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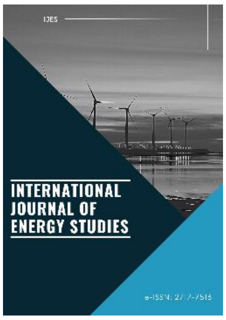

Research Article

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Effects of financial development, foreign direct investment, and economic growth on renewable energy consumption: Evidence from Czechia

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Highlights

- This study examines the effects of financial development, foreign direct investment (FDI), and economic growth on renewable energy consumption in Czechia.
- The analysis covers data from 1993 to 2023.
- ARDL analysis was performed to determine whether the variables' effects on renewable energy consumption differ in the short and long term.
- Increased financial development reduces renewable energy consumption in the short term. In the long term, financial development enables the increase of renewable energy consumption.
- FDI and economic growth do not affect renewable energy consumption in the short term. According to long-term results, economic growth increases the consumption of renewable energy.

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ABSTRACT

This study examines the effects of financial development, foreign direct investments (FDI), and economic growth on renewable energy consumption in Czechia. ARDL analysis was applied using data from the 1993-2023 period. Thus, we attempted to determine whether the short- and long-term effects of variables on renewable energy consumption differ. According to the analysis results, financial development decreases short-term renewable energy consumption and increases long-term renewable energy consumption. In the long term, economic growth also increases renewable energy consumption. Although the long-term effect of FDI on renewable energy consumption is positive, it is statistically insignificant. The model's error correction mechanism works, and approximately 47% of the deviations occurring in the short term are balanced in the next period. Czechia's emphasis on increasing financial development may help increase renewable energy consumption in the long term.

Keywords: Financial development, Foreign direct investment, Renewable energy consumption, ARDL

1. INTRODUCTION

Energy is a basic element necessary to sustain daily life and perform economic activities. Energy is required to operate many devices we use in our daily lives [34]. The production of more goods and services is necessary for economic growth. More energy is needed to produce more goods and services. Greater energy use supports economic growth by increasing the production of goods and services. Energy consumption is a necessary condition for economic growth. Simultaneously, an increase in economic growth increases the need for energy, increasing energy consumption. Thus, a mutual interaction emerges between economic growth and energy consumption [12].

As an important element of economic growth and daily life, energy consumption has increased rapidly, especially in recent years. Population growth, technological developments, increased economic competition, and industrialisation trigger an increase in energy consumption. Currently, energy consumption largely depends on fossil fuels [38]. However, fossil fuels are available in limited quantities in nature, and their distribution among countries is unequal. Therefore, the rapid depletion of fossil fuels creates the problem of increasing energy consumption becoming unaffordable. The imbalance in the distribution of fossil fuels among countries has caused some countries to become dependent on foreign energy sources. Additionally, fossil fuel consumption increases environmental pollution, triggers global warming, and accelerates the negative effects of climate change. For all these reasons, countries reduce fossil fuel consumption and increase renewable energy consumption [32]. Renewable energy sources are sustainable, do not harm the environment, and do not increase carbon emissions. Renewable energy helps to improve air quality, reduce the negative effects of climate change, and protect biodiversity. In addition, the transition to RE reduces countries' dependence on energy markets, creates new employment areas, and ensures energy security [15]. To reduce environmental pollution and make economic growth sustainable, increasing renewable energy consumption is necessary [10]. However, for renewable energy consumption to increase, renewable energy production must also increase. Some difficulties are encountered during the implementation of RE projects. The startup capital required for renewable energy projects is high. Cost of establishing production facilities and distributing energy. In this context, renewable energy is capital-intensive rather than labour-intensive. Meeting the financing required to establish a system based on renewable energy that uses only public resources is very difficult. The private sector must be involved in this process [4]. However, high costs are an obstacle for the private sector. However, the decreasing cost of renewable energy over time is promising for the energy transition. The table below clearly shows the decline in renewable energy costs over time. The Table 1 the costs per kWh in dollars for different types of RE. A significant decrease in renewable energy costs has been observed in the last decade. The cost reduction in other types of energy other than bioenergy is over 50%. The cost reduction in bioenergy is over 19%. The decline in renewable energy costs reveals the importance of the transition to renewable energy not only from an environmental but also an economic perspective. While renewable energy increases translation quality, it also ensures a more efficient use of financial resources.

Table 1. Renewable Energy Costs (Cost per kWh ($)) (2014-2023)

Year	Concentrated solar power	Offshore wind	Bioenergy	Solar PV	Onshore wind
2014	0,26	0,19	0,09	0,18	0,09
2015	0,25	0,15	0,08	0,13	0,07
2016	0,29	0,12	0,08	0,12	0,07
2017	0,28	0,11	0,08	0,09	0,06
2018	0,16	0,11	0,06	0,08	0,05
2019	0,24	0,09	0,07	0,07	0,05
2020	0,12	0,09	0,08	0,06	0,04
2021	0,12	0,08	0,07	0,05	0,04
2022	0,12	0,08	0,06	0,05	0,03
2023	0,12	0,07	0,07	0,04	0,03
Total change 2014-2023	**-54.2%**	**-60.0%**	**-19.4%**	**-75.0%**	**-62.3%**

Source: Our World in Data

At this point, a strong financial system is required to develop the renewable energy sector. The connection between financial development and REC can be established in two ways. The first is the relationship that emerges indirectly. The finance sector plays an active role in providing financing for renewable energy projects. As previously stated, facilities that produce renewable energy are needed to increase renewable energy consumption. Project managers should receive financial support under appropriate conditions to cover the costs required for the installation of these facilities and the realisation of production. The higher the degree of financial development of the country and the healthier the financial system functions, the more favourable conditions and lower financial support costs. The existence of developed capital markets reduces companies' liquidity risks and diversifies risks. This enables the emergence of transparent relationships between borrowers and lenders in financial markets. Directs collected funds to productive areas [31]. The second relationship between financial development and RE consumption is directly revealed. With financial development, consumers can borrow under more favourable conditions to purchase durable goods. Durable consumer goods, such as automobiles, computers, refrigerators, and air conditioners, consume large amounts of energy. Greater purchase and use of these goods may increase energy consumption, affecting the country's total energy consumption [46].

Developed financial systems are of great importance in establishing the infrastructure and technological systems necessary for renewable energy [11]. In addition to financial development, FDI play a key role in the widespread use of renewable energy. To increase renewable energy consumption, both capital and technology are required. FDI in a country increases technology inflows and capital flows. Multinational companies that come to the country as direct foreign investors bring not only capital but also knowledge, skills, expertise, and new technology-based production systems [27]. Direct foreign investments can be described as a driving force in the implementation of production systems that do not harm the environment and the adoption of green technologies [29]. However, FDIs improve environmental quality by accelerating the transition to renewable energy consumption, but they may also increase environmental pollution. Foreign direct investments increase the country's capital accumulation and help the country's economic growth. Economic growth increases the need for energy and increases energy consumption. Meeting the increasing energy need with fossil fuels instead of renewable energy sources increases environmental pollution [30]. Therefore, the relationship between FDI and RE consumption is ambiguous. With globalisation, direct foreign investments increased rapidly after 1980 [9]. Despite the increase in FDI, the amount of FDI used for renewable energy is very low [43]. The areas to which these investments are directed are as important as the amount of foreign investment. In the process of transitioning to renewable energy, whether foreign direct investment in the country will increase renewable energy consumption and, if so, at what rate should be determined. According to the results, the environmental, energy, and economic policies can be reshaped.

This study examines the impact of financial development, foreign direct investment, and economic growth on renewable energy consumption. It was examined for Czechia. Czechia has placed great emphasis on energy transformation, especially after 2000, and has implemented some policies to increase the consumption of renewable energy. While Czechia acts in line with EU targets in its energy policies, it also implements strategies specific to its internal dynamics in its national policies. The EU attaches great importance to energy efficiency, reducing greenhouse gas emissions, and increasing renewable energy consumption in the fight against climate change. As an EU member state, the Czechia also aims to achieve these goals [28]. There are significant differences in Czechia's renewable energy policies compared with those before and after 2004. 2004 is the year the Czechia became a member of the EU in 2004. Before 2004, only water resources were used as renewable energy sources in the Czechia. However, because of EU accession and adaptation to EU policies after 2004, the use of other renewable energy sources also began. With the law enacted in 2005, legal regulations were implemented to support the installation and operation of renewable energy sources. After this date, more favourable conditions were provided for the production and consumption of renewable energy [39]. Czechia focuses on financial incentives and legal regulations in line with renewable energy policies. Tax reductions, green premium payments, and exemptions from property taxes for renewable energy sources form the basis of the Czech Republic's energy policies. In addition, one of the most distinctive features of Czechia's energy policies is the provision of incentives to small-scale businesses. Various supports are provided to make renewable energy production sustainable and to increase small-scale producers' competitiveness. For example, small- and medium-sized fixed tariff support is applied. The state has committed to paying a fixed price to SME that produce electricity per unit of electricity they produce. In addition, different policies are implemented in Czechia depending on the type of renewable energy sources. Due to the natural conditions of the Czechia, solar, wind, and biomass energy are the main sources of renewable energy. The largest share of Czechia's renewable energy resources is in solar energy. The use of this type of energy is being expanded by giving subsidies by the state for solar panels to be placed on roofs [23].

Looking at the results of the implemented policies, while the Czechia's per capita renewable energy consumption was 446.24 kWh in 1993, this rate increased to 739.56 kWh in 2000 and 1186.46 kWh in 2008. It did not fall below 1000 kWh after 2008. In 2022 and 2023, the per capita renewable energy consumption was 3272.41 and 3220.89 kWh, respectively.

The share of renewable energy consumption energy consumption in the Czechia has also increased over time. This share was 3.6% in 1990 and 5.9% in 2000. In 2009, this rate increased above 10% and was calculated as 10.2%. The increase in the share of renewable energy consumption energy consumption in Czechia continued in subsequent years. This percentage reached 17% in 2020 and 2021. In the EU, the share of renewable energy consumption energy consumption was 6.9% in 1990. This rate reached 9% in 2000 and 13.6% in 2009. For the EU, this rate was 21% in 2020. As can be seen, while renewable energy consumption in the Czechia increased over time, it remains below that of the EU. This indicates that the Czechia's share of renewable energy consumption should be increased further.

Studies on how financial development, FDI, and economic growth affect renewable energy consumption have increased rapidly in the literature, especially in recent years. Similar studies should be conducted on different countries or country groups to explain the relationship between variables correctly, and the results should be compared. No study has examined the effects of these variables on renewable energy consumption in Czechia. For this reason, the analysis to be conducted on the Czechia will contribute to the literature. Since the 1990s, foreign direct investment inflows have increased rapidly in Czechia. Similarly, renewable energy consumption has also gradually increased. It is important to determine what policy Czechia should follow to further increase its renewable energy consumption. This study aims to examine how and in what direction some important factors affecting renewable energy consumption affect renewable energy consumption and to make suggestions for Czechia's energy policies. ARDL analysis was applied to determine whether the variables' effects on renewable energy consumption were different in the short and long term. The analysis covers data from 1993 to 2023.

2. LITERATURE REVIEW

The literature examining the effects of financial development, FDI, and economic growth on renewable energy consumption is expanding. Some studies examined the relationship between financial development and renewable energy consumption, and other studies examined the relationship between FDI, and renewable energy consumption was examined. Economic growth is an indicator included in most studies. The number of studies that examine financial development, FDI, economic growth, and renewable energy consumption together is relatively low. Variables' effects on renewable energy consumption vary depending on the country examined.

Many studies have determined that financial development and economic growth positively affect renewable energy consumption. Eren et al. [7] analysed the effects of financial development and economic growth on renewable energy consumption in India. Data from India from 1971 to 2015 were used. According to the co-integration analysis, the variables have a long-term relationship. According to the DOLS analysis, financial development and economic growth have a positive impact on renewable energy consumption. A two-way causality exists between economic growth and renewable energy consumption. A unidirectional relationship exists between financial development and renewable energy consumption, running from financial development to renewable energy consumption. Mukhtarov et al. [17] studied the relationship between financial development and renewable energy consumption in Azerbaijan. ARDL analysis was carried out using data from 1993 to 2015. In addition to financial development, the model incorporates economic growth and energy prices. The influence of financial development and economic growth on renewable energy consumption is positive and statistically significant. The influence of energy prices is negative. Alsagr and Van Hemmen [2] investigated the effects of financial development and geopolitical risk on renewable energy consumption. The analysis covers developing countries, and data from the countries for the period 1996-2015 was used. According to the results of the GMM analysis, financial development and geopolitical risk positively affect renewable energy consumption in developing countries, and these effects are more pronounced in the long term. Mukhtarov, Yüksel, and Dinçer [18] examined the impact of financial development and economic growth on Türkiye's renewable energy consumption of Turkiye. Data from 1980 to 2019 were used. ARDL and VECM were applied. The effects of financial development and economic growth on renewable energy consumption in Turkiye are positive and statistically significant. Shahbaz et al. [35] examined the effects of financial development, FDI, and economic growth on renewable energy consumption. Data covering the 2000-2019 period from 39 countries were used. Financial development, FDI, and economic growth have a positive impact on renewable energy consumption. Chang, Qian, and Dilanchiev [5] investigated the relationship between financial development and renewable energy. Data from 2000 to 2020 from 30 provinces in China were used. In China, financial development has led to an increase in renewable energy consumption. Each 1% increase in financial development increases renewable energy consumption by 0.24%. Samour et al. [33] investigated the impact of financial development, FDI, and economic growth on renewable energy consumption in the UAE. ARDL analysis and the Granger causality test were applied using data from 1989 to 2019. Financial development, direct foreign investment, and economic growth increase renewable energy consumption. Yu et al. [45] examined the relationship between financial development, IT, and renewable energy consumption. Data from 1996 to 2018 from 35 countries were used. Financial development and ICTs positively impact renewable energy consumption. Advances in information and communication technologies have increased the positive impact of financial development on renewable energy consumption.

Financial development may also have a negative impact on renewable energy consumption in some countries or groups of countries. Nawaz and Rahman [19] studied the effects of financial development, FDI, and economic growth on renewable energy consumption in Sub-Saharan African countries. In addition, the variables of corporate quality and human capital were included in the analysis. Data from 31 countries between 2002 and 2019 were used. Financial development negatively affects renewable energy consumption in Sub-Saharan African countries. However, FDIs do not significantly affect renewable energy consumption.

The impact of financial development on renewable energy consumption differs depending on the development level, economic, and social conditions of the countries examined. Amuakwa-Mensah and Nasström [3] empirically tested this difference. Amuakwa-Mensah and Nasström [3] examined the effect of financial development on renewable energy consumption in 124 countries with different income groups. Financial development is represented by banking performance, and five performance indicators are used. Indicators of return on assets, asset quality, market value, managerial efficiency, and financial stability were used. The effect of financial development on renewable energy consumption has been determined to differ depending on the development level of countries and creates heterogeneous effects.

There are also different results regarding the impact of FDI on RE consumption. While FDIs increase renewable energy consumption in some countries, they decrease it in others. Fan and Hao [8] studied the relationship between FDI, economic growth, and renewable energy consumption. Data from 31 provinces in China from 2000 to 2015 were used. In China, a long-term and stable balance relationship exists between FDI, economic growth, and renewable energy consumption. Shahzadi et al. [36] examined the effects of FDI, economic growth, and technological innovations on renewable energy consumption in developing countries. Data approximately 1991-2021 was used and the ARDL method was applied. FDI, economic growth, and technological innovation promote renewable energy consumption. Tariq et al. [40] discussed renewable electricity consumption rather than total renewable energy consumption. They conducted research on countries participating in China's Belt and Road Initiative project. ARDL method was applied using the dataset covering the years 2000-2020. Foreign direct investments and economic growth have a positive long-term impact on renewable electricity consumption but a negative short-term impact. Akpanke et al. [1] used the panel ARDL method to examine the impact of FDIs on renewable energy consumption using data from 15 countries in West Africa between 1990 and 2021. In addition to FDI, economic growth, inflation, and financial development are included in the model. Foreign direct investments have a long-term positive impact on renewable energy consumption. Economic growth has no significant effect on renewable energy consumption in the short and long term. The broadband money supply, an indicator of financial development, positively and negatively affects renewable energy consumption in the short and long term, respectively. Nor and Hassan Mohamud [21] examined the impact of FDI, economic growth, and trade openness on renewable energy consumption in Somalia. Data from 1990 to 2019 were used. According to the ARDL analysis, FDI, economic growth, and commercial openness increase renewable energy consumption in Somalia. Van Nguyen [42] investigated the effects of financial development, economic growth, and FDI on renewable energy consumption in Vietnam and other ASEAN countries. According to the results of the study using data from 1970 to 2022, financial development and economic growth negatively affect renewable energy consumption. The impact of direct foreign investments on renewable energy consumption is positive. Kang et al. [14] examined the impact of FDIs and economic growth on renewable energy consumption in selected South Asian countries. Data from 1990 to 2019 were used. According to FMOLS and DOLS methods, FDI has a negative impact on renewable energy consumption in South Asia. The influence of economic growth on renewable energy consumption is positive. Telatar and Adimli [41] examined the impact of FDI on the renewable energy consumption of Türkiye's Türkiye. In the study covering the period 1973-2022, the Fourier ARDL method was applied. Direct foreign investment negatively affects renewable energy consumption. Economic growth does not affect renewable energy consumption. Islam et al. [13] added inflation to the model while examining the effects of financial development, FDI, and economic growth on renewable energy consumption. Data from 1990 to 2022 were used in the analysis of the BRICS countries, and the DOLS method was applied. Long-term financial development, economic growth, and inflation increase renewable energy consumption. Increased direct foreign investment reduces renewable energy consumption.

3. DATA AND METHODS

In this study, the factors affecting renewable energy consumption were examined. Although many factors affect renewable energy consumption, this study discusses foreign direct investments, financial development, and economic growth variables. The links between these variables and RE consumption are explained in detail in the Introduction section. The per capita renewable energy consumption is used to represent renewable energy consumption. The share of net FDIs entering the country in GDP was used to represent direct foreign investments, and the net domestic credit volume was used to represent financial development. GDP per capita represents economic growth. Explanations of the variables are explained in the Table 2.

Table 2. Variables and Description

Variable	Symbols	Description	Data Source
Renewables energy	RENCONS	Renewable consumption per capita, measured in kWh per person.	Our World in Data
FDI	FDI	Foreign direct investment (FDI), net inflows (% of GDP)	World Bank
Economic Growth	GDP	GDP per capita (constant 2015 US$)	World Bank
Financial Development	FINDEV	Net domestic credit (current LCU)	World Bank

Analysis was performed for Czechia. The dataset covers the period 1993-2023. Since the direct foreign investment data for Czechia in the World Bank database start from 1993, the dataset began in 1993. The most recent data on the variables in the model are available for 2023; thus, the analysis includes the period 1993-2023. The analysis method is ARDL analysis. ARDL analysis has advantages such as being applicable to series with different degrees of stationarity, showing short- and long-term results, and providing healthy results even in small samples [24]. Since the degree of stationarity of the series used in this study differed from each other, the ARDL method was used.

When applying ARDL analysis, the following steps are followed [16]: First, unit root tests determine the stationarity degrees of the series. The lag length is then calculated. The ARDL model was established according to the calculated lag length, and it was tested whether there was a co-integration relationship between the variables. If a co-integration relationship exists, the model's long- and short-term coefficients are interpreted. Check whether the error correction model is working or not. Diagnostic tests are performed to examine whether the model has autocorrelation, heteroscedasticity, normal distribution, structural breaks, or stability problems.

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests were applied to determine stationarity. The ADF test was created by improving the Dickey-Fuller (DF) test proposed by Dickey and Fuller (1979). The DF test assumes that the model's error term does not contain correlation. The ADF test includes the model's lagged values of the dependent variable. Thus, the ADF test assumes that a correlation exists. The ADF test is based on the DF test, which involves three different situations. As shown in the equations below, different situations were tested depending on the existence of the constant and trend. Equation (1) shows the situation in which there is no constant and trend, equation (2) shows the situation in which there is a constant, and equation (3) shows the situation in which there is both a constant and trend [26].

$$\Delta_{yt} = \delta y_{t-1} + \sum_{i=1}^{p} \beta i \, \Delta y_{t-i} + \mu_t \quad (1)$$

$$\Delta_{yt} = \alpha 0 + \delta y_{t-1} + \sum_{i=1}^{p} \beta i \, \Delta y_{t-i} + \mu_t \quad (2)$$

$$\Delta_{yt} = \alpha 0 + \delta y_{t-1} + \alpha 2t + \sum_{i=1}^{p} \beta i \, \Delta y_{t-i} + \mu_t \quad (3)$$

Phillips and Perron [25] developed the PP unit root test. According to the PP test, the error terms may be heterogeneous, and weak dependency may exist among the error terms. The regression equations for the PP test are given in Eqs. (4) and (5).

$Y_t = \alpha_0 + \alpha_1 y_{t-1} + \mu_t$ (4)

$Y_t = \alpha_0 + y_{t-1} + \alpha_2 (t - T/2) + \mu_t$ (5)

(T= Number of observations, μ_t = The distribution of error terms)

After determining that the analysis was suitable for the ARDL method according to unit root tests, a model was created for the analysis. Equation (6) refers to the analysis model.

$$lnRENCONS_t = \beta_0 + \beta_1 lnFDI_t + \beta_2 lnFINDEV_t + \beta_3 lnGDP_t + \varepsilon_t \quad (6)$$

In equation (6), lnRENCONS is the dependent variable, whereas lnFDI, lnFINDEV, and lnGDP are the independent variables. The form of equation (6) adapted to ARDL analysis is shown in equation (7). In this equation, the coefficients β_1, β_2, β_3, β_4 show the short-term relationship between the variables. The coefficients β_5, β_6, β_7, β_8 show the long-term relationships between the variables. While Δ represents the first difference in the series, β0 is the slope coefficient.

$$\Delta lnRENCONS_t = \beta_0 + \Sigma_{i=1}^{k}\beta_1 \Delta lnRENCONS_{t-i} + \Sigma_{i=1}^{l}\beta_2 \Delta lnFDI_{t-i} + \Sigma_{i=1}^{m}\beta_3 \Delta lnFINDEV_{t-i} + \Sigma_{i=1}^{n}\beta_4 \Delta lnGDP_{t-i} + \beta_5 \Delta lnRENCONS_{t-1} + \beta_6 \Delta lnFDI_{t-1} + \beta_7 \Delta lnFINDEV_{t-1} + \beta_8 \Delta lnGDP_{t-1} + \varepsilon_t \quad (7)$$

The existence of a co-integration relationship between the variables is tested using the created ARDL equation. The H0 hypothesis states that no co-integration relationship exists between the variables, whereas the H1 hypothesis states that there is a co-integration relationship between the variables. Equations (8) and (9) provide the hypotheses for the co-integration test.

$H_0 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$ (8)

$H_0 \neq \beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$ (9)

The F-test statistic was used to determine the co-integration relationship. The F-test statistic values are compared with the lower and upper critical values determined for the variables according to different significance levels. If the F-Test statistic is greater than the upper critical value, a cointegration relationship exists among the variables. If the F-Test statistic is smaller than the lower critical value, no cointegration relationship exists between the variables. If the F-Test statistic lies between the lower and upper critical values, no definitive conclusion regarding the co-integration relationship can be reached [20].

Equation (10) shows the error correction model. 〖δECT〗_(t-i) is the error correction term, and δ is the coefficient of the error correction term. The error correction model explains whether short-term deviations eventually reach equilibrium. If the coefficient of the error correction term is negative, less than 1, and statistically significant, the error correction model works [37].

$$\Delta lnRENCONS_t = \beta_0 + \Sigma_{i=1}^{k}\beta_1 \Delta lnRENCONS_{t-i} + \Sigma_{i=1}^{l}\beta_2 \Delta lnFDI_{t-i} + \Sigma_{i=1}^{m}\beta_3 \Delta lnFINDEV_{t-i} + \Sigma_{i=1}^{n}\beta_4 \Delta lnGDP_{t-i} + \delta ECT_{t-i} + \varepsilon_t \quad (10)$$

The stages of ARDL analysis were performed, and the obtained results are explained in the next section.

4. RESULTS

In the first stage of the study, the descriptive statistics of the variables included in the model were examined. Table 3 shows that the model includes 31 observations. The variable with the highest standard deviation is lnRENCONS, whereas the variable with the lowest standard deviation is lnGDP. The skewness value is less than 0 for all variables, indicating that they are skewed to the left. Kurtosis values are 3 for all variables. Because it is smaller than 3, all series in the model exhibit a platykurtic distribution.

Table 3. Descriptive Statistics of Variables

	lnRENCONS	lnFDI	lnFINDEV	lnGDP
Mean	7.254.714	1.358.740	2.831.801	9.631.697
Median	7.078.726	1.448.671	2.848.337	9.711.476
Maximum	8.107.717	2.335.731	2.925.773	9.915.282
Minimum	6.100.855	-0.100870	2.733.645	9.233.465
Std. Dev.	0.699660	0.589754	0.557862	0.215431
Skewness	-0.022823	-0.301721	-0.015859	-0.334167
Kurtosis	1.354.798	2.727.300	1.640.605	1.780.247
Jarque-Bera	3.498.832	0.566406	2.388.240	2.498.690
Probability	0.173875	0.753367	0.302970	0.286693
Sum	2.248.961	4.212.094	8.778.582	2.985.826
Sum Sq. Dev.	1.468.572	1.043.429	9.336.285	1.392.314
Observations	31	31	31	31

After determining the descriptive statistics, unit root tests were performed to determine whether the model used in the study was suitable for ARDL analysis. The degree of stationarity of the series was determined according to the unit root test results. First, the ADF unit root test was performed. Unit root tests were conducted for the constant and trend models. Table 4 lists the test results. The information in parentheses indicates the probability values. According to the ADF unit root test, the dependent variable lnRENCONS is first-order stationary, that is, I (1). lnFINDEV and lnGDP are I (1) and lnFDI is I (0) among the dependent variables. Among the variables, no variable is I (2). The variables are either I (1) or I (0).

Table 4. ADF Unit Root Tests

Intercept			*Intercept and trend*		
At level			**At level**		
Variable	**Test Statistics**	**Critical Value**	**Variable**	**Test Statistics**	**Critical Value**
lnFDI	-4.571519 (0.0010)	-3.670170 (1%) *	lnFDI	-4.549256 (0.0055)	-4.296729 (1%) *
		-2.963972 (5%) **			-3.568379 (5%) **
		-2.621007 (10%) ***			-3.218382 (10%) ***
lnFINDEV	-0.041728 (0.9469)	-3.679322 (1%)	lnFINDEV	-2.886195 (0.1811)	-4.309824 (1%)
		-2.967767 (5%)			-3.574244 (5%)
		-2.622989 (10%)			-3.221728 (10%)
lnGDP	-1.767135 (0.3888)	-3.670170 (1%)	lnGDP	-1.398432 (0.8407)	-4.296729 (1%)
		-2.963972 (5%)			-3.568379 (5%)
		-2.621007 (10%)			-3.218382 (10%)
lnRENCONS	-1.196750 (0.6626)	-3.670170 (1%)	lnRENCONS	-1.639133 (0.7528)	-4.296729 (1%)
		-2.963972 (5%)			-3.568379 (5%)
		-2.621007 (10%)			-3.218382 (10%)
The first difference			**The first difference**		
Variable	**Test Statistics**	**Critical Value**	**Variable**	**Test Statistics**	**Critical Value**
lnFINDEV	-3.411763 (0.0188)	-3.679322 (1%)	lnFINDEV	-3.346035 (0.0789)	-4.309824 (1%)
		-2.967767 (5%) **			-3.574244 (5%)
		-2.622989 (10%) ***			-3.221728 (10%) ***
lnGDP	-4.226315 (0.0026)	-3.679322 (1%) *	lnGDP	-4.454873 (0.0071)	-4.309824 (1%) *
		-2.967767 (5%) **			-3.574244 (5%) **
		-2.622989 (10%) ***			-3.221728 (10%) ***
lnRENCONS	-6.022185 (0.0000)	-3.679322 (1%) *	lnRENCONS	-5.993168 (0.0002)	-4.309824 (1%) *
		-2.967767 (5%) **			-3.574244 (5%) **
		-2.622989 (10%) ***			-3.221728 (10%) ***

Note: *, **, and *** denote significance at 1%, 5%, and 10%, respectively.

In addition to the ADF unit root test, the PP unit root test was performed. Table 5 presents the results of the PP unit root test. The PP unit root test was also applied to the constant and trend models. The information in parentheses indicates the probability values. The dependent variable on the PP test is lnRENCONS I (1). Among the independent variables, lnFINDEV and lnGDP are I (1), whereas lnFDI is I (0).

Table 5. PP Unit Root Test Results

Intercept			*Intercept and trend*		
At level			**At level**		
Variable	Test Statistics	Critical Value	Variable	Test Statistics	Critical Value
lnFDI	-4.551746 (0.0011)	-3.670170 (1%) *	lnFDI	-4.523122 (0.0059)	-4.296729 (1%) *
		-2.963972 (5%) **			-3.568379 (5%) **
		-2.621007 (10%) ***			-3.218382 (10%) ***
lnFINDEV	-0.608185 (0.8543)	-3.670170 (1%)	lnFINDEV	-2.147707 (0.4998)	-4.296729 (1%)
		-2.963972 (5%)			-3.568379 (5%)
		-2.621007 (10%)			-3.218382 (10%)
lnGDP	-1.712948 (0.4148)	-3.670170 (1%)	lnGDP	-1.559394 (0.7850)	-4.296729 (1%)
		-2.963972 (5%)			-3.568379 (5%)
		-2.621007 (10%)			-3.218382 (10%)
lnRENCONS	-1.208197 (0.6576)	-3.670170 (1%)	lnRENCONS	-1.724240 (0.7153)	-4.296729 (1%)
		-2.963972 (5%)			-3.568379 (5%)
		-2.621007 (10%)			-3.218382 (10%)
The first difference			**The first difference**		
Variable	Test Statistics	Critical Value	Variable	Test Statistics	Critical Value
lnFINDEV	-3.396987 (0.0194)	-3.679322 (1%)	lnFINDEV	-3.282448 (0.0891)	-4.309824 (1%)
		-2.967767 (5%) **			-3.574244 (5%)
		-2.622989 (10%) ***			-3.221728 (10%) ***
lnGDP	-4.226371 (0.0026)	-3.679322 (1%) *	lnGDP	-4.416398 (0.0078)	-4.309824 (1%) *
		-2.967767 (5%) **			-3.574244 (5%) **
		-2.622989 (10%) ***			-3.221728 (10%) ***
lnRENCONS	-6.035168 (0.0000)	-3.679322 (1%) *	lnRENCONS	-5.998896 (0.0002)	-4.309824 (1%) *
		-2.967767 (5%) **			-3.574244 (5%) **
		-2.622989 (10%) ***			-3.221728 (10%) ***

Note: *, **, and *** denote significance at 1%, 5%, and 10%, respectively.

According to the ADF and PP unit root tests, there was no obstacle in applying ARDL analysis to the model. Therefore, after deciding on the analysis to be used, the next stage was started. ARDL analysis is sensitive to the lag length. Determining the lag length is important for the accuracy of the analysis results. Table 6 lists the lag length results. According to the information provided in the table, the suitable lag length was set to 1.

Table 6. Lag Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	7.018713	NA	9.54e-06	-0.208187	-0.019595	-0.149122

1	109.5018	169.6272*	2.49e-08*	-6.172537*	-5.229574*	-5.877213*
2	122.8447	18.40399	3.20e-08	-5.989288	-4.291955	-5.457705

Note: *Stands for the criterion selecting the lag order. LR, FPE, AIC, SC, and HQ represent the sequential modified LR test statistic, final prediction error, Akaike information criterion, Schwarz information criterion, and Hannan–Quinan information criterion, respectively.

The ARDL model was created after determining the appropriate lag length. As shown in Table 7, the (3,0,1,0) model is the most suitable ARDL model chosen according to the Akaike information criterion. The third lag of lnRENCONS, the model's dependent variable, was also included in the model. Among the independent variables, the lagged values of lnFDI and lnGDP were not considered, and the first lag of lnFINDEV was included in the model.

Table 7. ARDL (3,0,1,0) Model Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob.
lnRENCONS (-1)	0.711209	0.157513	4.515247	0.0002
lnRENCONS (-2)	0.357833	0.189791	1.885401	0.0740
lnRENCONS (-3)	-0.534064	0.173862	-3.071770	0.0060
lnFDI	0.063895	0.045319	1.409894	0.1739
lnFINDEV	-1.290967	0.472922	-2.729770	0.0129
LnFINDEV (-1)	1.636098	0.438875	3.727934	0.0013
lnGDP	0.849599	0.415530	2.044616	0.0543
C	-14.61753	3.488744	-4.189914	0.0005

Before examining the model's long- and short-term coefficients, we must test whether there is a co-integration relationship between the variables. If no co-integration relationship is concluded between the variables, interpreting the long-term coefficients will not make sense. F statistics were used to detect the co-integration relationship. Table 8 presents the F statistic results. The F statistic value is 5.906096. The F statistic value is greater than the lower and upper critical values at 5% and 10% significance levels, respectively. Therefore, a co-integration relationship exists among the variables in the model.

Table 8. Bound-Testing Co-integration Test (F-Bounds test)

k	F-statistic	Significance	I (0)	I (1)
	5.906096	1%	5.333	7.063
3		5%	3.710	5.018
		10%	3.008	4.150

Note: k is the number of independent variables.

The long-term coefficients in the ARDL model were interpreted because a cointegration relationship was determined among the variables. Table 9 presents the model's long- and short-term results. According to the analysis results, lnFDI in the Czechia positively affected lnRENCONS, but this effect was statistically insignificant. This shows that the increase in FDI increases renewable energy consumption. However, the statistical insignificance of this effect should be interpreted with caution. Because it may not be the right approach to say that there is no relationship between FDI and renewable energy consumption in the Czechia just by looking at this result. There may be many reasons for the insignificant relationship between variables. One of these reasons may be that although FDI has a positive impact on renewable energy consumption, this effect is too small to be observed. Additionally, FDI can have both positive and negative effects on renewable energy. The fact that these positive and negative effects balance each other eventually may also cause the effect to be meaningless. Another possibility is related to the dataset length. Although a minimum of 30 years of data is sufficient for ARDL analysis, a longer data set may be needed for FDIs to have a positive and statistically significant impact on renewable energy consumption in the Czechia. Therefore, this result between FDI and renewable energy consumption should be evaluated by considering these possibilities.

The lnFINDEV variable positively affects lnRENCONS. This impact is statistically significant. A 1% increase in financial development results in a 0.74% increase in renewable energy consumption. The effect of the LnGDP variable on the lnRENCONS variable is positive and statistically significant at the 10% level. A 1% increase in economic growth increases renewable energy consumption by 1.83%. According to the short-term results, lnFINDEV negatively affects lnRENCONS. In the short term, a 1% increase in financial development results in a 1.29% decrease in renewable energy consumption. This effect is statistically significant because the probability value is 0.0008. The coefficient of the error correction term is statistically significant and negative, smaller than 1. The error correction mechanism works. Approximately 47% of the deviations occur in the short-term reach balance in the next period.

Table 9. ARDL Regression Results

Long-run coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
lnFDI	0.137402	0.105925	1.297161	0.2064
lnFINDEV	0.742182	0.329618	2.251645	0.0334
lnGDP	1.827009	0.919381	1.987216	0.0580
Short Run Coefficients				

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ	-0.465022	0.089216	-5.212297	0.0000
D (lnRENCONS (-1))	0.176231	0.143832	1.225253	0.2329
D (lnRENCONS (-2))	0.534064	0.153671	3.475359	0.0020
D (lnFINDEV)	-1.290967	0.336716	-3.833999	0.0008
C	-14.61753	2.819534	-5.184379	0.0000

Diagnostic tests were performed after interpreting the model's long- and short-term coefficients. The diagnostic test results are included in Table 10. To determine whether an autocorrelation problem exists, the Breusch-Godfrey Serial Correlation LM Test was applied. The probability value of the test is >0.05. This means that there is no autocorrelation problem in the model. Jarque-Bera Test was performed to test the assumption of normality. According to the Jarque-Bera test, the error terms of the model exhibit a normal distribution, and the normality assumption is met. The Breusch-Pagan-Godfrey Test was applied to test the assumption of heteroscedasticity. Because the probability value of the test is greater than 0.05, the model has no heteroscedasticity problem. The probability value of the Ramsey Reset test was used to determine whether the model building error was greater than 0.05. A probability value greater than 0.05 indicates no model building error.

Table 10. Diagnostic Tests

Diagnostic Tests	F-Statistics	P-value
Breusch-Godfrey Serial Correlation LM Test	5.398897	0.0672
Jarque-Bera Normality Test	0.217519	0.896946
Breusch-Pagan-Godfrey Heteroskedasticity Test	9.604213	0.2121
Ramsey Reset Test	4.274624	0.0526

The CUSUM and CUSUMSQ tests were used to examine whether a structural break existed in the model. The following figure shows the results of these tests. The error terms of the model are within the confidence intervals; thus, there is no structural break, and the stability condition is satisfied.

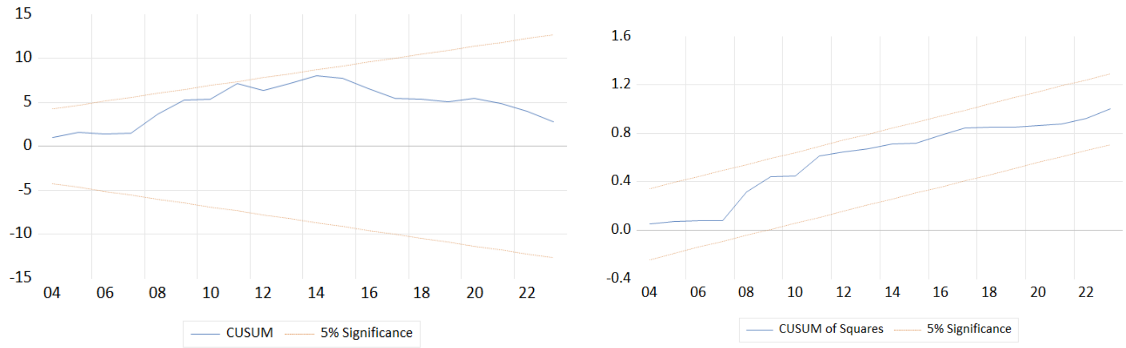

Figure 1. CUSUM and CUSUM Squares Test

Financial development positively affects Czechia's renewable energy consumption. This result is similar to those of Eren et al. [7], Mukhtarov et al. [17], Alsagr and Van Hemmen [2], Mukhtarov et al. [18], Shahbaz et al. [35], Chang et al. [5], Samour et al. [33], and Yu et al. [45]. The conclusion that economic growth positively affects renewable energy consumption is consistent with those of Eren et al. [7], Mukhtarov et al. [17], Mukhtarov et al. [18], Shahbaz et al. [35], Samour et al. [33], Shahzadi et al. [36], and Nor and Hassan Mohamud [21]. Although the analysis was conducted on different countries or groups of countries, similar results were obtained in terms of the variables' effects on renewable energy consumption.

5. CONCLUSION

This study sought to answer the question of how financial development, foreign direct investments, and economic growth affect renewable energy consumption in Czechia. ARDL analysis was carried out using Czechian data covering the period 1993-2023 from the Czechia. The results of the analysis reveal that the effects of the variables in the model on renewable energy consumption differ in the short and long term. Increased financial development reduces renewable energy consumption in the short term. In the long term, financial development enables the increase of renewable energy consumption. FDI and economic growth do not affect renewable energy consumption in the short term. According to long-term results, economic growth increases the consumption of renewable energy. Even if the relationship between FDI and renewable energy consumption is positive, it is statistically insignificant. However, the model's error correction mechanism is working. The coefficient of the error correction term is less than 1, which is statistically significant and negative. Thus, deviations occur in the short-term reach balance in the long-term.

The findings confirm that financial development should be given importance in order to increase renewable energy consumption in Czechia. This result supports the link between financial development and RE consumption. As stated in the introduction section of the study, new technologies and production systems are needed to increase the consumption of renewable energy. Because the realisation of this restructuring involves high costs, companies need financial support. Further development of the financial system is necessary so that companies can access low-cost financial support under favourable conditions. Domestic credit volume is used as a financial development indicator in this study. Therefore, to increase renewable energy consumption in Czechia, the domestic loan volume must be increased and regulations and improvements regarding the credit mechanism must be made. Policies can be produced, particularly for the financial system's credit channel. In addition to financial development, economic growth has been determined to increase renewable energy consumption. The rate of increase in renewable energy consumption can be increased with the help of policies that will increase economic growth.

Although this study contributes to the literature, some obstacles and limitations are encountered. It is important to explain these limitations as it will guide future studies. In this study, the effects of FDI, financial development, and economic growth on renewable energy consumption were investigated. The model's dependent variable is renewable energy consumption. Although different variables can be used to represent renewable energy consumption, renewable energy consumption per capita was used in this study. The use of per capita energy consumption instead of total energy consumption is important for comparing the study with different countries. The total energy consumption of countries with a small population, such as the Czechia, cannot be the same as the total energy consumption of countries with a large population. The amount of renewable energy per capita was preferred to avoid differences arising from population. One of the study's independent variables is FDI. Since the data on the share of FDI in GDP is available in the World Bank database starting from 1993, the dataset starts from 1993. Since the most recent data for all variables is from 2023, a dataset consisting of 31 observations covering the period between 1993 and 2023 is available. Although 31 years of data is sufficient for ARDL analysis, the number of independent variables that can be used is limited. Of course, different independent variables can be added to the model. However, considering the length of the data set, increasing the number of independent variables may damage the robustness of the analysis results. ARDL analysis includes the lags of each independent variable in the model and the lags of the dependent variable. As the number of independent variables increases, so does the total number of parameters, making it difficult to estimate the model. In addition, increasing the number of independent variables increases the possibility of multicollinearity problems in the model. Because of these factors, care was taken to avoid using too many independent variables in the model. Thus, the robustness and reliability of the analysis were preserved. Financial development is another independent variable of the study. Many variables can be used for financial development. Different variables, such as M2/GDP, the ratio of non-performing loans to total loans, loans given to the private sector, the IMF financial development index, and the ratio of banking sector assets to gross domestic product, can be used. Net domestic credits were used as a proxy for financial development in this study. There are two main reasons for this. First, Czechia has a paucity of data on other indicators representing financial development. A minimum of 30 years of observation is required for reliable ARDL analysis. The required number of observations would not be provided if other variables were chosen. The second reason is to examine the effects of financial support on RE consumption. Renewable energy investments should be increased to increase renewable energy consumption. Because renewable energy investments require high costs, a well-functioning credit mechanism is required to make these investments. The link between financial development and renewable energy consumption was revealed by choosing the net domestic credit indicator, which includes the credits provided by the financial sector to both the private sector and the government. Considering these limitations, future studies can compare the analysis with this study by examining different indicators. For example, using panel data instead of a single country could increase the number of observations, thereby increasing the number of available independent variables. Analysis can be conducted for different countries outside the Czech Republic, as data for some variables are available for longer periods of time for some countries outside the Czech Republic. Additionally, renewable energy consumption can be represented by studies examining sub-sectors instead of total consumption amount. For example, it can focus on specific areas such as wind or solar energy consumption. Therefore, other researchers can further contribute to the literature by comparing the findings of this study with different studies.

DECLARATION OF ETHICAL STANDARDS

The author of the paper submitted declares that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHOR(S)

Fergül Özgün: Conceptualization, methodology, investigation, modeling, visualization, data analysis, resources, manuscript writing, and editing.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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