development reflects the rise of production, consumption (at higher levels of disposable consumption) and technological advances as means to reduce poverty and promote development and progress. According to them, technological advancement is able to enhance the capacity of capital and shrink the constraints rising from the possible scarcity of resources that lead to sustainable growth. A number of economic theories are expressed in this school of thought, but a few of them that are most concerned with research topics are presented here. Finally, under the framework of the Cobb-Douglas production system, this unit of concerned research work sightsees the theoretical attributes to signify the association among disaggregated energy intensity and Economic performance with special effect of different sector-based configurations of the economy and energy mix.

4. Methodological Approach

Here, it is assumed that the aggregate output of the economy Y_{it} that is produced by several resources, namely, labor, capital, and energy usage

$$Y_{it}=Z_{it}\, B^{\theta}{}_{it} \quad (1)$$

$$Z_t = \left[\gamma_1 e_{1,t}^{\rho} + \gamma_2 e_{2,t}^{\rho} + \gamma_3 e_{3,t}^{\rho}\right]^{1/\rho} \quad (2)$$

Z_{it} is for all the inputs of energy in technology, and B_{it} is all the input resource, and $0<\theta<1$, $e_j{}^3{}_{j=1}$ different primary sources, $\gamma_j{}^3{}_{j=1}$ is produtivity productivity from different energy resources. ρ is rate of substitution to energy possessions is 1 / 1_ ρ. E_{it} is energy intensity, which is characterized as the primary energy demand**.** Here (j = 1) for renewable energy resources, (j = 2) for nuclear energy resources, and here (j = 3) for all types of fossil fuel energy consumption.

$$Yt = A\ K_t{}^{\alpha}\ L_t{}^{\beta}\ \mathrm{R}^{\gamma}{}_t\, \mathrm{N}^{\gamma}{}_t \quad (3)$$

R and N are represented by renewable and non-renewable (as briefly constructed in equation 5.3[2]). A set of macroeconomics variables (as control variables) that are based on human, capital and socio-economic order are incorporated which extensively used in literature. So, in terms of above-expressed energy shares and technological values the production function will be rewritten as:

$$Y_t = \exp\left\{\frac{b_0}{1-\theta}\right\} \cdot Y_{t-1}^{\frac{\delta}{1-\theta}} \cdot EI_t^{\frac{\theta-\pi}{1-\theta}} \cdot \bar{B}_t^{\frac{1}{1-\theta}} \cdot \left[\gamma_1\ {}_0 s_{1,t}^{\rho} + \gamma_2 s_{2,t}^{\rho} + \gamma\ {}_3 s_{3,t}^{\rho}\right]^{\frac{\theta}{(1-\theta)\rho}} \quad (4)$$

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[2] $Y_{it}=Z_{it}\, B^{\theta}{}_{it}$

y $_{t-1}$ as lagged values so that power will be $\delta/(1-\theta)$.

Although the signs of change in energy share $\frac{\partial y_t}{\partial s_{1,t}}$, $\frac{\partial y_t}{\partial s_{2,t}}$ is be influenced by signs of $\gamma_{0_1}s_{1,t}^{\rho}, \gamma_{0_2}s_{2,t}^{\rho}, \gamma_{0_3}s_{3,t}^{\rho}$(energy sources). According to Diaz and Puch (2018).

General derivation expression is given below:

$$\frac{\partial Y_t}{\partial s_{j,t}} = \frac{\theta Y_t}{(1-\theta)} \frac{\left(\gamma_j s_{j,t}^{\rho-1} - \gamma_3 s_{3,t}^{\rho-1}\right)}{\left[\gamma_1 s_{1,t}^{\rho} + \gamma_2 s_{2,t}^{\rho} + \gamma_3 s_{3,t}^{\rho}\right]} \gtrless 0 \tag{5}$$

Assuming $\rho = 1$ (i.e. perfect substitutes), these condition apply for simplicity

$$\frac{\partial y_t}{\partial s_{j,t}} = \frac{\theta Y_t}{(1-\theta)} \frac{\left(\gamma_{0_j} - \gamma_{0_3}\right)}{\left[\gamma_{0_1} s_{1,t} + \gamma_{0_2} s_{2,t} + \gamma_{0_3} s_{3,t}\right]} \gtrless 0 \tag{6}$$

In our mathematical explanation the sing of derivation will depends on $\gamma_{0_1} - \gamma_{0_3}$ and $\gamma_{0_2} - \gamma_{0_3}$. So, final appearance is generated as:

$$GY_{i,t} = \alpha + R_i + \beta \ln\left(Y_{i,t-1}\right) + \theta' XE_{i,t} + \boldsymbol{\lambda}' X_{i,t} + \varepsilon_{i,t} \tag{7}$$

Here $GY_{i,t}$ is used as depended variable for economic performance and is measure as GDPG in entire selected period, for countries "i" and "t" for years. Furthermore, R_i is for across country effects and T_t is for time. In addition, in beginning of the period taken GDP per capita taken at log $\left(Y_{i,t-1}\right)$ to avoid the initial conditional convergence and technology. In (5), this $\left(Y_{i,t-1}\right)$ expression is clarification of the Dynamic panel model, and R$_i$ is for regional specifications. The term $\theta' XE_{i,t}$is used as a set of energy variables. Primary energy mix (explained briefly in descriptive part of this chapter) and in different sector final consumption of energy. So $\theta' XE_{i,t}$ it is expressed,

$$\theta' XE_{i,t} \equiv \theta_0 \Delta EI_{i,t} + \sum_{j=1}^{J-1} \theta_j^m \Delta m_{j,i,t} + \sum_{k=1}^{K-1} \theta_k^s \Delta s_{k,i,t} \tag{8}$$

In above equation three terms are articulated as $\Delta EI_{i,t}, \Delta m_{j,i,t}, \Delta s_{k,i,t}$. $\Delta EI_{i,t}$ is for annual growth rate of energy intensity. Second, $\Delta m_{j,i,t}$ for annual change in energy consumption from different sources. Last $\Delta s_{k,i,t}$ *is* for annual sector's share of gross final energy consumption k. In (5) term $X_{i,t}$ as set of control variables as investment, inflation and trade opens. As a result, the energy variables in (6) are added to the framework in the following way: With this in-sequence strategy in mind, this study identified three modifications, labelled "as M_1, M_2 and M_3. To estimate energy and economic performance relationship, three specifications is establishing as M1, M2 and M3. These models represent as the Skelton model (M_1), the human capital model (M_2), and the policy model (M_3). For description of the variables in each selected models the functional as well as econometric forms of these models are presented given below.

M1 presented as Skelton model;

Economic performance= *f* (Energy intensity, Energy mix, Sectoral energy consumption)

$$GY_{i,t1} = \alpha + \Delta EI_{i,1} + \beta RE_i + \lambda NR_i \quad + \theta' SE_{i,1} + \varepsilon_{i,1} \tag{9}$$

M2 presented as human capital model;

Economic performance= *f* (Energy intensity, Energy mix, Sectoral energy consumption, Attain education)

$$GY_{i,t2} = \alpha + \Delta EI_{i,1} + \beta RE_i + \lambda NR_i + \theta' SE_{i,1} + \gamma AED_{i,2} + +\gamma X_{i,1} + \varepsilon_{i,2} \quad (10)$$

M3 presented as policy model;

Economic performance= *f* (Energy intensity, Energy mix, Sectoral energy consumption, population, inflation, trade)

$$GY_{i,t3} = \alpha + \Delta EI_{i,1} + \beta RE_i + \lambda NR_i + \theta' SE_{i,1} + \gamma \mathrm{Tr}_{i,3} + \gamma IN_{i,3} + \gamma P_{i,3} + \varepsilon_{i,3} \quad (11)$$

In above mention expressions GY as economic growth with proxy of GDP growth, RE and NR renewable and non-renewable energy are proxy of energy mix, SE sectoral energy consumption as agriculture, industrial and service sector, X is here as investment variable. AED is variable of attain education as primary and secondary education, Tr is trade, IN is inflation and P is population variable from policy model. To start up the indication, here take data of 37 European countries (EUR) of related variables because of avability of data. Our data sheet is unbalanced data sheet covering years from 1990-2020. Data of Primary energy variables are reclaimed from data source of International Energy Agency (2020), and other additional control variables, such as education levels, investment prices, inflation, trade openness and rate of population are retrieved from World Bank, specifically from section of world development indicators. As dynamic panel data is used so, from different technique of dynamic panel data most robust technique which is applying system GMM because it simultaneously estimates in difference and levels as compared to other dynamic panel data techniques.

5. Result and Discussion

Further, explicate the relationship between energy intensity (EI) and economic performance (EP), here use different categories of energy measures such as primary energy consumption[3], renewable[4] and nonrenewable energy inputs, and also extricate sector[5] wise final energy consumption descriptive statistics.

Table 1
Describtive Statistics

Variable	Unit	Mean	Std.
GDP per capita (trendy real terms)	Level, us-20010 $/ (person x 1000)	19.6 1.54	22.3 2.37
GDP per capita (trendy real terms)	Growth rate (%)	2.123	143.3
Intensity of Energy	TOE (primary) per 1M us$		
Proportion of fossils fuels	In contrast to primary energy, this equates to %.	70.1	28.5
Shares that are renewable	In contrast to primary energy, this equates to %.	27.3	30.5
Nuclear contribution	In contrast to primary energy, this equates to %.	1.6	4.8
Agriculture's portion	% based on the average amount of energy	3.0	4.2
Indusstrial's portion	% based on the average amount of energy	26.2	12.6
Share of transportation	% based on the average amount of energy	30.3	11.3
Share of the residence	% based on the average amount of energy	32.5	21.2
Share of Services	% based on the average amount of energy	26.2	12.6
Other sectors contribute	% based on the average amount of energy	1.2	6.5
Sample size		1023	

Source: Author generated

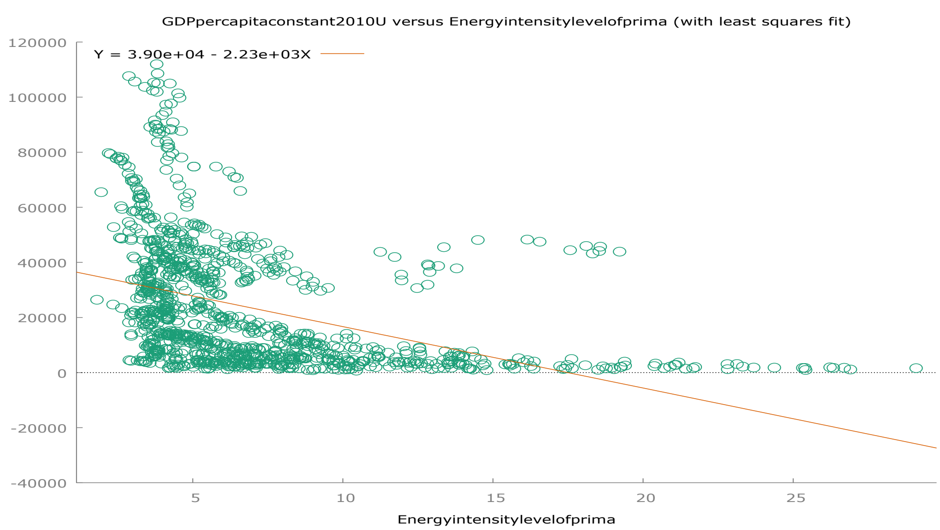
[3] Term Primary energy consumption; It is measured as (TOEs) in tons of oil equivalent of primary energy consumption.
[4] Renewable energy includes hydro and biomass energy (referred to as "conventional renewables"), as well as wind, solar, geothermal, and wave energy (referred to as "frontier renewables").
[5] final energy consumption sectors: Agriculture, industry, transportation, residential, commerce, and other services are all examples of industries.

In table 1, analysis of descriptive statistics for mean and measure of dispersion of sample of 1023 observations that restricted to GDP as EP proxy, energy variables, and along with control variables (related to human, physical capital, and socio-economic conditions) is elaborated and outcomes indicate that dispersion around the mean is as high as the standard deviation, at $22,342 because in data sample countries like Switzerland, Luxemburg and on the other hand Bosnia and Ukraine having huge deviation in their GDP so these deviations between the counties in concerned sample indicate the reason of dispersion around the mean in GDP per capita is huge (see figure 1 in introduction secession).

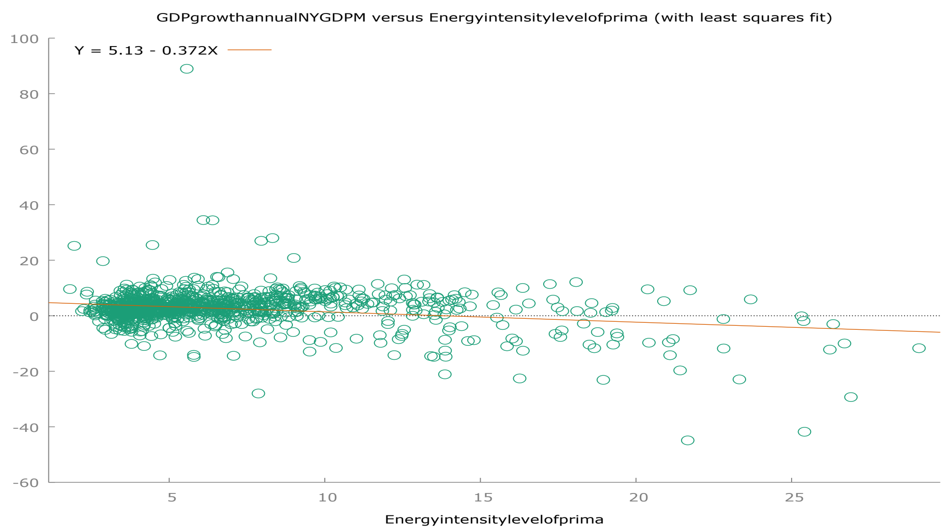
In the sample, both the GDP and energy intensity scatter show huge diversity between both of them. As a result, with low energy intensity, a large range in their degree of development was found. The scatter of GDP growth and energy intensity turns significant and evidently negative in figure5 (a, b). That simply indicates that high economic growth relates to decline in EI or expansions in use of energy, but the change between these variables is very weak. Again, reduction in energy intensity or efficient use of energy needs long-term operational changes and, generally, in experience, economies move toward these changes after achieving a high level of economic growth. Therefore, the perceived dispersion is very large, and there is a negative association between the levels among these parameters. The scatter of GDP growth and energy intensity links turns significant and evidently negative. Further parts of figure 5 (C, D) elaborate on the scatter of the share of renewable and GDP per capita, as well as the annual GDP growth dispersion in sample data. However, concerned studies have hypothesized that a switch to renewable resources can stimulate economic growth. The enormous diversity of both variables is observed when looking for a link among GDPPC and renewables share in the EUR, so that is feeble and negative. Despite the fact that GDPG and variation in share of renewable (D) energy in the EUR are both zero. Above mentioned, descriptive statistics are in favor of a negative association among growth and energy intensity, and across countries, the profile of energy mix reveals contradictory arrays.

Table 2 indicates that in the selected models, problem of heteroskedasticity and serial correlation occur. Tests results predict significant at 1%. But in case of cross-sectional dependency for all models, Results of Pesaran's test are different from other test. Because this test verdict in both case of fixed effect (FE) and random effect (RE) estimations that there is no cross-sectional dependency. After testing these diagnostic test finally applied econometric technique of dynamic panel data which is system GMM.

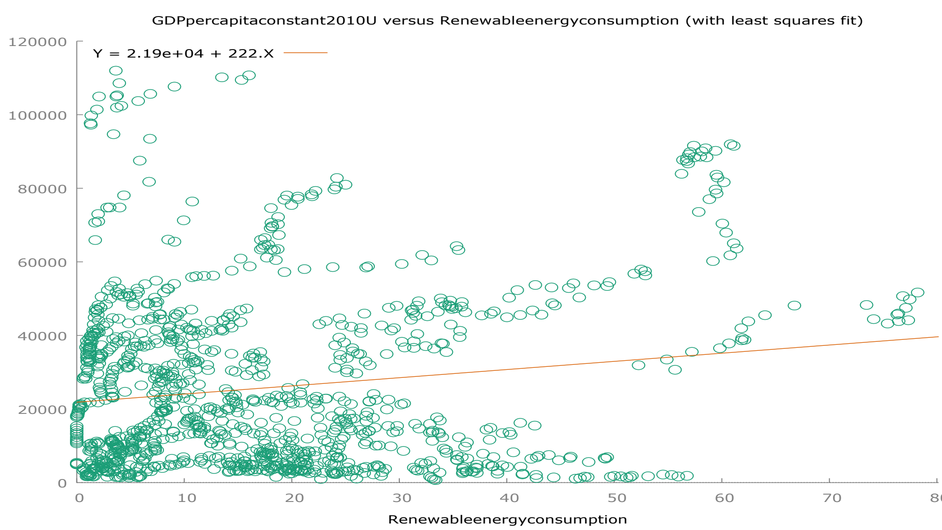
Figure 5: Income, energy intensity, and renewable sources statistic relation in EUR (A)



(B)


GDPgrowthannualNYGDPM versus Energyintensitylevelofprima (with least squares fit)
Y = 5.13 - 0.372X
100
80
60
40
20
0
-20
-40
-60
5
10
15
20
25
Energyintensitylevelofprima

(C)


GDPpercapitaconstant2010U versus Renewableenergyconsumption (with least squares fit)
Y = 2.19e+04 + 222.X
120000
100000
80000
60000
40000
20000
0
0
10
20
30
40
50
60
70
80
Renewableenergyconsumption

(D)

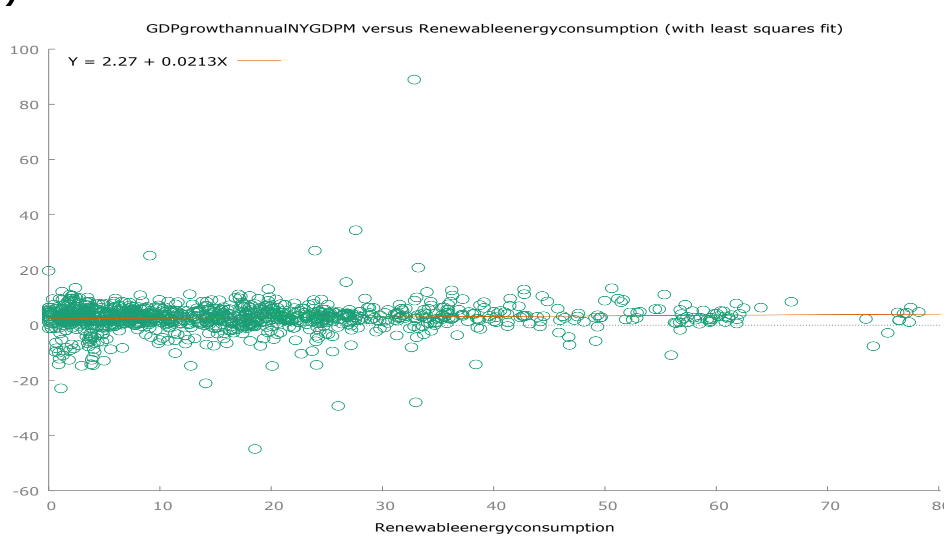

GDPgrowthannualNYGDPM versus Renewableenergyconsumption (with least squares fit)
Y = 2.27 + 0.0213X
100
80
60
40
20
0
-20
-40
-60
0
10
20
30
40
50
60
70
80
Renewableenergyconsumption

Table 2: Diagnostic Tests for M_1, M_2 and M_3

Model 1		
Cross-Sectional Dependence		
Pesaran (P-v)	0.202	0.104
Frees (Q)	4.143*	4.452*
Friedman (P-v)	*0.187*	*0.273*
Heteroskedasticity		
Modified Wald (P-v)	*0.002****	
Serial Correlation		
Wooldridge (P-v)	*0.001****	
Model 2		
Cross-Sectional Dependence		
Pesaran (P-v)	0.381	0.549
Frees (Q)	4.858*	4.093*
Friedman (P-v)	*0.404*	*0.605*
Heteroskedasticity		
Modified Wald (P-v)	*0.001****	
Serial Correlation		
Wooldridge (P-v)	*0.000****	
Model 3		
Cross-Sectional Dependence		
Pesaran (P-v)	0.381	0.549
Frees (Q)	4.858*	4.093*
Friedman (P-v)	0.404	0.605
Heteroskedasticity		
Modified Wald (P-v)	0.001***	
Serial Correlation		
Wooldridge (P-v)	0.000***	

Note: Estimates of fixed effects and random effects are denoted by FE and RE, respectively. The symbols *** and * designate Probability Value (p-values) and t - statistics is significant levels at 1% and 10%.

In the dynamic panel approach, table 3 is expressing the outcomes of the system GMM indicate 0.90% to 0.94%. In this point estimate, the main findings are first being the change and improvement in energy intensity combined with growth in gross domestic product GDPG. Concerned with GDP per capita level and energy mix, in this case, one percent (1%) reduction in EI is associated with low GDPC, depending on the model specification, though the shift is roughly between 0.5 and 0.1 percent. Furthermore, in a specific study area, a strong negative affiliation among EI and GDPG (as an indicator of economic performance) has been discovered in all models. The coefficient of variable "energy intensity" (EI) is substantially significant but invariably negative. This suggests that lower energy intensity is connected with greater GDP growth. They demonstrate a negative and highly elastic relationship between energy intensity and GDPC. The slope coefficient suggests that the percentage increase in year-lagged energy intensity reduces GDPC by 2.610, 2.613, and 2.666 percent in models 1, 2, and 3 respectively, which are shown as the Skelton model (M1), the human capital model (M2), and the policy model (M3). Rajbhandari (2018) also establish a negative link among variations in EI and GDPG. According to their expected values, higher levels of EI result in lower intensities of GDPG, which also discourages overall economic performance. As in macroeconomic literature, such a verdict is in practice where, due to an increase in energy prices, capital-excavating causes lower energy intensity (Díaz & Puch, 2018). As concerned specification of energy mix ($\theta^{m}{}_1$) and economic growth. With hypothesis that with primary energy consumption, there are inverse association among the share of renewable energy resources (RER) and GDPG. Results indicate that, at given GDPG level and EI, the share of renewable[6] (on average) is associated as average upturn of 1 p.p. Furthermore, overall moving to fossil fuel to renewables is impacting lower growth. But with passage of time moving from conventional to frontier renewable this relation with growth switch toward positive association.

[6] Here renewable is associated with fossil fuels. Because share of agriculture and fossil fuel having multicolinearity. To avoid multicolinearity both variables is omitted from the model.

Table 3: System-GMM estimation in Panel Data

Dependent Variable: GDPG	Model $_1$	Model $_2$	Model $_3$
log(income), lagged GDPC	0.933^{***}	0.934^{***}	0.967^{***}
	(41.57)	(35.64)	(52.35)
Log Energy Intensity (LEI)	-2.610^{***}	-2.613^{***}	-2.666^{**}
	(−7.54)	(−6.31)	(−12.43)
Renew. Mix, % change (RE)	-3.534^{***}	-3.613^{**}	-4.634^{***}
	(−2.15)	(−3.04)	(−2.44)
Nuclear. Mix, % change (NR)	−0.444	−0.623	−0.764
	(−0.20)	(−0.52)	(−0.49)
Industrial Sector, % change (IES)	0.0743	0.656	0.834
	(0.07)	(0.40)	(1.04)
Transport Sector, % change (TES)	0.145	0.561	0.036
	(0.14)	(0.76)	(0.05)
Residential Sector, % change (RES)	-5.624^{***}	-3.336^{***}	-3.724^{***}
	(−4.24)	(−3.67)	(−3.66)
Service Sector, % change (SES)	−2.430	−0.899	-2.242^{*}
	(−1.53)	(−0.36)	(−1.75)
Log (Invest. Price), lagged (LI)		-0.0132^{***} (−2.02)	
Attained primary ed., % over Pop., lagged		0.343^{***} (3.62)	
Attained secondary ed., % over Pop., lagged		−0.0341 −0.34	
Population, lagged			-0.0431^{***} (−2.35)
Inflation, 5-year average			-0.043^{**} −1.041
Trade openness			0.0550 (1.242)
Num Obs	987	992	823
Hansenp	0.0132	0.211	0.512
ar1p	0.000103	5.76e − 09	1.63e − 08
ar2p	0.723	0.562	0.474

Note: System GMM is applied at above models with one lag for instruments, significant values * is p is less than 0.10, ** 0.005 and *** and 0.01

The insertion of sectoral energy final consumptions Δsk,i,t has overall little influence on GDPG in selected area of investigation. Contribution of this variable to economic growth is estimated with interval -0.56 to -1.54 and remark able results is find in share of residential sector. According to models 1, 2, and 3, the slope coefficient shows a percentage increase in residential share of energy negativity and significantly decreases GDPPC by 5.624, 3.336, and 3.724 percent, respectively. These domino effects are significant because of the secular downward trend in agriculture. As Stern (2000) elaborates or justifies, economic performance is accompanied by rising share of the service economy and a move away from traditional patterns of economic growth and better mobilization of resources or efficient use of resources, then these conditions are relatively less energy intensive. In case of human capital variable of attain education, primary having positive but secondary having negative impact on economic performance, these results are justified because in Europe primary education is free for all but to get secondary education that is costly to attain so there is possibility of these expected sing in of this variable with relation to economic performance.

The Model (M3) induces policy variable specification with the dependent variable GDP per capita as an economic performance indicator. These alternative controls in the regression equation (8) are as follows: investment, inflation, trade open, and population. These variables are mentioned as institutional variables for estimation, but ultimately they have a direct impact on economic performance. The findings of this additional set of institutional variables incorporated into the regression have all the coefficients expected, which has been verified in the literature. Investment, education, and trade openness have a positive impact on GDPG, but the population has a significant but negative coefficient value. Result explains, exists a negative relationship between lag investment price and GDPPC, and a unitary percent change will reduce GDPPC by 0.0132 percent, as elaborated in table 3, but the result is significant.

6. Conclusion

The relationship between economic performance and energy intensity is too complex to elaborate because there is a list of facets that are related to the sectoral composition of an economy, the state of technology, and also policy measures. This research work is rudimentary, but the most important contribution of this research work is that it provides relative evidence (of all the above mentioned aspects) with the support of precise empirical specification. Relevant observed specifications are incorporated into dynamic panel data modelling, using indicators of energy intensity as an independent variable, primary energy mix shares (with differentiation between renewable and non-renewable resources), and economic sector final energy consumption shares. These three dimensions are elaborated with economic performance in this research work.

Despite the fact that the estimated EI equations expose numerous imperative growth-related features, the results show that a 1% increase in GDPG reduces EI by 1%, and in the second configuration, the renewables and residential share are significant and adversely related with EI. The key findings are that there is a negative and significant association among EI and EP in Europe, as determined by the model specification as well as the econometric technique. The greater the EI, the lesser the GDPG. The rest of the included sectoral variables have a minor impact on GDPG growth in the total European country data set. This study adds to the current literature by analyzing certain relationships concerning intensity of energy, energy intake structure, sectoral energy intake, and economic progress (or economic performance) with a particular set of control variable specifications that indicate economic performance.

It will aid in the discipline of the model's structure and narrative of alternative energy sources with technical expansion and development. This study accumulates three different dynamics of economic progress with major contributor (energy intensity) of economic performance in current situation. Last but not least, these findings provide strong evidence for further policy measures for sustainable development and enhanced economic performance through the utilization of these relationships as an efficient use of energy resources.

Authors Contribution

Fatima Gulzar: literature search, data collection, data analysis and interpretation, drafting
Fatima Farooq: study design, critical revision, incorporation of intellectual content

Conflict of Interests/Disclosures

The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

References

Aghion, P., Caroli, E., & Garcia-Penalosa, C. (1999). Inequality and economic growth: the perspective of the new growth theories. *Journal of Economic literature, 37*(4), 1615-1660. doi:https://doi.org/10.1257/jel.37.4.1615

Atkeson, A., & Kehoe, P. J. (1999). Models of energy use: Putty-putty versus putty-clay. *American Economic Review, 89*(4), 1028-1043. doi:https://doi.org/10.1257/aer.89.4.1028

Bataille, C., Jaccard, M., Nyboer, J., & Rivers, N. (2006). Towards general equilibrium in a technology-rich model with empirically estimated behavioral parameters. *The Energy Journal*(Special Issue# 2). doi:https://doi.org/10.5547/ISSN0195-6574-EJ-VolSI2006-NoSI2-5

Chen, J., Zhou, C., Wang, S., & Li, S. (2018). Impacts of energy consumption structure, energy intensity, economic growth, urbanization on PM2. 5 concentrations in countries globally. *Applied energy, 230*, 94-105. doi:https://doi.org/10.1016/j.apenergy.2018.08.089

Díaz, A., Marrero, G. A., Puch, L. A., & Rodríguez, J. (2019). Economic growth, energy intensity and the energy mix. *Energy economics, 81*, 1056-1077. doi:https://doi.org/10.1016/j.eneco.2019.05.022

Díaz, A., & Puch, L. A. (2018). Investment, technological progress and energy efficiency. *The BE Journal of Macroeconomics, 19*(2). doi:https://doi.org/10.1515/bejm-2018-0063

Dıaz, A., Puch, L. A., & Guilló, M. D. (2004). Costly capital reallocation and energy use. *Review of Economic Dynamics, 7*(2), 494-518. doi:https://doi.org/10.1016/j.red.2003.09.005

Emir, F., & Bekun, F. V. (2019). Energy intensity, carbon emissions, renewable energy, and economic growth nexus: new insights from Romania. *Energy & Environment, 30*(3), 427-443. doi:https://doi.org/10.1177/0958305X18793108

Ferraro, D., & Peretto, P. F. (2018). Commodity prices and growth. *The Economic Journal, 128*(616), 3242-3265. doi:https://doi.org/10.1111/ecoj.12559

Fiorito, G. (2013). Can we use the energy intensity indicator to study "decoupling" in modern economies? *Journal of Cleaner Production, 47*, 465-473. doi:https://doi.org/10.1016/j.jclepro.2012.12.031

Iwata, H., Okada, K., & Samreth, S. (2011). A note on the environmental Kuznets curve for CO2: a pooled mean group approach. *Applied energy, 88*(5), 1986-1996. doi:https://doi.org/10.1016/j.apenergy.2010.11.005

Lee, C.-C., & Chang, C.-P. (2008). Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. *Resource and energy Economics, 30*(1), 50-65. doi:https://doi.org/10.1016/j.reseneeco.2007.03.003

Liddle, B. (2010). Revisiting world energy intensity convergence for regional differences. *Applied energy, 87*(10), 3218-3225. doi:https://doi.org/10.1016/j.apenergy.2010.03.030

Mahmood, T., & Ahmad, E. (2018). The relationship of energy intensity with economic growth: Evidence for European economies. *Energy strategy reviews, 20*, 90-98. doi:https://doi.org/10.1016/j.esr.2018.02.002

Mallick, H. (2009). Examining the linkage between energy consumption and economic growth in India. *The Journal of Developing Areas, 43*(1), 249-280.

Mulder, P., & de Groot, H. L. (2011). Energy productivity performance across 14 OECD countries: the role of energy-extensive sectors. In *Improving Energy Efficiency through Technology: Trends, Investment Behaviour and Policy Design* (pp. 67-96). Cheltenham: Edward Elgar.

Saunders, H. D. (1992). The Khazzoom-Brookes postulate and neoclassical growth. *The Energy Journal, 13*(4). doi:https://doi.org/10.5547/ISSN0195-6574-EJ-Vol13-No4-7

Stern, D. I. (2000). A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy economics, 22*(2), 267-283. doi:https://doi.org/10.1016/S0140-9883(99)00028-6

Stern, D. I., Common, M. S., & Barbier, E. B. (1994). *Economic growth and environmental degradation: a critique of the environmental Kuznets curve*. Retrieved from

Wang, C. (2013). Changing energy intensity of economies in the world and its decomposition. *Energy economics, 40*, 637-644. doi:https://doi.org/10.1016/j.eneco.2013.08.014

Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: progress towards green economy. *Renewable energy, 71*, 123-132. doi:https://doi.org/10.1016/j.renene.2014.05.012