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Exploring the Macroeconomic Determinants of Carbon Emissions in Transitional Economies: A Panel Data Analysis Approach

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ABSTRACT

The study's main objective was to investigate the macroeconomic determinants of carbon emissions in transitional economies using panel methods with data ranging from 1996 to 2014. The main data analysis was done using econometric estimation methods such as fixed effects, random effects, pooled ordinary least squares (OLS) and the dynamic generalized methods of moments (GMM) approach whilst robustness tests were done under the umbrella term, the lagged independent variable approach. To a larger extent, infrastructural development, economic growth, trade openness, financial development and natural resources were found to have had a significant positive effect on carbon emissions, in line with major theoretical predictions. On the other hand, renewable energy consumption, foreign direct investment, information and communication technology and human capital development were mainly found to have reduced carbon emissions in transitional economies. The results are firmly supported by literature. Transitional economies are therefore urged to increase their use of renewable energy and information and communication technology (ICT) infrastructure, attract more foreign direct investment (FDI) and implement policies aimed at enhancing human capital development to reduce carbon emissions. Given data availability, future studies must investigate whether other macroeconomic variables mentioned in the empirical literature that they determine carbon emissions are relevant in transitional economies.

Keywords: Carbon Emissions, Transitional Economies, Panel Data
JEL Classifications: P2; P52; B23

1. INTRODUCTION

The relationship between the growth of the economy and carbon emissions has for the past few decades been the subject of discussion among environmental economists, researchers and in finance (Hooi and Smyth, 2010; Lee and Lee. 2009; Narayan and Narayan. 2010; Ahmed et al., 2017). Central to such a discussion is The Environmental Kuznets Curve (EKC) which has been described by some researchers as U-shaped (Hooi and Smyth, 2010) and has been used to explain the relationship between emission of pollutants and economic activities. Over time, the determinants of carbon emissions have included a whole lot of other factors explained in Table 1 from a theoretical point of view. These include trade openness, foreign direct investment (FDI), financial development, renewable energy consumption, human capital development, tourism, infrastructural development, information and communication technology, among others. However, the empirical findings on the determinants of carbon emissions are mixed and include quite divergent and convergence views in some instances, evidence that there is no yet consensus on the list of factors which affect carbon emissions.

The economic growth-led carbon emissions nexus is the side of the relationship between carbon emissions and economic activities that has been well researched, and the findings are no longer contestable. What is still not yet quite known is an agreeable list

Table 1: Theory intuition and a priori expectation

Variable	Proxy used	Theory intuition	Expected sign
The lag of carbon emissions (CO_2lag)	Carbon emissions (metric tons per capita)	Carbon emissions trigger more carbon emissions as the situation gets out of hand, consistent with Morales-Lage et al. (2016)	+
Economic growth (GROWTH)	GDP per capita	Economic growth is associated with high level of economic activities associated with a lot of energy usage which produces more pollution and carbon emissions, following Aye and Edoja (2017). A study done by Aye and Edoja (2017) in developing nations also revealed that economic growth increased carbon emissions	+
Natural resources (NAT)	Total natural resources rents (% of GDP)	Kwakwa et al. (2018) argued that the extraction of natural resources is done using heavy equipment and machinery which emit carbon dioxide and uses a of energy	+
Trade openness (OPEN)	Total trade (% of GDP)	According to Grossman and Krueger (1991), increased trade openness means that more production activities in the economy can happen as domestic companies can now easily source inputs from other countries wherever they are found. The same authors argued that with high levels of trade openness, the country can now import clean energy using machinery and or efficient machinery from advanced economies hence contributing to lower carbon emissions	+/−
Human capital development (HCAP)	Human capital development index	According to Saleem et al. (2019), human capital development reduces usage of fossil fuel hence enhancing the quality of the environment through reducing pollution without necessarily negatively affecting economic growth. Human capital development reduces carbon emissions by improving the efficiency of energy usage (Saleem et al., 2019:2)	+
Renewable energy consumption (RENEW)	Renewable energy consumption (% of total final energy consumption)	Renewable energy usage is associated with less pollution and carbon emissions (Dogan and Seker, 2016; Bento and Paulo, 2014; Balogh and Jambor, 2017)	+
Information and Communication Technology (ICT)	Individuals using internet (% of population)	Following Zhang and Liu (2015), the continuous use of ICT technology is associated with more energy consumption which consequently emit more carbon emissions. Lee and Brahmasrene (2014) also noted that ICT brings in a lot of energy usage efficiency thus triggering less carbon emissions and pollution	+/−
Foreign direct investment (FDI)	Net FDI inflow (% of GDP)	In the case of China, FDI reduced carbon emissions only up to a certain level (Cheng and Yang, 2016). Foreign direct investment into the host country is associated with increased manufacturing activities which produces more pollution and carbon emissions (Blanco et al., 2013).	+/−
Infrastructure development (INFR)	Individuals using the internet (% of population)	Contrary to theoretical expectation, clean infrastructure such as internet infrastructure had an insignificant positive effect on carbon emissions in the OECD countries (Salahuddin et al., 2016). Consistent with Kwakwa et al. (2018), the use of heavy infrastructure in the process of extracting natural resources involve emission of carbon dioxide	+
FIN	Domestic credit provided by the financial sector (% of GDP)	Financial development increases carbon emissions in the following three ways. Firstly, availing credit to the consumers can increase the purchase of equipment (automobiles and machinery) which uses more energy (Xing et al., 2017). According to Aye and Edoja (2017:10), financial development attracts FDI into more energy usage activities	+

Source: Author compilation

of determinants of carbon emissions determinants hence the reason why this author attempts to contribute to literature by investigating the determinants of carbon emissions in transitional economies. Not a single study that has so far explored the determinants of carbon emissions has exclusively focused on transitional economies as a bloc of countries. The current study therefore seeks to tell a story on the determinants of carbon emissions in transitional economies to fill such a gap.

Most of the empirical studies that have been done so far on carbon emissions determinants on transitional economies focused on single country studies. For example, Rasool et al. (2019), Zhang et al. (2016), Khan et al. (2019), Zheng et al. (2016), Cosmas et al. (2019), Solarin (2014), Farisal et al. (2018) and Rahman (2019) focused on Pakistan, China, Pakistan, China, Nigeria, Malaysia, Indonesia and Turkey respectively. The methodological weaknesses of such studies are that they ignore cross-sectional characteristics of the data, the endogeneity problems and the dynamic features of the carbon emissions data.

However, closest empirical studies have been done by Magazzino and Cerulli (2019), Zakarya et al. (2015) and Nordin et al. (2015) which respectively focused on Middle East and North African (MENA) countries, BRICS (Brazil, Russia, India, China, South Africa) and ASEAN countries. Although majority of countries in these groups are emerging economies, these groupings of countries are far from being a true representation of transitional economies bloc of countries. Still, these closest empirical studies suffer from

methodological deficiencies such as failure (1) to capture the dynamic characteristics of carbon emissions data, (2) to address the endogeneity problem and (3) to accept reality that the impact of one macroeconomic variable on another is not immediate. The current study addresses all these methodological concerns.

The remaining section of the paper is structured into five main headings: Section 2 is the theoretical literature on the determinant of carbon emissions whilst Section 3 presents the determinants of carbon emissions from an empirical point of view. Section 4 is the broad research methodology which encompasses data and its description, pre-estimation diagnostics, diagnostic tests (panel unit root tests and co-integration), main data analysis, discussion and interpretation of results. Section 5 concludes the study whilst Section 6 is the bibliography.

2. DETERMİNANTS OF CARBON EMİSSİONS (CO_2) -THEORETİCAL LİTERATURE REVİEW

Table 1 is a summary of determinants of carbon emissions, their relevant proxies and how each of them is related to carbon emissions.

3. DETERMİNANTS OF CARBON EMİSSİONS (CO_2) -EMPİRİCAL LİTERATURE REVİEW

Table 2 below is a discussion of the empirical literature on the determinants of carbon emissions.

A variety of variables have been mentioned in Table 2 as having conflicting influence on carbon emissions, itself one of the reasons why the current study is pursuing further empirical tests to address that problem.

4. RESEARCH METHODOLOGY

4.1. Data Used in the Study

The study used panel data ranging from 1996 to 2014 extracted from international reputable databases such as World Development Indicators, African Development Bank Indicators, International Monetary Fund (IMF) and the United Nations Development Programme. Twenty emerging countries, in line with IMF (2015) and factoring in data availability considerations were used for the purposes of this study. These countries include Argentina, China, Brazil, Czech Republic, Colombia, Hong Kong, Greece, India, Indonesia, Malaysia, Mexico, Philippines, Peru, Portugal, Poland, Russia, Republic of Korea, Turkey, Thailand, South Africa and Singapore (Table 3).

4.2. Pre-estimation Diagnostics, Panel Root and Co-integration Tests

The following variables were found to be positively and significantly related with carbon emissions, in line with theoretical predictions (Table 4), namely economic growth, trade openness, foreign direct investment, financial development, infrastructural development, information and communication technology and human capital development. As expected, renewable energy consumption and carbon emissions are negatively and significantly related. A non-significant positive relationship between natural resources and carbon emissions was detected. The maximum size of the relationship was found to be between FDI and trade openness (79%), hence there is no multi-collinearity problem in the data set used, consistent with Stead (1996).

Economic growth data has got abnormal values since standard deviation is far more than 100. The range value of economic growth also supports this argument. All the probabilities of the Jarque-Bera criteria are equal to zero, an indication that the data for all the variables is not normally distributed. This is the main reason why the author had to transform all the data sets into natural logarithms before using it for main data analysis in order to effectively address such a statistical problem.

The data was integrated of order 1 (Table 5) whilst a long run relationship between and among the variables was also detected (Table 6), thus clearing way for main data analysis, in line with Odhiambo (2009).

4.3. General Model Description

In line with theoretical literature and some of the most recent empirical literature (Zakarya et al., 2015; Kongo, 2018; Gianmoena and Ibanez. 2018; Faisal et al., 2018) on the determinants of carbon emissions, equation 1 is the general model specification used in the study.

$$CO_2 = f(GROWTH, NAT, OPEN, HCAP, RENEW, ICT, FDI, INFR, FIN) \quad (1)$$

Where the description of GROWTH, NAT, OPEN, HCAP, RENEW, ICT, FDI, INFR, FIN and CO_2 is shown in Table 7.

Equation 2 shows an econometric equation on the relationship between carbon emissions and its determinants in transitional economies (a transformation of equation 1).

$$CO_{2it} = \beta_0 + \beta_1 GROWTH_{it} + \beta_2 NAT_{it} + \beta_3 OPEN_{it} + \beta_4 HCAP_{it} + \beta_5 RENEW_{it} + \beta_6 ICT_{it} + \beta_7 FDI_{it} + \beta_8 FIN_{it} + \varepsilon it \quad (2)$$

Equation 2 variables are explained in Table 8.

The current study estimated equation 2 using panel data analysis methods such as fixed effects, random effects and pooled OLS approaches, whose main strengths have already been elucidated. The findings are included in Table 9.

According to Table 9, economic growth had a significant positive impact on carbon emissions across all the three panel data analysis methods (fixed effects, random effects, pooled OLS), a finding which resonates with Aye and Edoja (2017) whose argument is that economic growth is associated with high level of economic activities associated with a lot of energy usage which produces more pollution and carbon emissions. Under

Table 2: The determinants of carbon emissions (CO_2) – An empirical view

Author	Country/Countries of study	Period	Methodology	Results
Sharma (2011)	69 countries	1985-2005	Panel data analysis	Trade openness, energy consumption, economic growth had positive effects on carbon emissions whilst urbanization was found to have a negative impact on carbon emissions for low income, middle income and high-income countries. For a world-wide panel, economic growth and energy consumption were found to be statistically significant determinants of carbon emissions whilst electric power consumption, trade openness and urbanization were found to have a deleterious effect on carbon emissions
Dogan and Seker (2016)	European Union	1980-2012	Panel data analysis	Renewable energy and trade were found to have reduced carbon emissions whilst the use of non-renewable energy increased carbon emissions in the European Union
Bento and Paulo (2014)	Italy	1960-2012	Autoregressive Distributive Lag (ARDL) and Error Correction Method (ECM)	The use of renewable energy reduced carbon emissions in Italy both in the short and long run
Balogh and Jambor (2017)	Global perspective	1990-2013	Generalized Methods of Moments (GMM)	Nuclear and renewable energy reduced carbon emissions
Magazzino and Cerulli (2019)	Middle East and North African (MENA) countries	1971-2013	Responsiveness Scores approach	Economic growth and energy consumption reduced carbon emissions whilst urban population and trade reduced carbon emissions
Rasool et al. (2019)	Pakistan	1971-2014	ARDL and Vector Error Correction Model (VECM)	Economic growth and oil prices helped to reduce transport sector's carbon emissions. Rising road infrastructure, population concentration and energy intensity increased transport sector's carbon emissions
Zhang et al. (2016)	China	1990-2014	Logarithmic mean Divisia index (LMDI) approach	Capital productivity effect, industrial scale effect contributed to increase in carbon emissions whilst the energy intensity effect led to a decrease in carbon emissions in China
Khan et al. (2019)	Pakistan	1972-2017	ARDL and ECM	Urbanization and energy consumption increased carbon emissions whilst trade openness and financial development were found to have had a deleterious effect on carbon emissions
Zheng et al. (2016)	China	2002-2012	Linear mixed effect model	In Chinese cities, factors which increased carbon emissions include population size, energy consumption, urbanization and economic growth
Cosmas et al. (2019)	Nigeria	1981-2016	ARDL and non-ARDL approaches	Economic growth had a positive impact on carbon emissions in Nigeria. The feedback effect between economic growth and energy consumption had a negative impact on carbon emissions in Nigeria
Jawara and Liadi (2016)	Gambia	1966-2011	VECM	Population density and economic growth had a positive impact on carbon emissions whilst trade balance had a deleterious influence on carbon emissions in Gambia
Croci et al. 2011)	Seven global cities (Bangkok, Chicago, London, Madrid, Mexico, Milan, New York)	2000-2015	Panel data analysis	Urban density, electrical consumption and technological power generation increased carbon emissions
Dogan and Seker (2016)	Organization for Economic Cooperation and Development (OECD)	1975-2011	Panel data analysis	Increase in financial development and trade openness reduced carbon emissions whilst energy consumption was found to have led to an increase in carbon emissions in OECD group of countries
Solarin (2014)	Malaysia	1972-2010	VECM	The study revealed that an increase in tourist arrivals, economic growth, financial development, energy consumption and urbanization increased carbon emissions
Nordin et al. (2015)	ASEAN countries	1970-2010	Panel data analysis	Energy production and fossil fuel energy consumption had a significant positive impact on carbon emissions
Faisal et al. (2018)	Indonesia	2011-2014	Multiple regression analysis	Energy consumption, financial development and trade openness were some of the prominent variables found to have led to more greenhouse gas emissions in Indonesia
Morales-Lage et al. (2016)	European Union	1971-2012	GMM	Population density, energy intensity and economic growth were found to have increased carbon emissions in the European Union

(Contd...)

Table 2: *(Continued)*

Author	Country/Countries of study	Period	Methodology	Results
Gianmoena and Ibanez (2018)	123 countries	1991-2014	Spatial Bayesian Model Averaging Technique	Prices of gasoline, intensity of fossil fuel consumption and economic growth had a higher impact on carbon emissions in comparison to religious attitudes, age composition and social globalization
Rahman (2019)	Turkey	1970-2017	ARDL	Trade openness, fiscal development, electric consumption and economic growth increased carbon emissions in Turkey
Kongo (2018)	Kenya	1970-2015	ARDL and ECM	Trade openness, imported energy, economic growth and population growth had a significant positive influence on carbon emissions in the long run. The study noted that imported energy, fossil fuel, nuclear and renewable energy had a positive effect on carbon emissions in Kenya in the short run
Zakarya et al. (2015)	BRICS (Brazil, Russia, India, China, South Africa)		Panel data analysis	FDI, energy consumption and economic growth had a positive influence on carbon emissions in BRICS

Source: Author compilation

Table 3: Correlation analysis

	CO_2	GROWTH	NAT	OPEN	RENEW	FDI	FIN	INFR	ICT	HCAP
CO_2	1.00									
GROWTH	0.48***	1.00								
NAT	0.01	−0.37***	1.00							
OPEN	0.31***	0.70***	−0.20***	1.00						
RENEW	−0.78***	−0.55***	0.06	−0.48***	1.00					
FDI	0.16***	0.63***	−0.20***	0.79***	−0.33***	1.00				
FIN	0.188***	0.45***	−0.28***	0.42***	−0.22***	0.32***	1.00			
INFR	0.58***	0.76***	−0.37***	0.48***	−0.65***	0.45***	0.49***	1.00		
ICT	0.39***	0.69***	−0.09*	0.41***	−0.47***	0.35***	0.35***	0.48***	1.00	
HCAP	0.55***	0.68***	−0.33***	0.44***	−0.68***	0.37***	0.29***	0.78***	0.49***	1.00

Source: Author compilation from E-Views. ***/**/* denotes statistical significance at the 1%/5%/10% level respectively

Table 4: Descriptive statistics

	CO_2	GROWTH	NAT	OPEN	RENEW	FDI	FIN	INFR	ICT	HCAP
Mean	5.46	9973	3.70	95.2	18.2	4.2	78.7	23.8	27.6	0.77
Median	4.53	6447	2.24	58.6	13.9	2.58	64.9	19.9	20.8	0.77
Maximum	15.4	56284	21.7	455.3	53.8	39.9	236.0	62.1	90.4	0.94
Minimum	0.77	408.2	0.0003	15.6	0.33	0.03	12.7	1.49	0.01	0.48
Standard. deviation	3.55	10048	4.33	96.4	14.6	5.96	46.85	16.5	25.0	0.09
Skewness	0.42	1.80	1.59	2.28	0.64	3.51	0.80	0.72	0.66	−0.40
Kurtosis	2.03	6.77	5.4	7.4	2.33	16.4	2.78	2.48	2.21	2.75
Jarque-Bera	27.1	451	265	662	35.1	3819	43.2	38.7	39.2	11.5
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	399	399	399	399	399	399	399	399	399	399

Source: Author compilation from E-Views. ***/**/* denotes statistical significance at the 1%/5%/10% level respectively

Table 5: Panel unit root tests –individual intercept

	Level				First difference			
	LLC	IPS	ADF	PP	LLC	IPS	ADF	PP
CO_2	−0.06	2.42	41.76	50.69	−9.38***	−8.38***	149.7***	226.7***
GROWTH	0.58	4.41	10.8	11.9	−11.83***	−8.38***	152.53***	148.49***
NAT	−3.08***	−0.84	43.24	47.42	−14.26***	−11.60***	201.81***	324.89***
OPEN	−1.95**	0.45	34.75	52.36	−11.78***	−9.37***	166.63***	287.91***
RENEW	0.94	3.18	22.32	35.66	−6.04***	−7.51***	137.23***	296.81***
FDI	−6.34***	−5.44***	103.47***	147.318**	−13.46***	−13.68***	238.54***	1497.18***
FIN	−3.75***	−0.71	53.53	36.77	−3.84***	−5.28***	100.32***	192.25***
INFR	−1.97**	0.20	43.65	62.13	−2.96***	−2.19**	66.17**	110.00***
ICT	−14.6***	−12.2***	218.70***	2207.4***	−10.52***	−6.20***	118.83***	281.44***
HCAP	−10.38***	−6.99***	123.83***	173.29***	−17.27***	−14.78***	257.08***	2159.16***

Source: Author's compilation from E-Views. LLC, IPS, ADF and PP stands for Levin et al. (2002); Im et al. (2013); ADF Fisher Chi-square and PP Fisher Chi-square tests respectively. *, ** and *** denote 1%, 5% and 10% levels of significance, respectively

Table 6: Kao residual co-integration test - individual intercept

	T-statistic	Probability
Augmented Dickey-Fuller (ADF)	−3.0190***	0.0013

Source: Author's compilation from E-Views

Table 7: Variables and their proxies

Abbreviation	Variables used	Proxy used
CO_2	Carbon emissions	Carbon emissions (metric tons per capita)
GROWTH	Economic growth	GDP per capita
NAT	Natural resources	Total natural resources rents (% of GDP)
OPEN	Trade openness	Exports +Imports (% of GDP)
HCAP	Human capital development	Human capital development index
RENEW	Renewable energy consumption	Renewable energy consumption (% of total final energy consumption)
ICT	Information and Communication Technology	Individuals using internet (% of population)
FDI	Foreign direct investment	Net FDI (% of GDP)
FIN	Financial development	Domestic credit provided by the financial sector (% of GDP)

Source: Author compilation

Table 8: Equation 2 signs and their interpretations

CO_{2it}	Carbon emissions in country i at time t
$GROWTH_{it}$	Economic growth in country i at time t
NAT_{it}	Natural resources in country i at time t
$OPEN_{it}$	Trade openness in country i at time t
$HCAP_{it}$	Human capital development in country i at time t
$RENEW_{it}$	Renewable energy in country i at time t
ICT_{it}	Information and communication technology in country i at time t
FDI_{it}	Foreign direct investment in country i at time t
FIN_{it}	Financial development in country i at time t
ε_{it}	Error term
i	Country
t	Time
β_0	Intercept term
β_1 to β_8	Co-efficient of the independent variables

Source: Author compilation

fixed effects, natural resources had a non-significant positive effect on carbon emissions whereas random and pooled OLS shows that natural resources had a significant positive influence on carbon emissions, results which are in line with Kwakwa et al. (2018) whose study noted that the extraction of natural resources is done using heavy equipment and machinery which emit carbon dioxide.

A significant positive relationship running from trade openness towards carbon emissions was also observed across all the three panel data analysis methods, a finding which agrees Grossman and Krueger's (1991) view that high level of trade openness promote more industrial activities in the local economy which are associated with more carbon emissions. FDI was found to have had a significant negative impact on carbon emissions, results

Table 9: Determinants of CO_2 in emerging markets

	Fixed effects	Random effects	Pooled OLS
GROWTH	0.2011***	0.1928***	0.3673***
NAT	0.0211	0.0385***	0.1793***
OPEN	0.1634***	0.1159***	0.1529***
RENEW	−0.4335***	−0.4079***	−0.3848***
FDI	−0.0175*	−0.0186**	−0.1047***
FIN	0.0803**	0.0817**	0.1865***
INFR	0.1646***	0.1639***	0.3877***
ICT	−0.0343***	−0.0328***	−0.1261***
HCAP	−0.0428	−0.0249	−0.5875**
Number of countries	21	21	21
Number of observations	399	399	399
Adjusted Rsquared	0.9811	0.5913	0.7743
F-statistic	714.16	64.98	152.74
Prob (F-statistic)	0.00	0.00	0.00

Source: Author's compilation from E-Views. ***, ** and * denote 1%, 5% and 10% levels of significance, respectively

which are in line with Cheng and Yang (2016) finding that FDI had a deleterious effect on carbon emissions up to a certain level in China.

A significant positive relationship running from financial development towards carbon emissions across all the three panel data analysis methods resonates with Aye and Edoja (2017:10), that financial development attracts FDI into more energy usage activities which consequently emit more carbon dioxide. Consistent with Kwakwa et al. (2018) whose view is that the use of heavy infrastructure to extract natural resources produces more carbon dioxide, the study found out that infrastructural development had a significant positive impact on carbon emissions under fixed effects, random effects and pooled OLS.

Across all the three panel methods, ICT had a significant negative influence on carbon emissions in line with Lee and Brahmasrene (2014) whose view is that ICT enables more energy efficiency usage hence lowering the amount of carbon emissions emitted. According to the fixed and random effects, human capital development had a non-significant negative effect on carbon emissions yet a significant negative relationship running from human capital development towards carbon emissions was observed under the pooled OLS approach. These results resonate with Saleem et al.'s (2019) argument that human capital development enhances efficiency in the use of energy thereby lowering the quantity of carbon emissions.

To capture Morales-Lage et al. (2016) argument that carbon emissions trigger more carbon emissions as the situation gets out of hand, the current study captured the dynamic characteristic of carbon emissions data (see equation 3).

$$CO_{2it} = \beta_0 + \beta_1 CO_2LAG_{it} + \beta_2 ROWTH_{it} + \beta_3 NAT_{it} + \beta_4 OPEN_{it} + \beta_5 HCAP_{it} + \beta_6 RENEW_{it} + \beta_7 ICT_{it} + \beta_8 FDI_{it} + \beta_9 FIN_{it} + \varepsilon_{it} \quad (3)$$

Where $\beta_1 CO_2LAG_{it}$ captures the dynamic feature of the carbon emissions data. Equation 3 was estimated using the dynamic GMM approach, whose results are presented in Table 10.

Table 10: Dynamic Generalised Methods of Moments (GMM) Results

	Co-efficient	Standard error	t-statistic
CO_{2it-1}	0.9532***	0.0106	89.6222
GROWTH	0.0151	0.0104	1.4447
NAT	0.0095	0.0032	2.9737
OPEN	−0.0012	0.0109	−0.1063
RENEW	−0.0247***	0.0078	−3.1779
FDI	−0.0033	0.0048	−0.6958
FIN	0.0145	0.0088	1.6374
INFR	0.0182	0.0120	1.5181
ICT	−0.0051	0.0042	−1.2040
HCAP	−0.1282**	0.0622	−2.0594
Adjusted R-squared	0.9877		
J-statistic	388.00		
Prob (J-statistic)	0.00		

Source: Author's compilation from E-Views. ***, ** and * denote 1%, 5% and 10% levels of significance, respectively

Table 11: Determinants of CO_2 in emerging markets: Lagged independent variable approach (t−1)

	Fixed effects	Random effects	Pooled OLS
GROWTH	0.1628***	0.1545***	0.2932***
NAT	0.0338**	0.0513***	0.1772***
OPEN	0.1792***	0.1316***	0.1239**
RENEW	−0.4406***	−0.4131***	−0.3924***
FDI	−0.0141	−0.0150*	−0.0872***
FIN	0.0802**	0.0823**	0.1965***
INFR	0.1762***	0.1779***	0.4149***
ICT	−0.0297***	−0.0281***	−0.0990***
HCAP	0.0621	0.0764	−0.5249*
Number of countries	21	21	21
Number of observations	399	399	399
Adjusted R-squared	0.9805	0.5818	0.7738

Source: Author's compilation from E-Views. ***, ** and * denote 1%, 5% and 10% levels of significance, respectively

Consistent with Morales-Lage et al. (2016) argument that carbon emissions trigger more carbon emissions, the dynamic GMM approach shows that carbon emissions were positively and significantly affected by its own lag (see results in Table 10). Economic growth and natural resources had a separate non-significant positive influence on carbon emissions, findings which are supported by existing literature (Table 1). A non-significant negative relationship from trade openness to carbon emissions was observed, in line with Grossman and Krueger (1991) whose study noted that high trade openness means that local companies are now able to import clean energy from international markets.

A significant negative relationship running from renewable energy consumption towards carbon emissions was observed under the dynamic GMM method, a finding which is consistent with Dogan and Seker (2016) that renewable energy usage is associated with less pollution and carbon emissions. The dynamic GMM approach produced results which show a non-significant negative influence of FDI on carbon emissions, in line with Cheng and Yang's (2016) findings. In line with Xing et al. (2017) and Aye and Edoja (2017), the study noted that financial development had a non-significant positive influence on carbon emissions.

The dynamic GMM approach also observed that infrastructural development had an insignificant positive effect on carbon emissions, findings which are aligned with those of Salahuddin et al. (2016) and Kwakwa et al. (2018). ICT reduced carbon emissions, in line with Lee and Brahmasrene (2014)'s view that ICT is associated with energy usage efficiency. Last but not least, the dynamic GMM method noted that human capital development had a significant negative influence on carbon emissions, a finding which is in line with Saleem et al. (2019) which says that high level of human capital development enhances efficiency in the use of energy.

4.4. Robustness Tests Using the Lagged Panel Data Analysis Framework

Matthew and Johnson's (2014) approach is that it takes time for one macroeconomic variable to affect another (the current study assumed it takes 1 year) – see equation 4.

$$CO_{2i,t} = \beta_0 + \beta_1 GROWTH_{i,t-1} + \beta_2 NAT_{i,t-1} + \beta_3 OPEN_{i,t-1} + \beta_4 HCAP_{i,t-1} + \beta_5 RENEW_{i,t-1} + \beta_6 ICT_{i,t-1} + \beta_7 FDI_{i,t-1} + \beta_8 FIN_{i,t-1} + \varepsilon \quad (4)$$

The results are quite robust because they mirror the main results of the study. According to the lagged independent variable approach (robustness checks approach), the variables which were found to have had a significant positive influence on carbon emissions include economic growth, natural resources, trade openness, financial development and infrastructural development. These results mirror the main findings presented in Table 11. The lagged independent variable approach also indicates that renewable energy consumption reduced carbon emissions in a significant way, findings which are firmly rooted in literature. The robustness approach also shows that separately, both FDI and ICT had a deleterious effect on carbon emissions, in line with majority theoretical predictions. The notable difference is that the robustness approach shows that fixed and random effects had a non-significant positive influence on carbon emissions, a finding which is contrary to available literature.

5. CONCLUSİON

The study's main objective was to investigate the macroeconomic determinants of carbon emissions in transitional economies using panel methods with data ranging from 1996 to 2014. The main data analysis was done using econometric estimation methods such as fixed effects, random effects, pooled OLS and the dynamic GMM approach whilst robustness tests were done under the umbrella term, the lagged independent variable approach. To a larger extent, infrastructural development, economic growth, trade openness, financial development and natural resources were found to have had a significant positive effect on carbon emissions, in line with major theoretical predictions (Table 1). On the other hand, renewable energy consumption, foreign direct investment, information and communication technology and human capital development were mainly found to have reduced carbon emissions in transitional economies.

The results are firmly supported by literature (Table 1). Transitional economies are therefore urged to increase their use of renewable

energy and ICT infrastructure, attract more FDI and implement policies aimed at enhancing human capital development in order to reduce carbon emissions. Given data availability, future studies must investigate whether other macroeconomic variables mentioned in the empirical literature that they determine carbon emissions are relevant in transitional economies.

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