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Article

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The Impact of Human Capital on Energy Consumption in Vietnam

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ABSTRACT

The paper studied the impact of human capital on energy consumption in Vietnam using the ARDL model during the period from 1986 to 2019. The results showed that there exists a long-term positive relationship between human capital and aggregate energy consumption, fossil energy consumption, average renewable energy consumption. Besides, the study also revealed the impact of economic growth on fossil energy consumption in the short term. These findings helped proposing a number of recommendations for the government such as improving the quality of human capital, using more renewable energy and the need to fund research and development.

Keywords: Human Capital, Energy Consumption, Renewable Energy Consumption, Vietnam
JEL: O44, Q20, Q40, J0

1. INTRODUCTION

The role of energy in Vietnam's economic and social development has been crucial, particularly in light of the recent trends of urbanization and economic growth. The energy demand has risen significantly in Vietnam over the years, therefore posing a challenge for the country's policymakers to ensure a reliable and sustainable supply of energy. According to the report by the General Statistics Office of Vietnam, in the period from 2011 to 2019, energy consumption in Vietnam increased from about 48 million tons of oil equivalent (TOE) to about 89 million TOE, equivalent to an annual growth rate of 5.9%. Vietnam is also one of the countries with the fastest energy demand in Southeast Asia, along with Indonesia and the Philippines. However, the use of non-renewable energy sources still accounts for a large proportion of the country's total energy demand. The search for new and renewable energy sources as well as improving energy efficiency has become a major challenge for Vietnam. Furthermore, according to the Japan International Cooperation Agency (JICA), Vietnam ranks third in Asia in terms of inefficient energy use. During the period 1990-1998, Vietnam consumed 1.5 units of electricity to generate one unit of GDP. From 1998 to the present, to generate one unit of GDP, the level of energy consumption has risen by 1.83 units. Consequently, in the face of the requirements posed by the industrialization and modernization of the nation, the demand for energy consumption in Vietnam is incessantly escalating. The robust growth in energy consumption, predominantly fossil fuels, has resulted in a rapid increase in CO_2 emissions in Vietnam. The average rate of increase is 9.1% per annum, escalating from 21.2 million tons in 1990 to 247.7 million tons in 2019. Currently, Vietnam's sustainable development is being limited by energy shortages, energy security concerns, and environmental pollution issues. The nation faces the daunting task of balancing economic growth while also committing to reach net-zero emissions by 2050 through conventional means. Vietnam has historically concentrated on expanding its economy rather than transitioning to an energy-shifted economy, making this a challenging feat to accomplish. Vietnam has been proactive in its efforts to address the challenges posed by the rapidly increasing energy demand and low energy use efficiency. In this regard, the National Energy Development Strategy of Vietnam until 2030, with a vision to 2045, has been implemented, which underscores the importance of linking energy development with the implementation of environmental protection policies. The strategy aims to achieve the goal of reducing greenhouse gas emissions, promoting a circular economy, and sustainable development. Given the pressing need to consider the environmental implications of economic and energy development plans, it is imperative to identify and address the factors that impact and reduce total energy consumption in Vietnam.

The significance of human capital in promoting economic growth is widely acknowledged in endogenous growth theories. Human capital has emerged as a decisive factor in fostering growth and reducing poverty (Lucas, 1988; Mankiw et al., 1992; Romer, 1986; Schultz, 1999). Research on the contribution of human capital began several decades ago and has since been increasingly attracting the attention of scholars and policymakers alike. The role of the human factor in the development of national economies is gaining more importance as other resources become scarce and environmental degradation continues to pose a challenge. Notably, human capital has a positive impact on the achievement of the millennium goals in developing countries (Baldacci et al., 2008). The accumulation, improvement, or increase in human capital reduces energy consumption and increases energy efficiency, thereby promoting the realization of sustainable development goals (Akram et al., 2019; Shahbaz et al., 2019; Yao et al., 2019; Edziah et al., 2021; Gao et al., 2022). In line with the economic development strategy for the period up to 2030 and beyond, Vietnam has embarked on a green growth - sustainable development model that prioritizes human capital as a critical factor requiring utmost attention. However, in the case of Vietnam, there are almost no studies evaluating the impact of human capital on energy consumption. This paper will analyze the impact of human capital on Vietnam's energy consumption using the autoregressive distributed lag (ARDL) method for empirical estimates based on Vietnam's data from 1986 to 2019. The paper consists of five parts: (1) introduction, (2) research overview, (3) research data and econometric model, (4) analysis of empirical estimation results, (5) conclusion and some recommendations.

2. LITERATURE REVIEW

2.1. Energy Consumption and Economic Growth

Energy is a key input in the process of economic growth. The causal relationship between economic growth and energy consumption was demonstrated in the study by Kraft and Kraft (1978). Subsequently, researchers have continued to assert that energy consumption is a prerequisite for economic growth because energy is a direct input in the production process as well as an indirect input for labor and capital inputs (Templet, 1999). In the era of economic liberalization, privatization, and globalization, energy assumes a paramount role as a principal contributor to the process of growth. This is particularly conspicuous in nations characterized by a low per capita income (Cleveland et al., 1984). Energy consumption emerges as an integral and pivotal element in the trajectory of economic growth across a majority of nations (Hatemi and Irandoust, 2005). The accessibility and availability of energy input sources have been instrumental in catalyzing economic growth in industrialized and emerging economies alike (Pablo-Romero and Sánchez-Braza, 2015). According to Lee (2005), the implementation of energy conservation measures may have adverse effects on the economic development of developing nations, regardless of the duration of such impact. This assertion is supported by the findings of Lee and Chang (2008) and Apergis and Payne (2009), which established a unidirectional causal relationship between energy consumption and economic growth, thus lending credence to the theory of energy-led growth. The examination of the association between energy demand and production, with a focus on production functions, has revealed that energy has a significant direct influence on production. Notably, regions such as East/Southeast Asia and the Pacific, Europe, and Central Asia have experienced remarkable economic growth driven by energy consumption, particularly electricity (Sharma, 2010). The interdependence between energy consumption, economic growth, and CO_2 emissions has been extensively studied by scholars, as evidenced by the works of Magazzino (2016), Gozgor et al. (2018), and Pegkas (2020). Notably, the consumption of non-renewable energy sources has been identified as a major contributor to CO_2 emissions (Ahmadi and Frikha, 2023). Consequently, certain studies have identified a causal relationship between economic growth and energy consumption, while others have established a reverse causative relationship, with energy consumption influencing growth. It is well-established that the use of fossil energy sources significantly contributes to CO_2 emissions. A potentially influential factor that affects both economic growth and energy consumption is human capital.

2.2. Human Capital and Energy Consumption

The concept of human capital has been approached from various perspectives, one of which views human capital as an asset from a personal standpoint. This perspective was first introduced by Schultz (1961), who argued that the productive capacity of humans is much greater than all other forms of wealth. This viewpoint later gained widespread acceptance among researchers. Human capital is a multifaceted concept that encompasses skills, knowledge, labor capacity, health, and human values that are acquired and accumulated over a person's lifetime through long-term investments. In this process, education is regarded as the primary source of accumulation. Human capital is a critical resource that plays a significant role in generating economic productivity (Romer, 1990). It encompasses the level of skills and knowledge that individuals possess and exhibit in their ability to work, thereby creating economic value (O'Sullivan, 2003). Healy and Côté (2001) defines human capital as the knowledge, skills, abilities, and potential attributes in each individual that contribute to economic and social prosperity, as well as their overall well-being. Numerous theories and models have emphasized the importance of human capital in economic growth. For instance, human capital is considered an input factor of economic growth (Solow, 1956). Furthermore, it is believed to act as a direct factor (Lucas, 1988; Mankiw, 1992) or indirectly influence economic growth (Romer, 1990). According to Romer (1990), countries with a superior level of human capital are better equipped to absorb and adapt to technological advancements, leading to faster growth. At the regional and macroeconomic level, human capital, particularly those with a higher level of education, is regarded as the primary factor influencing the degree of technological and economic development (Gylfason, 2001). Therefore, it can be argued that human capital is an essential component of economic growth. From the above discussion, it can be inferred that human capital can augment energy consumption through scale effects.

However, human capital will be improved, leading to more efficient energy consumption. There are various ways to enhance human capital, but primarily through education and training; thus, education may have directly and indirectly influenced energy demand. Indirectly, education is considered a crucial pillar of economic development as it encourages societal innovation to renew production processes, leading to improved work efficiency and living standards (Gylfason, 2001; Inglesi-Lotz and Morales, 2017). Directly, education promotes businesses to produce energy-saving technologies and exploit environmentally friendly energy sources such as renewable energy. Education also enables consumers to use energy-saving goods for their daily needs (Inglesi-Lotz and Morales, 2017). Individuals, and households with better education, improved human capital will help them consume more energy-saving devices, help them use less electricity and pay attention to energy efficiency (Broadstock et al., 2016, Li and Lin, 2016).

Research on the impact of human capital on energy consumption, using provincial-level data from China for the period 1990-2010, shows that a 1% increase in human capital will reduce energy consumption by approximately 0.18-0.45%. This impact can be explained by the strong accumulation of human capital after compulsory education in China. In the context of heated debates about environmental and energy security issues, the findings of the study suggest that energy savings in China can be achieved by improving post-compulsory human capital components such as on-the-job training, experience, and work-study (Salim et al., 2017). Another study, by Mehrara et al. (2015), using the Bayesian Model Averaging (BMA) and Weighted Least Squares (WALS), with data from the period 1992 to 2011 in countries of the Economic Cooperation Organization (ECO), found that institutional environmental factors, urban population, and human capital are the most important variables affecting renewable energy consumption in the ECO economy. Research on the impact of human capital on energy consumption of a group of OECD economies during the period 1965-2014 showed that a 1% increase in human capital reduces aggregate energy consumption by 15.36%. And human capital creates significant positive external impacts on the environment. Specifically, a 1% increase in human capital is associated with a 17.33% reduction in dirty energy consumption and an 85.54% increase in clean energy consumption (Yao et al., 2019).

Also using annual data for the period 1980-2014 in India, through the Autoregressive Distributed Lag (ARDL) model to test whether human capital can contribute to energy conservation by reducing energy consumption. The results show that there is a negative relationship between human capital and energy consumption in both the long term and short term. This implies that improving human capital will reduce energy consumption in various forms of energy consumption, except for petroleum consumption (Akram et al., 2019).

With the analysis of factors determining energy demand in the United States during the period 1975-2016, assessing how education contributes to energy demand for the U.S. economy, using the ARDL model. The empirical results show that the variables have a cointegrated relationship in the long run. Education has a negative relationship with energy demand. Education reduces long-term energy demand due to increasing awareness of energy efficiency and the availability of cleaner energy sources (Shahbaz, 2019).

Another study examined the causal relationship between human capital, energy consumption, CO_2 emissions, and economic growth in Indonesia with data from the period 1985-2017. The findings of the study reveal that there is no conclusive evidence of a long-term causal relationship between human capital, per capita CO_2 emissions, and actual per capita GDP to per capita energy consumption in Indonesia (Bashir et al., 2019).

The empirical findings of a study conducted on 73 income-based countries and regions (including advanced, developing, and emerging economies in Asia, Africa, Europe, and Latin America) during the period of 1990-2014 reveal that human capital exerts a negative influence on energy consumption. In other words, an improvement in human capital can lead to a reduction in energy consumption, thereby promoting energy conservation and environmental protection. The study suggests that policies aimed at enhancing economic efficiency and educational attainment can facilitate economies in achieving sustainable growth with low energy consumption (Akram, 2020).

According to a recent study conducted by Fang and Yu (2020), which analyzed data from 56 countries over a period from 1970 to 2014, there exists a causal relationship between energy and economic growth, and thereby highlights the crucial role of human capital in this relationship. The study reveals that energy is a significant input for economic growth, and it complements human capital development. Furthermore, the findings suggest that human capital development enhances the growth-enhancing effects of energy.

Another study investigates the association between energy consumption, human capital, inflation, and economic growth in Indonesia. The research employs ARDL model and utilizes data from 1970 to 2018. The findings of the study demonstrate that human capital exhibits a positive impact on Indonesia's energy consumption. Specifically, a 1% increase in human capital results in a 3.206% increase in energy consumption during the period from 1970 to 2018. This empirical evidence sheds light on the importance of human capital in promoting energy consumption in the Indonesian context and contributes to the ongoing discourse on sustainable economic growth in the region (Hadi and Campbell, 2020).

A recent study by Alvarado et al. (2021) investigated the relationship between economic development, human capital, globalization, and energy consumption in 27 OECD member countries over the period of 1980-2015. The study employed both linear and non-linear econometric models to examine the impact of these variables on energy consumption from fossil sources as well as non-renewable energy consumption. The results indicated that while economic development did not reduce energy consumption from fossil sources, human capital had a significant impact in reducing non-renewable energy consumption. Additionally, the study found evidence of a long-run relationship between the variables, suggesting that the human capital index and globalization have the potential to accelerate the transition to more sustainable energy use in developed countries. Overall, the findings of this study provide valuable insights into the role of human capital and globalization in promoting sustainable energy consumption patterns in developed countries.

In the study by Ozcan and Danish (2022), an examination of the dynamic influences of globalization, human capital, and economic growth on renewable energy consumption in Turkey was undertaken. This analysis utilized annual data spanning from 1980 to 2017 and employed the autoregressive distributed lag (ARDL) model. The empirical findings from this research indicate that the process of globalization, an augmentation in human capital, and the rate of economic growth in Turkey are positively associated with an increase in renewable energy consumption.

A recent study has estimated the impact of human capital on energy consumption, utilizing a panel data set of 30 Chinese provinces from 1997 to 2018. The findings of the study indicate that human capital has a positive impact on energy consumption. According to the study, a 1% increase in human capital can result in an increase in energy consumption of approximately 0.3%. It is noteworthy that the positive impact of human capital on energy consumption mainly stems from the scale effect. However, human capital with higher education levels has an impact that leads to less energy consumption, a finding that highlights the importance of education in promoting energy efficiency (Wang et al., 2022).

In a study conducted by Shahbaz et al. (2022) explores the intricate relationship between human capital, energy consumption, and economic growth by analyzing the data of the Chinese economy spanning from 1971 to 2018. The empirical findings of the study indicate that the accumulation of human capital has a noteworthy and statistically significant adverse impact on overall energy consumption and dirty energy consumption, while having a positive impact on clean energy demand.

According to a study by Bouznit et al. (2023) which examines the impact of human capital on energy consumption in Algeria utilized data from 1970-2017. Using both direct and indirect effects models, the study finds that while human capital has a direct negative effect on energy demand; it also indirectly increases energy demand through income and physical capital channels. However, the direct effect is greater than the indirect effect. In light of these findings, the study suggests that investing in renewable energy, education, and human resources development can be effective strategies for reducing energy consumption and protecting the environment without compromising economic growth, thus providing a promising path for the Algerian government to pursue.

In the most recent empirical study conducted by Pegkas (2024), the autoregressive distributed lag (ARDL) methodology was employed to analyze the relationship between human capital and energy consumption. This analysis was based on annual data from Greece spanning the period of 1990-2021. The findings from this rigorous investigation revealed that human capital exerts a significant negative influence on energy consumption, both in the short and long term. More specifically, it was observed that human capital fosters the consumption of renewable energy while concurrently reducing the consumption of non-renewable energy. Furthermore, it was noted that human capital with a higher level of education contributes to a decrease in non-renewable energy consumption and an increase in renewable energy consumption. The implications of these research findings underscore the necessity of investing in human capital as a strategy to reduce energy consumption and thereby achieve the objectives of sustainable development.

A comprehensive review of extant literature reveals that human capital exerts influence on energy consumption through several mechanisms. Firstly, the accumulation of human capital acts as a catalyst in bolstering sustainable economic development, thereby facilitating economic growth and mediating the nexus between human capital and energy consumption. Secondly, an augmentation in per capita gross domestic product (GDP) enables nations to allocate more resources towards research and development (R&D), thereby paving the way for the application of more efficient devices. This, in turn, contributes to the utilization of cleaner energy and promotes energy efficiency. Lastly, human capital, when supplemented with physical capital investment - particularly investment capital earmarked for technology - can lead to efficient energy usage and a transformation in energy consumption patterns, aligning them with environmental protection objectives. The influence of human capital on energy utilization has been scrutinized at both micro and macroeconomic levels. The ramifications of human capital on energy consumption exhibit heterogeneity across various economic systems. On one hand, an augmentation in human capital, which engenders innovation, leads to a decrement in energy consumption by fostering energy savings, enhancing energy efficiency, and instigating a shift in the energy structure towards the utilization of cleaner energy sources. Conversely, under the impetus of economic growth, energy consumption continues to escalate. Presently, scholarly consensus regarding the impact of human capital on energy consumption remains elusive. Certain studies suggest that this relationship is highly susceptible to the choice of sample, econometric techniques, and the measurement of human capital (Alvarado et al., 2021). Other researchers postulate that these disparate effects can be elucidated by varying levels of development (Salim et al., 2017). Specifically, in the context of Vietnam, there is a dearth of research evaluating the influence of human capital on the consumption of renewable and fossil energy. Therefore, to illuminate the empirical issue, this article will undertake an analysis of the impact of human capital on Vietnam's energy consumption. This endeavor aims to contribute to academic discourse and provide valuable insights for policymaking.

3. METHODOLOGY

3.1. Data

The paper uses time series data for the period (1986-2019). This limitation is due to the fact that as of now (2024), data on the human capital index (HCI) is provided up to 2019 and 1986 is the year Vietnam started the process of economic policy reform. The variables and data collection sources are as follow in Table 1.

3.2. Model

The general model proposed in the article is based on the model used in previous empirical studies (such as the research of Salim et al., 2017; Yao et al., 2019; Pegkas, 2024). The level of energy consumption is expressed as a function including human capital variable and control variables as follows:

$$PEC_t = \alpha_1+\beta_1 HCI+\gamma_1 GDP_t+\theta_1 K_t+\phi_1 OPI_t+\varepsilon_{t1}$$

$$FEC_t = \alpha_2+\beta_2 HCI+\gamma_2 GDP_t+\theta_2 K_t+\phi_2 OPI_t+\varepsilon_{t2}$$

$$REC_t = \alpha_3+\beta_3 HCI+\gamma_3 GDP_t+\theta_3 K_t+\phi_3 OPI_t+\varepsilon_{t3}$$

Where: PEC represent the per capita energy consumption, HCI denote the human capital index, GDP, K, and OPI are control variables for energy consumption, representing economic growth, physical capital, and oil price index respectively, and εt is the error term.

The dependent variables in the model are as follows: Per Capita Energy Consumption (PEC): This represents the average energy consumption per person, measured in MWh. Per Capita Fossil Energy Consumption (FEC): This represents the average fossil energy consumption per person, also measured in MWh. Per Capita Renewable Energy Consumption (REC): This represents the average renewable energy consumption per person, measured in MWh. These variables help to clarify the impact of human capital on the consumption levels of both fossil and renewable energy. As human capital improves, the consumption of fossil energy is expected to decrease, while the consumption of renewable energy is expected to increase. This model provides a comprehensive framework for understanding the relationship between human capital and energy consumption patterns.

Regarding human capital, in this study, it is measured by the HCI index based on the number of years of schooling and returning to education. This index is introduced by Penn World Table 10.01 (Feenstra et al., 2015). There have been many studies using this index to measure human capital such as the research of Akram et al., 2019; Edziah et al., 2021; Bouznit et al., 2023; Pegkas, 2024. In this study, the improvement of the HCI index in Vietnam over the years is expected to help save fossil fuel consumption and use renewable energy efficiently as the result of the most recent studies (such as those of Bouznit et al., 2023; Pegkas, 2024).

Economic growth. In countries with low-income levels, economic growth reduces energy consumption, while in countries with higher income levels, economic growth increases energy consumption (Pablo-Romero et al., 2019). Another study in China found that as household income in China increases, the average electricity consumption also increases (Yin et al., 2016). Wealthier countries consume more energy (Salim et al., 2017). Increased income leads to increased gasoline consumption (Akram et al., 2018); GDP growth increases aggregate energy consumption and non-renewable energy consumption (Pegkas, 2024). Therefore, this study also expects to find a positive correlation between energy consumption and income.

Physical capital is incorporated into the research model to represent technology (Li and Lin, 2016). Technology reduces the consumption of natural gas, hydrocarbon gas, and petroleum because as technology advances, households switch to using energy-saving devices (Akram et al., 2019). An increase in the stock of physical capital leads to an increase in overall energy consumption and non-renewable energy consumption (Pegkas, 2024).

The price index has been used in many studies to examine its impact on energy consumption, such as the price index for purchasing power fuel (Wang et al., 2022), crude oil prices (Bouznit et al., 2023); energy component of the consumer price index (Pegkas, 2024). The results show differences in studies, Akram et al. (2019) found the role of energy prices in reducing the consumption of electricity, coal, natural gas, hydrocarbon gas, and petroleum. While the study of Pegkas (2024) found that higher energy prices do not reduce total energy consumption and non-renewable energy. In this study, the world crude oil price index is considered an additional control variable and is expected to have an inverse relationship between energy prices and energy consumption according to the law of demand.

Table 1: Data sources

Variables	Explanation of variables	Data sources
PEC	Energy consumption per capita (MWh)	https://ourworldindata.org (2024)
REC	Renewable energy consumption per capita (MWh)	
FEC	Primary energy consumption per capita (MWh)	
GDP	This variable represents the growth rate of Vietnam's economy, calculated based on GDP per capita at constant 2017 prices (%)	www.ggdc.net/pwt (2024)
HCI	Human capital index, based on years of schooling and returns to education	
K	This variable measures the growth rate of physical capital, calculated based on Capital stock at constant 2017 national prices (%)	
OPI	Oil spot crude price index (West Texas Intermediate)	https://ourworldindata.org (2024)

PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, GDP: Gross domestic product, HCI: Human capital index, OPI: Oil price index, K: Physical capital

The methodology employed for the analysis of the data is the autoregressive distributed lag (ARDL) approach. This method was pioneered by Pesaran et al. in 2001. The choice of this method is justified by several salient advantages it offers. These advantages are: (i) flexibility in the degree of co-integration testing (Jhingan, 2010); (ii) can be effectively applied to small sample sizes (Odhiambo, 2009); (iii) the estimated coefficients in the long-term model are unbiased coefficients (Harris and Sollis, 2003).

For time series data, a good analytical model requires the data series to be stationary because non-stationary series can lead to spurious or meaningless regression. Therefore, the author uses two popular unit root tests for small samples, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP), to test the stationarity of the data series.

All variables are converted to natural logarithms to reduce the phenomenon of changing error variance that may occur in the model.

To examine the impact of human capital on Vietnam's energy consumption, the paper uses the ARDL model in the form of:

$$\Delta LnPEC_t = \alpha_1 + \sum_{i=0}^{q}\beta_{1i}\Delta LnHCI_{t-i} + \sum_{i=1}^{p}\gamma_{1i}\Delta LnGDP_{t-i} + \sum_{i=0}^{q}\theta_{1i}\Delta LnK_{t-i} + \sum_{i=0}^{q}\phi_{1i}\Delta LnOPI_{t-i} + \mu_1 LnHCI_{t-1} + \eta_1 LnGDP_{t-1} + \lambda_1 LnK_{t-1} + \xi_1 LnOPI_{t-1} + \varepsilon_{1t}$$

$$\Delta LnFEC_t = \alpha_2 + \sum_{i=0}^{q}\beta_{2i}\Delta LnHCI_{t-i} + \sum_{i=1}^{p}\gamma_{2i}\Delta LnGDP_{t-i} + \sum_{i=0}^{q}\theta_{2i}\Delta LnK_{t-i} + \sum_{i=0}^{q}\phi_{2i}\Delta LnOPI_{t-i} + \mu_2 LnHCI_{t-1} + \eta_2 LnGDP_{t-1} + \lambda_2 LnK_{t-1} + \xi_2 LnOPI_{t-1} + \varepsilon_{2t}$$

$$\Delta LnREC_t = \alpha_3 + \sum_{i=0}^{q}\beta_{3i}\Delta LnHCI_{t-i} + \sum_{i=1}^{p}\gamma_{3i}\Delta LnGDP_{t-i} + \sum_{i=0}^{q}\theta_{3i}\Delta LnK_{t-i} + \sum_{i=0}^{q}\phi_{3i}\Delta LnOPI_{t-i} + \mu_3 LnHCI_{t-1} + \eta_3 LnGDP_{t-1} + \lambda_3 LnK_{t-1} + \xi_3 LnOPI_{t-1} + \varepsilon_{3t}$$

Where: Δ is first-differencing, and the information of the variables which are presented in Table 2.

Finally, there are tests for the quality of the ECM model and the reliability of the estimation results.

According to the statistics on Vietnam's national energy by the National Program on Energy Efficiency and Conservation in 2019, during the period 2010-2019, total energy consumption grew by 4.3% per year. Industry and Transport are the two sectors with the highest energy consumption and are expected to increase in the coming years. The aggregate energy and fossil energy consumption tends to increase annually throughout the period 1986-2019, and the renewable energy consumption is more volatile compared to the aggregate energy and fossil energy consumption. The average value of Vietnam's human capital is 2.15, the value of this factor has increased more than 1.5 times from 1986 to 2019, increasing from 1.75 to 2.87, indicating that Vietnam's human capital has significantly improved. The standard deviation of human capital is calculated as 0.38, indicating that human capital can increase or decrease. The variables GDP and K increased in the period from 1990 to 1995, then there was less fluctuation than in the previous period, while OPI also showed a tendency to fluctuate over time (Figure 1).

4. RESULTS

4.1. Unit Root Test

The study uses two popular unit root tests for small samples, the augmented dickey-fuller (ADF) and Phillips-Perron (PP), to test the stationarity of the data series. From the unit root test results in Table 3, some data are stationary at the root variable, while others are not. All variables become stationary after taking the first difference. Therefore, the data series satisfies the stationarity condition to proceed with the next steps of the ARDL model to understand the impact of human capital on Vietnam's energy consumption during the period 1986-2019.

Table 4 and Figure 2 show that there are three models selected: ARDL1 (3, 0, 3, 4, 0); ARDL2 (4, 0, 3, 4, 2) and ARDL3 (1, 0, 0, 3, 0) with the smallest AIC values. These three models are used for analysis.

4.2. Bounds Test

The bounds test is used to examine the long-term relationship between variables in the model. The F-test statistic is used in hypothesis testing and is compared with the upper bound and lower bound values.

The ARDL bounds test results presented in Table 5 for all three models indicate the existence of a long-term relationship between the variables in Model 1, Model 2, and Model 3. This is when the variables Ln PEC, LnFEC, and LnREC are the dependent variables because the F-statistic value is greater than the upper bound value in both models at the 1% significance level. Therefore, a long-term relationship exists between the variables.

The results of the long-term model estimation are shown in Table 6. Based on the results of the cointegration test, there is a long-term relationship between the variables in the two models with three dependent variables: lnPEC, lnFEC, and lnREC.

For Model 1, when LnPEC is the dependent variable, the long-term coefficient estimates of the ARDL (3, 0, 3, 4, 0) model are shown in Table 6. The long-term impact calculations from the ARDL model show that human capital (HCI) has a statistically significant positive impact on per capita energy consumption (PEC) in the long run, specifically the impact coefficient is 4.061

Table 2: Descriptive statistics of the variables in the model

Statistics	HCI	GDP	K	OPI	FEC	REC	PEC
Mean	2.152169	5.048560	8.067900	67.83172	3.562708	0.854069	4.416777
Median	2.076354	5.587819	8.943244	47.10462	2.725304	0.641234	3.392543
Maximum	2.869998	7.672187	13.18317	153.4589	10.58558	2.491923	12.58557
Minimum	1.696076	0.240736	1.393474	22.06260	0.875306	0.065343	1.091651
Standard Deviation	0.379243	1.719433	3.190719	43.95999	2.661297	0.687170	3.316681
Observations	34	34	34	34	34	34	34

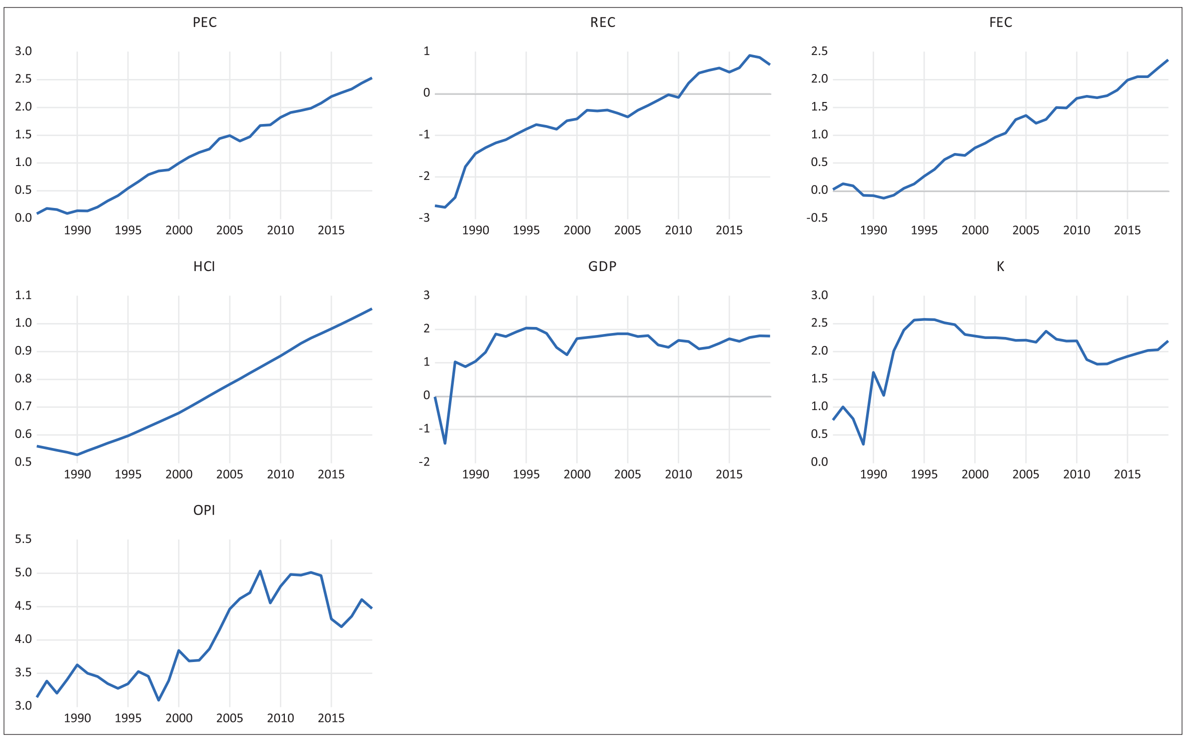
PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, GDP: Gross domestic product, HCI: Human capital index, OPI: Oil price index, K: Physical capital. Source: Authors' calculation

Table 3: Unit test results

Variable Name	ADF test		PP test	
	Root level	First difference	Root level	First difference
LnPEC	−3.030444	−4.779028***	−3.052459	−4.914596***
LnREC	−2.451036	−3.959564***	−2.439340	−3.999515***
LnFEC	−2.801611	−4.103503***	−2.774499	−4.639016***
LnHCI	−5.166117***	-	−11.01005***	-
LnGDP	−8.672614***	-	−3.024847	−8.930673***
LnK	−2.242746	−7.818880***	−2.149347	−7.479551***
LnOPI	−1.756971	−5.582708***	−1.837206	−5.619421***

PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, GDP: Gross domestic product, HCI: Human capital index, OPI: Oil price index, ADF: Augmented Dickey-FulleK: Physical capital. Source: Authors' calculation. Note: ***, **, * correspond to statistical significance levels of 1%, 5%, and 10% respectively

Figure 1: The fluctuation of the variables



(All data are in logarithmic form.)

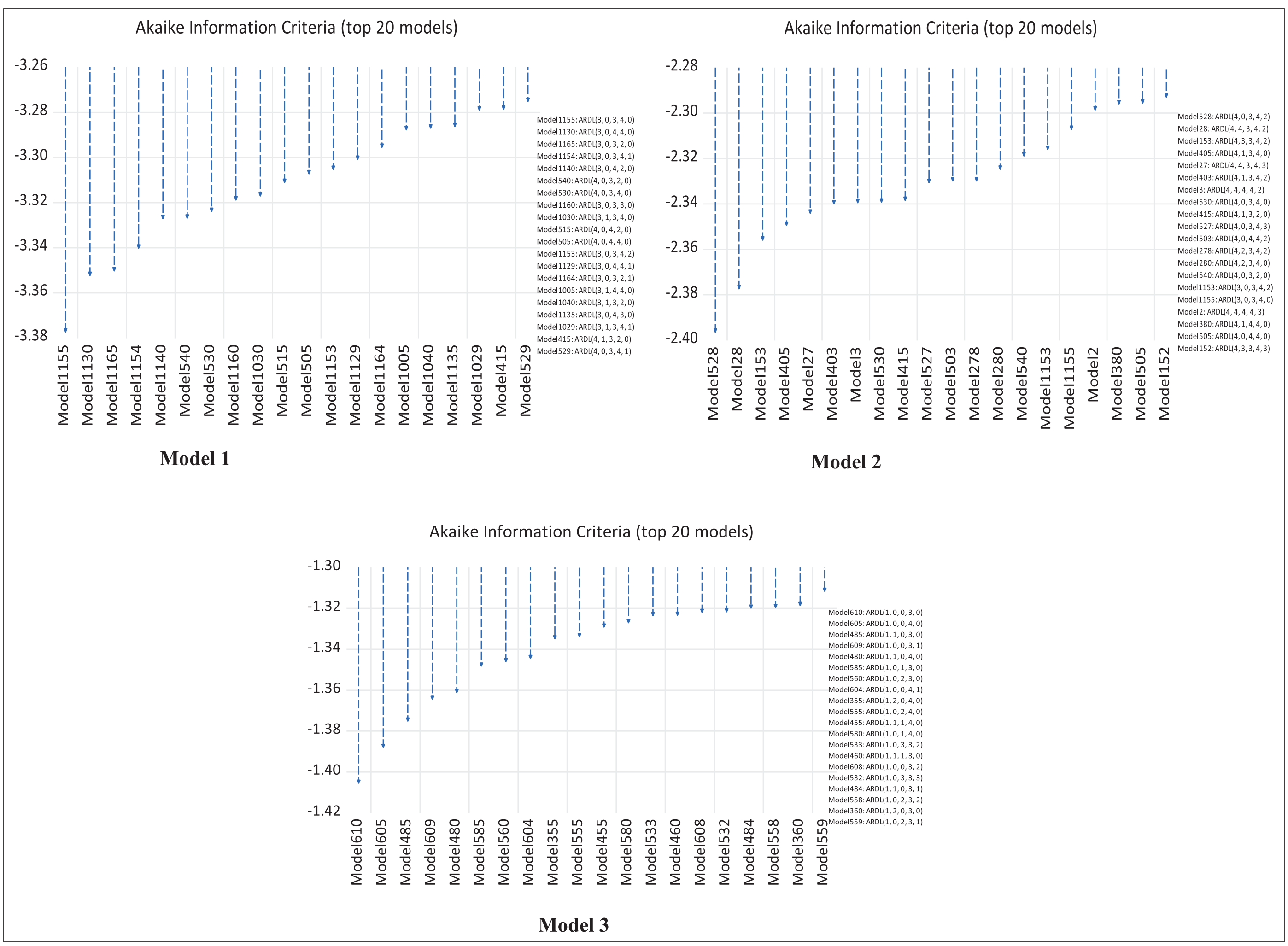
and is statistically significant at the 1% level. For Model 2, when LnFEC is the dependent variable, the research results in Table 6 also show that human capital (HCI) has a statistically significant positive impact on per capita fossil energy consumption (FEC) in the long run, specifically the impact coefficient is 5.012 at the 1% significance level. These research results are similar to the research results of Fang and Yu (2020); Hadi and Campbell (2020), Wang et al. (2022). However, the results of this study contradict the research results of Akram et al. (2020); Shahbaz (2022); Bouznit et al. (2023); Pegkas (2024) which argue that human capital has a negative impact on average energy consumption and average fossil energy consumption. This could be due to the fact that Vietnam's economy is a developing economy, growth is a top priority, and energy consumption promotes economic growth (Tang et al., 2016), reasonable electricity consumption (both in the short and long term) will promote economic growth (Quyết and Khánh, 2014). Furthermore, the support policies for encouraging the consumption of renewable energy in Vietnam are either inadequate or have not been effectively implemented. The adoption of renewable energy technologies requires significant

Table 4: Results of optimal lag selection

Model 1: Dependent variable PEC						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	41.79305	NA	5.92e-08	−2.452870	−2.219337	−2.378161
1	222.8870	289.7504	1.84e-12	−12.85914	−11.45794	−12.41088
2	264.8013	53.09136*	6.93e-13	−13.98675	−11.41789	−13.16495
3	304.4408	36.99688	4.04e-13	−14.96272	−11.22619	−13.76737
4	356.8122	31.42286	1.88e-13*	−16.78748*	−11.88329*	−15.21859*
Model 2: Dependent variable FEC						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	32.80713	NA	1.08e-07	−1.853809	−1.620276	−1.779099
1	212.4372	287.4082	3.69e-12	−12.16248	−10.76129	−11.71423
2	252.2091	50.37770	1.61e-12	−13.14727	−10.57841	−12.32547
3	289.3323	34.64826	1.11e-12	−13.95548	−10.21896	−12.76014
4	353.9635	38.77872*	2.27e-13*	−16.59756*	−11.69337*	−15.02867*
Model 3: Dependent variable REC						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	24.64750	NA	1.86e-07	−1.309833	−1.076300	−1.235124
1	198.2821	277.8154	9.49e-12	−11.21881	−9.817611	−10.77055
2	242.5698	56.09772	3.05e-12	−12.50465	−9.935792	−11.68285
3	281.5932	36.42184	1.85e-12	−13.43955	−9.703020	−12.24420
4	345.5786	38.39124*	3.97e-13*	−16.03857*	−11.13438*	−14.46968*

PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, Source: Authors' calculation

Figure 2: The illustration of the (AIC) for the top 20 best autoregressive distributed lag models



Source: Authors' calculation`

Table 5: The results of the bounds test

Test Statistic	Value	Significance (%)	I (0)	I (1)
Asymptotic: n=1000				
Model 1				
F-statistic	11.51586	10	2.2	3.09
k	4	5	2.56	3.49
		2.5	2.88	3.87
		1	3.29	4.37
Model 2				
F-statistic	5.248186	10	2.2	3.09
k	4	5	2.56	3.49
		2.5	2.88	3.87
		1	3.29	4.37
Model 3				
F-statistic	13.31095	10	2.2	3.09
k	4	5	2.56	3.49
		2.5	2.88	3.87
		1	3.29	4.37

Source: Authors' calculation

Table 6: The results of long-term coefficient estimation

Variable	Coefficient	Standard error	t-Statistic	Probability
Model 1				
LnHCI	4.061008	0.634599	6.399330	0.0000
LnGDP	0.230330	0.239034	0.963588	0.3505
LnK	0.003214	0.150121	0.021409	0.9832
LnOPI	0.477256	0.453917	1.051417	0.3097
C	−2.714604	0.818190	−3.317817	0.0047
Model 2				
LnHCI	5.012016	1.352827	3.704846	0.0030
LnGDP	−0.561733	0.953962	−0.588841	0.5669
LnK	−0.108500	0.297986	−0.364110	0.7221
LnOPI	−2.173665	3.123885	−0.695821	0.4998
C	1.163859	4.959413	0.234677	0.8184
Model 3				
LnHCI	3.323646	0.906985	3.664500	0.0014
LnGDP	−0.161014	0.317761	−0.506715	0.6174
LnK	−0.190683	0.245774	−0.775846	0.4461
LnOPI	0.083149	0.213921	0.388690	0.7012
C	−2.359031	0.883262	−2.670816	0.0140

PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, GDP: Gross domestic product, HCI: Human capital index, OPI: Oil price index. Source: Authors' calculation

capital investments, which businesses and households may not be willing to make at present. Despite the gradual increase in the consumption of renewable energy, it remains insignificant compared to the total energy consumption in Vietnam. To meet the growing energy demand, the majority of the energy supply still heavily depends on fossil fuels. Moreover, while Vietnam has made remarkable progress in improving its human capital index between 1986 and 2019, it still lags behind many countries in the world in terms of human capital development. Specifically, when compared with Greece, the human capital index in this country in 1986 was 2.45 and in 2019 it was 3.14, their human capital index is much higher than that of Vietnam (countries with results showing that human capital reduces average fossil energy consumption and overall energy consumption, research results of Pegkas, 2024). This shows that, with a limited human capital index, it is not enough to promote the transition from traditional energy sources to renewable energy, as well as efficient energy consumption.

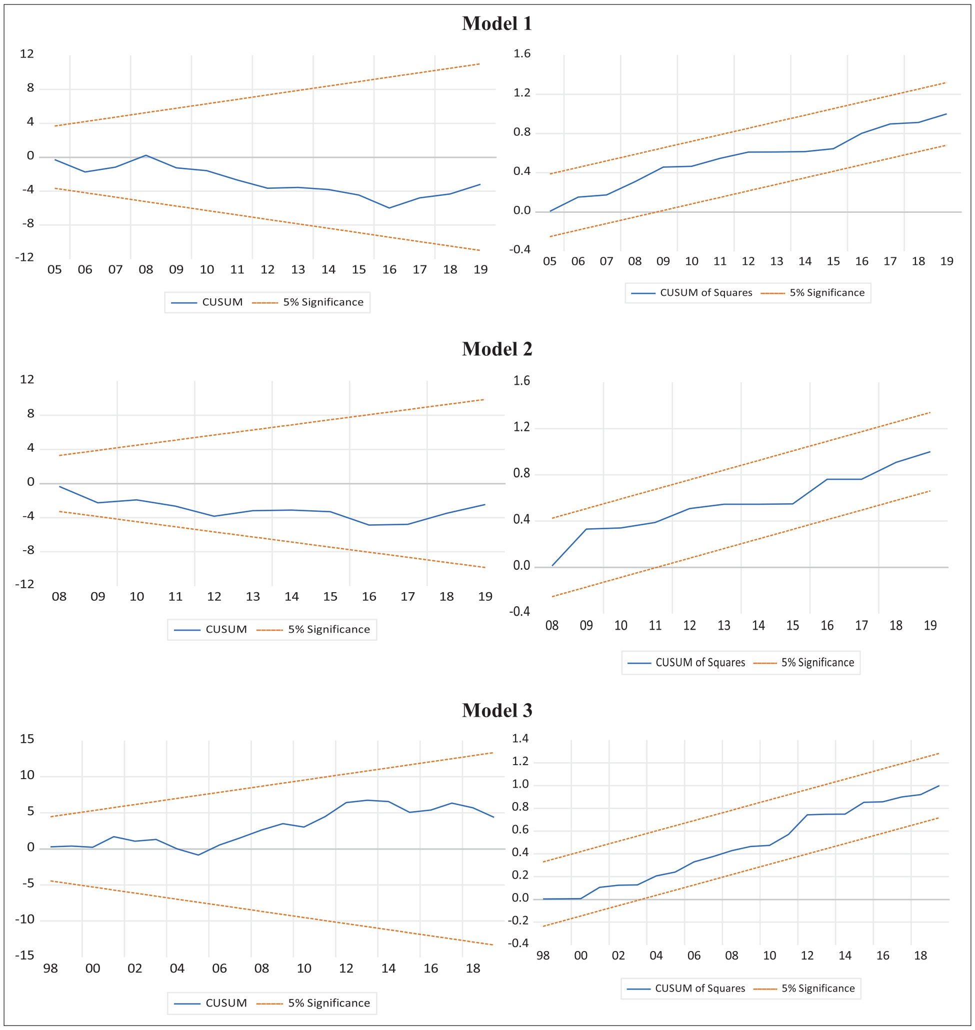
Table 7: The short-term impact calculation results using the Error Correction Model

Variable	Coefficient	Standard Error	t-Statistic	Probability
Model 1				
DLn (PEC(-1))	0.034882	0.120718	0.288951	0.7766
DLn (PEC(-2))	−0.758976	0.130513	−5.815333	0.0000
DLn (K)	−0.006922	0.025423	−0.272274	0.7891
DLn (K(−1))	−0.164253	0.031383	−5.233795	0.0001
DLn (K(−2))	−0.104451	0.024183	−4.319137	0.0006
DLn (OPI)	0.005501	0.030145	0.182470	0.8577
DLn (OPI(−1))	−0.124249	0.030675	−4.050472	0.0010
DLn (OPI(−2))	−0.004743	0.026968	−0.175889	0.8627
DLn (OPI(−3))	−0.067995	0.026973	−2.520814	0.0235
CointEq(−1)*	−0.313617	0.032674	−9.598276	0.0000
Model 2				
DLn (FEC(−1))	−0.409243	0.191249	−2.139848	0.0536
DLn (FEC(−2))	−1.228316	0.205782	−5.969030	0.0001
DLn (FEC(−3))	−0.377183	0.197665	−1.908198	0.0806
DLn (K)	0.040465	0.041515	0.974701	0.3489
DLn (K(−1))	−0.237287	0.055713	−4.259119	0.0011
DLn (K(−2))	−0.230933	0.057380	−4.024636	0.0017
DLn (OPI)	−0.039580	0.053233	−0.743520	0.4715
DLn (OPI(−1))	−0.286829	0.055217	−5.194532	0.0002
DLn (OPI(−2))	−0.079516	0.051882	−1.532630	0.1513
DLn (OPI(−3))	−0.174324	0.047638	−3.659346	0.0033
DLn (GDP)	0.402127	0.075349	5.336872	0.0002
DLn (GDP(−1))	−0.188392	0.071864	−2.621517	0.0223
CointEq(−1)*	-0.211718	0.031699	-6.679041	0.0000
Model 3				
DLn (OPI)	−0.001381	0.075778	−0.018228	0.9856
DLn (OPI(−1))	−0.029192	0.070712	−0.412827	0.6837
DLn (OPI(−2))	−0.228102	0.075546	−3.019368	0.0063
CointEq(−1)*	−0.376252	0.038004	−9.900354	0.0000

PEC: Per capita energy consumption, REC: Renewable energy consumption, FEC: Fossil energy Consumption, GDP: Gross domestic product, OPI: Oil price index. Source: Authors' calculation

The findings presented in Table 7 indicate that in Model 3, with lnREC serving as the dependent variable, human capital (HCI) holds a statistically significant association with the average per capita renewable energy consumption (REC) in Vietnam, at the 1% level of significance. Specifically, the results demonstrate that a 1% increase in human capital leads to a 3.323% increase in average renewable energy consumption. These outcomes align with previous research studies (e.g., Ozcan and Danish, 2022; Shahbaz, 2022; Pegkas, 2024) and are consistent with the authors' expectations. From this, it can be inferred that human capital development could be leveraged as an effective means of promoting renewable energy consumption. Higher levels of human capital have the potential to spur R and D activities and technological innovation in renewable energy production. Furthermore, individuals with elevated human capital, including higher levels of education, income, and capacity, are more likely to adopt clean energy practices, thereby driving renewable energy consumption. Notably, the research results demonstrate that the economic growth variables (GDP), physical capital (K), and oil price index (OPI) are not statistically significant across all three models. This implies that these factors have not yet directly impacted the average energy consumption, average fossil energy consumption, and average renewable energy consumption.

Figure 3: Results of the stability test



Source: Authors' calculation

Table 8: The summary of model tests

Types of tests	Hypothesis	F-statistic	Conclusion
	Model 1		
Ramsey	H0: The model is correctly specified.	0.299919 (0.5926)	Do not reject H0
Serial correlation LM	H0: There is no autocorrelation.	0.789796 (0.4746)	Do not reject H0
Breusch - Pagan -Godfrey	H0: The variance of the error does not change	0.561706 (0.8559)	Do not reject H0
Jarque-Bera	H0: The residuals are normally distributed	5.083112 (0.078744)	Do not reject H0
	Model 2		
Ramsey	H0: The model is correctly specified	0.321540 (0.5821)	Do not reject H0
Serial correlation LM	H0: There is no autocorrelation	1.289311 (0.3176)	Do not reject H0
Breusch - pagan -Godfrey	H0: The variance of the error does not change	0.456989 (0.9317)	Do not reject H0
Jarque-Bera	H0: The residuals are normally distributed	0.539982 (0.763386)	Do not reject H0
	Model 3		
Ramsey	H0: The model is correctly specified	0.007985 (0.9296)	Do not reject H0
Serial Correlation LM	H0: There is no autocorrelation	1.303271 (0.2937)	Do not reject H0
Breusch - pagan -Godfrey	H0: The variance of the error does not change	0.793949 (0.6137)	Do not reject H0
Jarque-Bera	H0: The residuals are normally distributed	0.493947 (0.781162)	Do not reject H0

Source: Authors' calculation

The findings presented in Table 6 indicate that in Model 3, with lnREC serving as the dependent variable, human capital (HCI) holds a statistically significant association with the average per capita renewable energy consumption (REC) in Vietnam, at the 1% level of significance. Specifically, the results demonstrate that a 1% increase in human capital leads to a 3.323% increase in average renewable energy consumption. These outcomes align with previous research studies (e.g., Ozcan and Danish, 2022; Shahbaz, 2022; Pegkas, 2024) and are consistent with the authors' expectations. From this, it can be inferred that human capital development could be leveraged as an effective means of promoting renewable energy consumption. Higher levels of human capital have the potential to spur R and D activities and technological innovation in renewable energy production. Furthermore, individuals with elevated human capital, including higher levels of education, income, and capacity, are more likely to adopt clean energy practices, thereby driving renewable energy consumption. Notably, the research results demonstrate that the economic growth variables (GDP), physical capital (K), and oil price index (OPI) are not statistically significant across all three models. This implies that these factors have not yet directly impacted the average energy consumption, average fossil energy consumption, and average renewable energy consumption.

The coefficient of the Error Correction Model (ECM) has been observed to be statistically significant at the 1% level and has exhibited a negative sign in both Model 1, Model 2 and Model 3. This outcome is in line with the anticipated results and serves to reinforce the notion of a long-term relationship between average energy consumption, average fossil energy consumption, average renewable energy consumption, and human capital, along with several control variables included in the model, as previously determined by the ARDL bounds test (Table 8).

The stability analysis of the CUSUM and CUSUMQ regression coefficients has been illustrated in Figure 3. It can be seen that both CUSUM and CUSUMQ lines stay within the critical bounds at the 5% significance level, which suggests that the residuals of the model are stable. Consequently, it can be ascertained that the model is appropriate for analytical purposes

5. CONCLUSION AND POLICY IMPLICATIONS

This study presents an in-depth analysis of the impact of human capital on Vietnam's energy consumption patterns from 1986 to 2019. By employing the Autoregressive Distributed Lag (ARDL) methodology, the study examines the long-term relationship between human capital and aggregate energy consumption, consumption of fossil fuels, and the mean consumption of renewable energy. The findings of the study reveal a positive and significant correlation between human capital and energy consumption. Moreover, the study highlights the catalytic effect of economic growth on the consumption of fossil fuels in the short run. At the first and second difference levels, the study observes that changes in the oil price index lead to a reduction in the mean energy consumption, consumption of fossil fuels, and renewable energy. Additionally, the study reveals that modifications in physical capital result in a decline in the mean energy consumption and consumption of fossil fuels at the first difference level.

The research results confirm the positive impact of human capital on the consumption of renewable energy, fossil energy, and synthetic energy in Vietnam. Therefore, in the future, the Government needs to do the followings:

1. The development of human capital has a significant impact on the efficient consumption of energy, as it is humans who decide to consume environmentally friendly products and conduct research and development to create energy-saving technologies. To enhance the human capital index of Vietnam, it is crucial to increase the average number of years of schooling for the Vietnamese populace. This requires investing in infrastructure, renewing equipment, improving the quality of teachers and education management staff, and building a continuous and regular learning environment to encourage the populace to access training forms easily. Efforts must also be made to improve the quality of vocational education, particularly by adopting a learner-centric approach that promotes independence, autonomy, and creativity. Despite the significant increase in university and college enrollment rates of Vietnamese students in 2019 compared to 1986, the country's rate still lags behind that of other ASEAN countries and nations with high average incomes. Students from low-income families and ethnic minorities, in particular, have a considerably lower rate of access to university education. Therefore, there is a need for various training models, learning forms, and appropriate financial support policies to ensure that all high school graduates have equal opportunities to enroll in colleges or universities. Integrating the goal of energy-saving and efficiency into the strategy of building and developing culture and people is essential to meeting the requirements of sustainable national development. To achieve this, it is necessary to promote propaganda activities and improve the awareness of individuals and communities about saving electricity, using energy-saving and efficient appliances, and closely linking these efforts with the development of Vietnamese people to build a new society responsible for national energy resources, with a focus on preserving energy resources for future generations.
2. The transition towards a greater reliance on renewable energy sources is a process that necessitates acceleration. In the context of Vietnam, this energy transition is a complex undertaking that demands substantial investment capital, paradigm shifts in thinking, alterations in management methodologies, and technological innovation. Given the modest scale of Vietnam's economy and the increasing dependence of the domestic energy market on the global energy market, these challenges are particularly pronounced. However, this transition process also presents several advantages. The proportion of renewable energy is experiencing a rapid increase, facilitated by advancements in technology and significant cost reductions. Furthermore, this transition aligns with the global objective of achieving net-zero emissions, as stipulated by international commitments. Thus, despite the inherent challenges, the energy transition in Vietnam holds promise for a sustainable future.
3. The government needs to foster research and development (R and D) in technology, particularly in activities that innovate for energy conservation and efficiency. Commercial enterprises, being significant consumers of energy, should be incentivized to adopt innovative technologies, implement green technologies, and minimize energy consumption. The objective of utilizing energy in a manner that is both efficient and conserves resources should be integrated into the national strategy for technological and technical innovation. A roadmap should be established to phase out antiquated

technologies, techniques, machinery, and equipment that are characterized by low energy and electrical efficiency. The goal of using energy efficiently and conservatively should also be incorporated into the plan for economic restructuring. The economic structure should be transformed in a manner that promotes harmony and sustainability, limiting and ultimately eliminating the reliance on energy consumption for economic growth. This approach aligns with the broader global commitment to sustainable development and the prudent use of resources.

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