

## Could Financial Deepening Be the Solution to the Carbon Emission Problem? Empirical Evidence from CEE Countries

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### **Abstract**

Financial deepening has increased in recent decades in CEE countries that have transitioned from a centrally planned economy to a market economy. However, its impact on carbon emissions is controversial. Although the determinants of emissions have been frequently examined in line with the EU's goal of net zero carbon emissions, the empirical literature on the effects of financial deepening is insufficient. In that context, this study aims to investigate the impact of financial depth on the level of carbon emissions in CEE countries. A panel threshold regression model was carried out for a set of 11 countries, from 1995 to 2018. The main findings confirmed the existence of a double threshold effect. While in the low financial depth regime, financial deepening increases carbon emissions, in the medium regime it reduces them. In the high regime, however, no statistically significant effects were observed regarding the effects of the financial deepening. Moreover, emissions are reduced with taxes. None of the countries in the sample has financial depth index value between threshold values, according to the last three years' averages. The findings argue that financial deepening will not be an adequate solution to reducing emissions and point to the importance of public tax policies.

**Keywords:** financial depth, public policy, environmental taxes.

## 1. Introduction

Over the past decades, the problem of climate change has attracted the attention of many researchers, politicians, and national and international organizations. It is accepted that greenhouse gas (GHG) emissions, especially carbon, are the main factor underlying this problem. In this context, the European Union (EU) aims to reduce GHG emissions by 55% in 2030 and to be carbon neutral in 2050, within the framework of the European Green Deal. This goal, which is difficult to achieve, also presents difficulties for Central and Eastern European (CEE) countries. In these countries, growth-oriented economic strategies have generally been based on energies produced from solid fuels, and environmental effects have not been given enough attention over the years (Pakulska, 2021). However, with EU accession and political transformation, environmental effects have come to the fore. Therefore, it is crucial for these countries to analyze the determinants of carbon emissions and take measures to reduce them. Li *et al.* (2022) drew attention to the importance of going beyond traditional determinants in this process, and working on deeper environmental factors such as financial depth. Financial depth is a measure of the financial sector in terms of size and liquidity. Thus, it refers to the size of banks, other financial institutions, and financial markets in a country relative to total economic output (WB, 2020). As Shahbaz *et al.* (2013a) suggest, the exclusion of financial variables in the growth-emissions nexus may lead to the omission of an important variable in the regression. However, the impact of this transformation on carbon emissions is uncertain. Some studies conducted in recent years (Paramati, Mo and Huang, 2021; Li *et al.*, 2022; Wang and Dang, 2022) emphasized the importance of the issue. However, these studies do not focus on CEE countries. However, testing the effects of financial depth on carbon emissions for CEE countries has differences and will make a significant contribution to the literature in at least two respects. Firstly, globalization in CEE countries started especially after the Cold War period, therefore its effects appeared later. Secondly, due to the delay in economic integration, financial depth in CEE countries remained on average lower than in other European countries. While the financial market depth index of the International Monetary Fund (IMF) was 0.35 in Europe as a whole in the 1995–2018 period, in countries such as Bulgaria, Romania, Slovakia, Estonia, Latvia, and Lithuania, it did not even reach the level of 0.10.

Based on the above discussions, this study aims to examine the determinants of carbon emissions across CEE countries with special attention to the impact of financial depth. For that purpose, in line with the maximum data availability, this study focuses on 11 CEE countries (Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovak Republic, Slovenia, Estonia, Latvia, and Lithuania) for the period 1995–2018. This study employs the panel threshold regression methodology developed by Hansen (1999) to test the non-linear impacts of financial depth. This methodology avoids the multicollinearity that may arise if the products and squares of the variables are used. Moreover, it allows us to calculate the specific threshold values that divide the regime into two or more components. Thus, it is possible to make more concrete policy recommendations for each country by comparing the actual financial depth with the calculated threshold values.

This study has some additional contributions to the literature. Namely, most of the existing empirical literature focused on the effects of financial development and approximated it by two indicators: the ratio of private credit to GDP, and stock market capitalization to GDP. Still, Svirydzhenka (2016) draws attention to the multidimensional nature of financial development. With an increase in globalization over time, banks have begun to share their important role in the financial system with actors such as investment banks, insurance companies, mutual funds, pension funds, and so on. According to Abbasi and Riaz (2016), as economies develop, the share of financial sectors in the total economy increases, and the stock market becomes more important than the banking sector. The economic agents now have an opportunity to raise their money through stocks, bonds, and wholesale money markets. Therefore, instead of using proxies that focus on one dimension of financial development, IMF put forth a financial development index that summarizes how developed financial institutions and markets are.

The index focuses on three factors: depth, access, and efficiency as indicators of financial development. In line with the main objective of the study, we focused on the financial depth index. The index was obtained with a three-step approach. First, the data set was normalized. Second, the normalized variables were aggregated into the sub-indices. And third, sub-indices were aggregated into the final index. We also dealt with the market and institution depth, separately. In measuring the financial institutions' depth – private sector credit to GDP, pension fund assets to GDP, mutual fund assets to GDP and insurance premium, life and non-life to GDP were used. In measuring the financial market depth – stock market capitalization to GDP, stocks traded to GDP, international depth securities of government to GDP, total depth securities of financial corporations to GDP, and total depth securities of nonfinancial corporations to GDP were used. Therefore, instead of focusing on a single variable, these indices contain more information by making use of different variables.

In sum, the present study will contribute to the existing literature in the following ways. First, this study empirically investigates the impact of the financial depth in the CEE region. Second, it uses the financial depth index in contrast to previous studies that used a single variable to proxy financial development. Third, the relationship between financial depth and carbon emissions is determined through non-linear panel threshold regression. Thus, the multicollinearity problem has been avoided. Fourth, second-generation unit root tests were used considering the cross-sectional dependency. Fifth, thanks to the empirical methodology, it is possible to calculate specific values of thresholds that have regime-switching effects. And sixth, the study differentiates from the previous studies by employing two different dimensions of the financial depth of CEE countries: financial market depth and financial institutions depth.

The rest of the paper is presented as follows: Section 2 provides a brief review of the related literature; Section 3 presents the methodology; Section 4 presents data; Section 5 reports empirical findings; and Section 6 provides a conclusion and presents relevant policy suggestions.

## 2. Literature review

In the literature, the views on the relationship between financial indicators and carbon emissions are controversial. The first view suggests that financial development increases carbon emissions by alleviating credit constraints and increases total output which results in more energy consumption and hence more emissions. As Sadorsky (2010) suggests, financial development can increase demand for energy by making it easier for consumers to buy big-ticket items like automobiles, houses, and air conditioners. Similarly, thanks to financial development, businesses may expand their existing work by hiring more employees, and purchasing more machinery, thereby increasing their carbon emissions.

On the other hand, the second view suggests that financial development decreases carbon emissions by boosting environmentally-friendly technologies in the production process. Financial development may improve environmental quality through initiated green financing projects such as investment in renewable energy sources, alternative energy fuels, and sustainable projects (Vo and Zaman, 2020). Financial development, on the one hand, provides the necessary capital for green technology investments and reduces financial costs, on the other hand, it may improve allocation efficiency and risk management (Paramati, Mo and Huang, 2021).

A plethora of empirical work focuses on the nexus of financial indicators – carbon emissions. However, these studies generally focus on financial development as an indicator instead of financial deepening. The studies of Shahbaz *et al.* (2013a, 2013b) are among the pioneering studies investigating the relationship between financial indicators and carbon emissions using time series data. In Shahbaz *et al.* (2013b), the nexus was investigated for the case of Malaysia using a bounds testing approach. They used real domestic credit to private sector per capita as a proxy of financial development and included a squared term of financial development in the regression to observe nonlinear effects. While the coefficient of this term was found to be insignificant, they found a negative relationship between financial development and carbon emissions. On the other hand, they confirmed the presence of an inverted U-shaped relationship between financial development and carbon emissions in Indonesia in their other study (Shahbaz *et al.*, 2013a).

In a later study, Abbasi and Riaz (2016) explored the impact of financial development on carbon emissions in Pakistan. They considered the full sample period of 1971–2011 and a reduced sample sub-period (1988–2011) that corresponded to greater financial development. They employed the share of total credit and the share of private sector credit as the indicators of financial intermediation development. By using the Autoregressive Distributed Lag (ARDL) approach, they observed that financial development mitigates carbon emissions only in the latter sample. On the other hand, financial development increases carbon emissions in the early stages of financial development. Gill, Hassan and Haseeb (2019) investigated the nexus between income and carbon emissions considering the moderating role of financial development in Malaysia. The results of the ARDL bounds test indicate a significant moderating impact of financial development on the income-emission relationship. In addition, they observed a negative relationship between financial development and carbon emissions.

Rahman *et al.* (2019) investigated the nexus between income and carbon emissions by considering the moderating role of financial development in Pakistan. They used a composite financial development index, and they employed the ARDL approach. Their results confirm the moderating role of financial development on the Environmental Kuznets Curve (EKC) and the authors argue that policymakers should take this into account. In a later study, Rahman *et al.* (2020) examined the relationship between financial development and carbon emissions in the case of Lithuania. They employed the bounds testing approach and the Granger causality test. The results of the study advocate a U-shaped relationship between financial development and carbon emissions. Additionally, the result obtained from the Granger causality test points to a unidirectional causality running from financial development to carbon emissions. Shahbaz *et al.* (2020) examined the role of financial development on carbon emissions in the United Arab Emirates by using a cointegration test. They generated a financial development index comprising three bank-based and two stock-based financial indicators by using principal component analysis. They included squared term and cubic term of financial development. According to the results of the cointegration test, the coefficient estimate of the square of financial development was positive, while the coefficient estimate of the cube was negative. Therefore, financial development reduces carbon emissions in the first place, increases it after a certain level, and decreases it after a new certain level. This relationship between financial development and carbon emissions is similar to the U and inverted-N shapes.

There are also empirical studies that use samples based on panel data while examining the relationship between financial development and carbon emissions. From these studies, Jiang and Ma (2019) tested the nexus between financial development and carbon emissions in a panel of 155 countries. The results obtained from system-GMM methodology showed that there is a positive relationship between the financial development and emissions. Similarly, the results of Saud *et al.* (2019), based on dynamic seemingly unrelated regression, suggest that there is a positive relationship between financial development and carbon emissions in the 18 CEE countries. The country-wise results also show that environmental quality decreases due to the increase in financial development in six of the countries in the sample. Similarly, Vo and Zaman (2020) tested the impact of financial development on carbon emissions in a panel of 101 countries by using data from 1995 to 2018. They used broad money supply as a financial development indicator and employed a dynamic Generalized Method of Moments (GMM) estimator as the methodology. Their results showed that financial development decreases carbon emissions across countries. In another panel data study, Tahir *et al.* (2021) tested the relationship between financial development and carbon emissions in South Asian economies. They used the index of financial development that includes ‘domestic credit by the financial sector’, ‘domestic credit to the private sector’, and ‘domestic credit to the private sector by the banks’ as a proxy of financial development. Their results confirmed that financial development increases carbon emissions.

Instead of financial development, Le, Le and Taghizadeh-Hesary (2020) focused on the effects of financial inclusion. They used principal component analysis to determine

the indicators of financial inclusion and tested the impact of financial inclusion on carbon emissions using a sample of 31 Asian countries. Their results confirmed that an increase in financial inclusion leads to higher carbon emissions.

Finally, few studies focused on the effects of financial deepening itself on carbon emissions. In the first of these studies, Paramati, Mo and Huang (2021) investigated the role of financial deepening on carbon emissions in a panel of 25 OECD economies. Their results based on an augmented mean group estimator suggest that all financial indicators increase carbon emissions. However, they employed the financial institution index, financial market index, and overall financial development index of the IMF as the indicator of financial deepening. Therefore, special attention has not been paid to the financial market and institutions deepening. Besides, they assume a linear relationship between financial indicators and carbon emissions ignoring non-linear effects. In a later study, Li *et al.* (2022) captured the impact of financial deepening on carbon emissions. Their study focuses on BRICS economies during the period 1990–2019. Different indices such as the financial deepening index, financial institution deepening index, and financial market deepening index have been used as proxies. By using panel ARDL methodology, the study concludes that financial institution deepening and financial market deepening affect carbon emissions positively in the long run, in linear models. In nonlinear models, all measures of financial deepening trigger carbon emissions in the long run. However, they assumed a linear relationship between financial deepening and environmental quality ignoring non-linear effects between the related variables. Besides, their results cannot be generalized to different country groups.

To sum up, to the best of our knowledge, there is no previous study in the literature that deals with financial deepening with the separation of market and institutions for CEE countries and also considers non-linear relations. It is hoped that this study will serve to make up for this deficiency.

### **3. Methodology**

In testing the relationship between financial depth and carbon emissions, the panel threshold regression model of Hansen (1999) has been used due to some of its advantages. Firstly, as the methodology employs a panel dataset, the degree of independence increases, which increases the reliability of empirical estimates. Secondly, the methodology eliminates the multicollinearity problem that may arise while using squares, cubes, or multiplications of the variables. And lastly, the methodology estimates the specific threshold values that divide the sample into two or more regimes. Hence, depending on whether the threshold variable is below or above the threshold value for each country, it is possible to make perceptible policy recommendations.

In this section, the panel threshold regression method is explained. This paper aims to investigate the possible threshold effect of financial depth on carbon emissions. Therefore, the panel single threshold regression model proposed by Hansen (1999) is employed as

follows:

$$car_{it} = \mu_i + \beta_{11}FD_{it}I(FD_{it} \leq \lambda) + \beta_{12}FD_{it}I(FD_{it} > \lambda) + e_{it} \quad (1)$$

Where  $car_{it}$  is the CO<sub>2</sub> emissions (metric tons in capita) of country  $i$  in time  $t$ ,  $FD_{it}$  is the threshold variable indicating financial depth index in country  $i$  in time  $t$ . In the analysis section, financial institution depth and financial market depth indices will be used separately as financial deepening indicators.  $I(\cdot)$  is the indicator function,  $\lambda$  is the threshold parameter that separates the model into two regimes with coefficients  $\beta_{11}$  and  $\beta_{12}$ ,  $e_{it}$  is the error term, and the parameter  $\mu_i$  is the individual fixed effect.

Equation (1) can be re-written as follows:

$$car_{it} = \mu_i + \beta' x_{it}(\lambda) + e_{it} \quad (2)$$

where  $\beta = (\beta_{11}, \beta_{12})'$  and  $x_{it} = (FD_{it}I(FD_{it} \leq \lambda), FD_{it}I(FD_{it} > \lambda))$

Taking averages of equation (2) over time gives:

$$\overline{car}_i = \mu_i + \beta' \bar{x}_i(\lambda) + \bar{e}_i \quad (3)$$

And taking the difference between (2) and (3) yields

$$car^*_{it} = \mu_i + \beta' x^*_{it}(\lambda) + e^*_{it} \quad (4)$$

where  $car^*_{it} = car_{it} - \overline{car}_i$ ,  $x^*_{it} = x_{it} - \bar{x}_i$ , and  $e^*_{it} = e_{it} - \bar{e}_i$ .

All observations and errors are stacked for each individual:

$$Y^* = X^*(\lambda)\beta + e^* \quad (5)$$

where  $Y^*$  is the vector of the dependent variable,  $X^*(\lambda)$  is the vector of independent variables and  $e^*$  is the vector of errors.

The slope coefficient can be calculated with the OLS estimator as follows:

$$\hat{\beta}(\lambda) = (X^*(\lambda)'X^*(\lambda))^{-1}X^*(\lambda)' Y^* \quad (6)$$

With the vector of residuals as in equation (7):

$$\hat{e}^*(\lambda) = Y^* - X^*(\lambda)\hat{\beta}(\lambda) \quad (7)$$

The sum of squared errors will be as in equation (8):

$$S(\lambda) = \hat{e}^*(\lambda)\hat{e}^*(\lambda)' \quad (8)$$

Here,  $\lambda$  can be calculated by minimizing the concentrated sum of squared errors. Hence, the least squared estimator is:

$$\hat{\lambda} = \underset{\lambda}{\operatorname{argmin}} S(\lambda) \quad (9)$$

The estimator of the residual variance is:

$$\hat{\sigma}^2 = \frac{1}{n(T-1)} \hat{e}^*{}' \hat{e}^* = \frac{1}{n(T-1)} S(\hat{\lambda}) \quad (10)$$

Where the coefficient estimate is  $\hat{\beta} = \hat{\beta}(\lambda)$  the residual vector is  $\hat{e}^* = \hat{e}^*(\lambda)$ ,  $n$  is the number of countries in the sample and the  $T$  is the number of years.

In this step, it is necessary to test whether the threshold effect is statistically significant in the model given in equation (1). The null and alternative hypotheses are:

$$H_0: \beta_{11} = \beta_{12}$$

$$H_1: \beta_{11} \neq \beta_{12}$$

We use the likelihood ratio test of the null hypothesis, and if the probability value is below the critical value, the null hypothesis of no threshold is rejected.

#### 4. Data and description

This study uses yearly data from 1995 to 2018 to observe the impact of financial depth on carbon emissions in 11 CEE economies. Due to the availability of the data, we selected the sample countries as follows: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia.

To examine the impact of financial depth on carbon emissions, we benefit from two different financial depth indicators of the IMF: the financial market depth index and the financial institutions depth index. Instead of focusing on a single variable, these indicators make use of different variables to present a composite index with more information. They also allow for a more detailed analysis by considering the market and institution depth, separately. These indices were also used in some preliminary studies in the literature (e.g., Saud *et al.*, 2019; Paramati, Mo and Huang, 2021; Li *et al.* 2022). The financial institutions depth index is calculated by using four different indicators: private sector credit to GDP, pension fund assets to GDP, mutual fund assets to GDP, and insurance premium, and life and non-life to GDP. Similarly, the financial markets depth index is calculated by five different indicators: stock market capitalization to GDP, stocks traded to GDP, international depth securities of government to GDP, total depth securities of financial corporations to GDP, and total depth securities of nonfinancial corporations to GDP. The index ranges from 0 (not deep) to 1 (highest degree of depth).

Carbon emissions are considered to be the main cause of climate change. Many studies in the literature (e.g., Narayan and Narayan, 2010, Aye and Edoja, 2017; Hashmi and Alam, 2019; Neves, Marques and Patricio, 2020; Demiral, Akca and Tekin, 2021) used CO<sub>2</sub> emissions as an indicator. Similarly, in this study CO<sub>2</sub> emissions (metric tons per capita) data obtained from the WB database were used in the logarithmic form (*car*).

The Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model which has been widely used by scholars (York, Rosa and Dietz, 2003; Hashmi and Alam, 2019), was mainly used to determine the empirical model. This model is an expanded version of the IPAT (Impact= population\*affluence\*technology) model which is proposed by Ehrlich and Holdren (1971). The IPAT model measures the environmental impact by using population, affluence, and technology. Later, Dietz and Rosa (1997) expanded this model by using its stochastic version to account for the impacts of other factors. Based on the STIRPAT model, we used urban population (*urbp*), GDP

per capita in constant 2015 USD (*gdppc*), and share of services sector in GDP (*ser\_gdp*) as the indicators of population, affluence, and technology, respectively.

We also extended the STIRPAT model incorporating new variables including the foreign direct investments as a percentage of GDP (*fdi\_gdp*) and the environmental taxes as a percentage of GDP (*tax\_gdp*). There is growing literature on the effects of foreign direct investments on carbon emissions. There are studies which both support the pollution haven hypothesis (e.g., Blanco, Gonzalez and Ruiz, 2013; Kiviyiro and Arminen, 2014; Gokmenoglu and Taspinar, 2016; Bae, Li and Rishi, 2017; Hanif *et al.*, 2019) and the pollution halo hypothesis (e.g., Pao and Tsai, 2011; Kiviyiro and Arminen, 2014; Hao and Liu, 2015; Mert and Boluk, 2016; Rafindadi, Muye and Kaita, 2018; Balsalobre-Lorente *et al.*, 2019; Mert and Caglar, 2020; Neves, Marques and Patricio, 2020). Besides, environmental taxes are expected to reduce emissions (Lin and Li, 2011; Hao *et al.*, 2021).

All explanatory variables and the dependent variable are converted to the natural logarithmic form. Table 1 gives the descriptions and sources of the variables. Annex 1 shows the summary statistics of all the variables in the model.

**Table 1:** Data description and sources

Dependent Variable	Definition	Source
<i>car</i>	CO <sub>2</sub> emissions (metric tons per capita)	World Bank, WDI (2022)
Explanatory Variables	Definition	Source
<i>urbp</i>	Urban population, total	World Bank, WDI (2022), own calculations
<i>gdppc</i>	GDP per capita (constant 2015 USD)	World Bank, WDI (2022)
<i>ser_gdp</i>	Services, value added (% of GDP)	World Bank, WDI (2022)
<i>tax_gdp</i>	Environmentally related tax revenue (% of GDP)	OECD.Stat. (2022), World Bank, WDI (2022), own calculations
<i>fdi_gdp</i>	Foreign direct investments, net inflows (% of GDP)	World Bank, WDI (2022)
<i>trade_gdp</i>	Exports and imports (% of GDP)	World Bank, WDI (2022), own calculations
<i>fmd</i>	Financial markets depth index	IMF (2022)
<i>fid</i>	Financial institutions depth index	IMF (2022)

## 5. Empirical analysis

In the first step, the impact of financial market depth and financial institutions depth on carbon emissions were tested by using robust fixed-effects models. The regression results are summarized in Table 2. In the first model, the effects of financial depth indicators were tested by using the basic STIRPAT model. In the second model, environmental tax and FDI variables were added to the model. In the third model, we tested for the existence of the environmental Kuznets curve by including the square of per capita GDP (*gdppc\_sq*)

in logarithmic form. And, in the last model, the nonlinear effect of financial market depth was tested by including the square of financial market depth ( $fmd\_sq$ ).

Table 2: Fixed effect regression results

Dependent variable: <i>car</i>	Model 1	Model 2	Model 3	Model 4
<i>urbp</i>	-1.3142*** (0.3242)	-1.3468*** (0.3257)	-1.3439*** (0.2676)	-1.3705*** (0.3227)
<i>gdppc</i>	-0.1781* (0.0865)	-0.1454 (0.0943)	-0.1185 (1.1967)	-0.1750* (0.0901)
<i>gdppc_sq</i>			-0.0033 (0.1569)	
<i>ser_gdp</i>	-0.2754* (0.1392)	-0.1930* (0.1034)	-0.1933* (0.0969)	-0.1960* (0.1013)
<i>tax_gdp</i>		-0.0423** (0.0181)	-0.0424* (0.0198)	-0.0443** (0.0172)
<i>fdi_gdp</i>		0.0035*** (0.0009)	0.0035*** (0.0009)	0.0035*** (0.0008)
<i>fmd</i>	0.2762** (0.1146)	0.2844** (0.1105)	0.2845** (0.1110)	0.5687*** (0.1683)
<i>fmd_sq</i>				-0.7499** (0.2473)
<i>fid</i>	0.0445 (0.1157)	0.0036 (0.1119)	0.0031 (0.1058)	0.0139 (0.1094)
<i>cons</i>	11.1954*** (2.3211)	10.2248*** (2.3613)	10.1504*** (3.0289)	10.4572*** (2.3416)
Num. of obs.	264	264	264	264
F-stat.	9.03	13.34	11.84	22.18
R-square	0.2718	0.3526	0.3526	0.3641

Note: \*\*\*, \*\*, and \* denote statistical significance at 1%, 5%, and 10% levels, respectively. White heteroscedasticity consistent standard errors are in parentheses.

While there is no empirical evidence to support the Environmental Kuznets Curve according to model 3, we observed significant and alleviating effects of environmental taxes in the last three models. Moreover, models involving FDI variable support the pollution haven hypothesis. This finding is consistent with the studies of Blanco, Gonzalez and Ruiz (2013), Kiviyiro and Arminen (2014), Gokmenoglu and Taspinar (2016), Bae, Li and Rishi (2017), and Hanif *et al.* (2019).

All four models indicate a positive and statistically significant relationship between financial market depth and carbon emissions. On the other hand, none of the models indicate a statistically significant relationship between financial institution depth and carbon emissions. Therefore, we continue our analysis by focusing on the financial market depth. Another important finding that Table 2 shows us is that the financial market depth affects carbon emissions in a non-linear way. According to model 4, while the financial market depth increases carbon emissions, the square of the variable affects it

negatively<sup>1</sup>. This result constitutes an important reason for testing the relationship with threshold analysis.

Therefore, in the next step, we tested the possible threshold effect of financial market depth on carbon emissions by using the panel threshold regression of Hansen (1999). This methodology allows us to observe non-linear relationships and determine a specific threshold value that has a regime-switching effect. In this way, it is possible to make inferences by country. Moreover, the methodology removes the multicollinearity problem that may arise if the products and squares of the variables are used as in Table 2.

To avoid spurious regression problem, all variables in the panel threshold model must be stationary. However, as the sample includes similar countries in terms of geography, culture, and economics, we first need to test for cross-sectional dependency. And, if cross-sectional dependence among observed cross-sections exists, then we must use second-generation panel unit root tests which give more robust results than the first-generation tests.

**Table 3:** Residual cross-sectional independence

Test	Statistic	P-value
LM	103.8	0.0001
LM adj.	7.026	0.0000
LM CD	5.996	0.0000

To check for cross-sectional dependency, we benefited from three different tests: Breusch-Pagan (1980) Lagrange Multiplier (LM) test, the Pesaran, Ullah, and Yamagata (2008) bias-adjusted LM test, and the Pesaran (2004) Cross-Sectional Dependence (CD) test. The null hypothesis of each test states that the covariance between the residuals of cross-sections is equal to zero. As can be seen in Table 3, we reject the null hypothesis at a 1% level of statistical significance in all three tests.

Therefore, in the next stage, the second-generation panel unit root test of the Cross-Sectionally Augmented Dickey-Fuller (CADF) test of Pesaran (2007) was used to test for stationarity. The results of the stationarity test can be seen in Table 4.

As can be seen from Table 4, *car*, *urbp* and *tax\_gdp* series are not stationary at the level at 10% level of significance. These non-stationary series were made stationary by taking their first differences. At the next stage, panel single and double threshold models (M1) were estimated by using financial market depth as both threshold and regime-dependent variable:

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1 The findings were compared with the findings of the random effects model, and as a result of the Hausman (1978) test, the null hypothesis was rejected at the 5% significance level. Thus, the fixed effects model was preferred (Chi-square value = 46.03, probability value = 0.0000).

Table 4: Pesaran (2007) CADF second generation unit root test results

		Z(t-bar)		p-value	
		Without trend	With trend	Without trend	With trend
<i>car</i>	level	1.252	-1.135	0.8950	0.1280
	1 <sup>st</sup> diff.	-6.711***	-5.878***	0.0000	0.0000
<i>urbp</i>	level	-1.450*	0.213	0.0730	0.5840
	1 <sup>st</sup> diff.	-1.565*	1.195	0.0590	0.8840
<i>gdppc</i>	level	-5.959***	-3.601***	0.0000	0.0000
	1 <sup>st</sup> diff.	-3.805***	-1.390*	0.0000	0.0820
<i>ser_gdp</i>	level	-2.532***	-0.358	0.0060	0.3600
	1 <sup>st</sup> diff.	-6.078***	-5.121	0.0000	0.0000
<i>tax_gdp</i>	level	-1.221	0.353	0.1110	0.6380
	1 <sup>st</sup> diff.	-4.529***	-3.1130***	0.0000	0.0010
<i>fdi_gdp</i>	level	-5.908***	-3.767***	0.0000	0.0000
	1 <sup>st</sup> diff.	-9.531***	-7.535***	0.0000	0.0000
<i>fmd</i>	level	-1.390*	-2.732***	0.0820	0.0030
	1 <sup>st</sup> diff.	-4.487***	-3.573***	0.0000	0.0000

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

$$M1: carp_{it} = \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \alpha_5 fdi\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda) + \beta_2 fmd_{it} I(fmd_{it} > \lambda) + e_{it}$$

$$carp_{it} = \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \alpha_5 fdi\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda_1) + \beta_2 fmd_{it} I(\lambda_1 < fmd_{it} \leq \lambda_2) + \beta_3 fmd_{it} I(fmd_{it} > \lambda_2) + e_{it}$$

We also constituted two different models (R1 and R2) by using different explanatory variables to check for robustness. In model R(1), FDI variable was removed from the model and in model R(2) trade variable was substituted:

$$R1: carp_{it} = \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda) + \beta_2 fmd_{it} I(fmd_{it} > \lambda) + e_{it}$$

$$carp_{it} = \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda_1) + \beta_2 fmd_{it} I(\lambda_1 < fmd_{it} \leq \lambda_2) + \beta_3 fmd_{it} I(fmd_{it} > \lambda_2) + e_{it}$$

$$R2: carp_{it}$$

$$= \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \alpha_5 trade\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda) + \beta_2 fmd_{it} I(fmd_{it} > \lambda) + e_{it}$$

$$carp_{it} = \mu_i + \alpha_1 urb_{pit} + \alpha_2 gdppc_{it} + \alpha_3 ser\_gdp_{it} + \alpha_4 tax\_gdp_{it} + \alpha_5 trade\_gdp_{it} + \beta_1 fmd_{it} I(fmd_{it} \leq \lambda_1) + \beta_2 fmd_{it} I(\lambda_1 < fmd_{it} \leq \lambda_2) + \beta_3 fmd_{it} I(fmd_{it} > \lambda_2) + e_{it}$$

The single and double threshold regression results are summarized in Table 5. According to Table 5, the first model has a double threshold at 5% level of significance. Therefore, there is a non-linear relationship between financial market depth and carbon emissions. The threshold values of (0.1108) and (0.1239) divide the observations into three regimes in which financial market depth has a different effect on carbon emissions. The results of the other two models (R1 and R2) confirm the findings obtained from M1.

Table 5: Testing the threshold effects of financial market depth on carbon emissions

		F-stats	P-Values	Critical Values		Threshold Values	95% Confidence Interval
				1%	5%		
M1	Single threshold	11.55**	0.0100	10.9034	8.6181	0.1108	(0.1077-0.1109)
	Double threshold	13.42**	0.0167	14.9504	10.8100	0.1108 0.1239	(0.1077-0.1109) (0.1183-0.1241)
R1	Single threshold	11.29**	0.0100	10.8518	8.0721	0.1108	(0.1077-0.1109)
	Double threshold	12.06**	0.0267	13.5992	10.4774	0.1108 0.1239	(0.1107-0.1109) (0.1183-0.1241)
R2	Single threshold	12.86***	0.0033	11.4624	7.6048	0.1108	(0.1077-0.1109)
	Double threshold	10.97**	0.0333	12.2582	10.0167	0.1108 0.1239	(0.1107-0.1109) (0.1177-0.1241)

**Note:** (1) The *car* is the dependent variable. The *fmd* is the threshold variable. (2) Three hundred bootstrap replications are employed for each of the bootstrap tests. (3) \*\*\*, \*\* and \* denote that variables are statistically significant at 1%, 5% and 10% levels, respectively.

The coefficient estimates of double regression models are given in Table 6. According to Table 6, urban population and carbon emissions have a negative relationship in all models. This finding is inconsistent with the expectations, but urbanization can be thought of as an indicator of economic development. The countries in the sample are already developed economies and urbanization in these countries may have a reducing effect on emissions. In addition, according to European Environmental Agency (EEA, 2022), agricultural sector greenhouse gas emissions in the sample are clearly positive in the 2005–2019 period, except for Croatia and Romania. Emissions from the agricultural sector are relatively high, especially in Hungary, Estonia, Latvia, and Lithuania. Therefore, the negative impact of the increase in urbanization on emissions can be considered normal.

On the other hand, GDP per capita in M1 and R2 models has been found to have a significant positive effect on carbon emissions. Accordingly, the countries in the sample are still sweating in the ascending part of the environmental Kuznets curve. This indicates that an increase in income is still polluting CEE countries and increases the importance of emission reduction policies.

The share of the service sector in GDP reduces carbon emissions in all three models. This finding is consistent with the expectations and some previous studies (Ouyang *et al.*, 2019; Wang and Shao, 2019). Another important finding of this study is that environmental tax policies are effective in reducing carbon emissions. This finding is also confirmed

**Table 6:** Double threshold regressions for the financial market depth

Dependent variable: <i>car</i>	M1	R1	R2
<i>urbp</i>	-3.4734*** (0.5732)	-3.5379*** (0.6547)	-3.4893*** (0.6074)
<i>gdppc</i>	0.0388*** (0.0114)	0.0352** (0.0112)	0.0108 (0.0229)
<i>ser_gdp</i>	-0.0830** (0.0331)	-0.0967** (0.0368)	-0.0922** (0.0356)
<i>tax_gdp</i>	-0.0375** (0.0134)	-0.0420*** (0.0113)	-0.0429*** (0.0112)
<i>fdi_gdp</i>	0.0021 (0.0013)		
<i>trade_gdp</i>			0.0159 (0.0110)
<i>fmd</i> ( $fmd \leq \lambda_1$ )	0.1722** (0.0737)	0.1794** (0.0722)	0.1968** (0.0774)
<i>fmd</i> ( $\lambda_1 < fmd \leq \lambda_2$ )	-0.1785** (0.0744)	-0.1632** (0.0714)	-0.1546** (0.0681)
<i>fmd</i> ( $fmd > \lambda_2$ )	0.0242 (0.0302)	0.0288 (0.0311)	0.0294 (0.0320)
R-square	0.1991	0.1784	0.1825
F-stat.	59.72	57.50	44.82
F-prob.	0.0000	0.0000	0.0000

Note: \*\*\*, \*\*, and \* denote statistical significance at 1%, 5%, and 10% levels, respectively. White heteroscedasticity consistent standard errors are in parentheses. The number of repetitions of the bootstrap method is equal to 300.

by the results of the robustness check models. FDI and trade variables are statistically insignificant.

In terms of our study, the most important coefficients presented by the analysis are the coefficients related to the financial market depth. According to findings, in the low-regime countries that have financial market depth index values lower than or equal to (0.1108), financial deepening increases carbon emissions. In the middle-regime countries that have financial market depth index values between (0.1108) and (0.1209), financial deepening moderates carbon emissions. In the high-regime countries that have financial market depth index values higher than (0.1209), there is no statistically significant relationship between financial market depth and carbon emissions. These findings are confirmed by the robustness check models. Moreover, the results of the fixed effects model (Table 2, model 4) can be thought of as another robustness check as they support the non-linear relationship between financial market depth and carbon emissions. Threshold values obtained from panel threshold regressions are exactly the same in all models as can be seen in Table 5 (0.1108 and 0.1209). And lastly, the coefficients of the financial market depth variable are close to each other in all three models (roughly 0.17 in the low regime and -0.17 in the

middle regime). Since the coefficient values are close to each other in absolute terms, it can be concluded that there are symmetric effects. Accordingly, while the increase in the financial market depth below the lower threshold value increases the carbon emissions, the increase in the financial market depth between lower and upper threshold values decreases the carbon emissions. These adverse effects are very close to each other in magnitude.

## 6. Conclusion

Although there is a widespread belief that there are environmental effects of financial deepening, there is no consensus in the literature on how and in what way the effects manifest. On the one hand, it is argued that financial deepening increases energy demand by removing credit constraints, thus triggering carbon emissions. On the other hand, some argue that financial deepening supports sustainable growth and reduces carbon emissions by promoting environmentally-friendly technologies and the use of renewable energy. It is a difficult process to test the effect of financial deepening on carbon emissions because there is no direct indicator of financial deepening and the relationship in question may not have a linear structure.

This study aims to test the relationship between financial depth and carbon emissions for CEE countries, by removing these constraints, and making policy recommendations for emission mitigation. For this purpose, the financial depth index, which is a current and comprehensive variable published by the IMF, was used as an indicator of financial depth, and the effects of depth indicators on financial markets and financial institutions were tested separately. In addition, two different methods, the fixed effects model and the panel threshold model, were used to reveal nonlinear relationships. With the panel threshold regression, the threshold values for the breakpoints of the nonlinear relationship were estimated. Estimation findings support the use of nonlinear analyses. Accordingly, while in low-regime countries (countries where the financial market depth index is less than or equal to the lower threshold value) financial market deepening increases carbon emissions, in middle-regime countries (countries where the financial market depth index is between the lower and upper threshold values) financial market deepening has a moderating effect. Moreover, there is no statistically significant relationship between financial market depth and carbon emissions, in the high-regime countries (countries where the financial market depth index is greater than the upper threshold value).

The countries in the sample are economies that have transitioned from a centrally planned economy to a market economy, and the financial deepening in these countries generally tends to increase over the years considered. In this context, testing the emission effects for the sample countries in line with the net zero carbon emissions target of the European Commission is of particular importance. In Romania, Slovakia, Latvia, and Lithuania, the financial market depth index value is below the lower threshold value of 0.1108 in all years between 1995 and 2018. Therefore, financial deepening has an increasing effect on carbon emissions, and active policies are needed to reduce carbon emissions in these countries. Increasing taxes on carbon emissions, re-allocation of marketable pollution

permits, increasing R&D expenditures for the development of low-carbon technologies, and increasing expenditures for the adoption of wind and solar energy systems would be appropriate policies. On the other hand, the financial market depth index is generally higher than the upper threshold value of 0.1209 in the Czech Republic, Hungary, and Poland. For this reason, the emission-reducing effects of financial deepening may not be evident in these countries. Therefore, these countries should also benefit from the aforementioned active policies to reduce their carbon emissions. In countries such as Bulgaria, Slovenia, and Estonia, the average financial deepening in the last three years is quite close to the lower threshold (0.1040, 0.1013, and 0.1023, respectively). Thus, if the lower threshold value is exceeded in these countries, the emission mitigating effects of financial deepening may prevail. However, it should be noted that the general findings obtained from the analyses emphasize that financial deepening alone is not a sufficient remedy to reduce carbon emissions. Looking at the average value of the financial market depth index in the sample for the last three years, it will be seen that none of the countries are between lower and upper threshold values. In this context, it is important to implement market-based and non-market-based active public policy instruments that can be effective in reducing carbon emissions. Considering that the countries in the sample have adopted the market economy, it can be argued that market-based policies such as carbon taxes and tradable emission permits will be compatible with the economic systems. Environmental taxes, among these tools, are effective in reducing carbon emissions according to the analyses' findings; moreover, the policy option in question can make it possible to obtain public revenue and double dividend by replacing taxes in ineffective areas.

Using the findings of this study, it can be deduced that financial deepening in developing and transition countries will have an increasing effect on carbon emissions. In the most developed EU countries, it is possible that financial deepening may have an emission-reducing effect or its effect on emissions may be meaningless. Therefore, in any case, it would be appropriate to benefit from direct policies aimed at reducing carbon emissions. Studies to be carried out for different country groups will contribute to the discussion. Additionally, in future studies it will be beneficial to use different environmental pollution indicators instead of carbon emissions and to consider a longer time period with the development of the data set.

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### Annex 1: Summary statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
car	264	0.7834	0.1799	0.4664	1.1704
urpb	264	6.5652	0.4259	5.9530	7.3774
gdppc	264	4.0169	0.1848	3.5486	4.3705
ser_gdp	264	4.0252	0.0828	3.6849	4.1886
tax_gdp	264	-17.1861	1.2601	-22.3730	-16.2766
fdi_gdp	264	0.9344	1.8628	-6.9078	3.9921
trade_gdp	264	4.6522	0.3249	3.7779	5.2507
fmd	264	0.1081	0.0808	0.0046	0.4011
fid	264	0.2223	0.0853	-0.0346	0.3897