The CO2 emissions drivers of post-communist economies in Eastern Europe and Central Asia

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Abstract

Background. The CO2 emissions became a key environmental contaminant which is responsible for climate change in general and global warming in particular. Two geographical groups of countries that previously belonged to the former bloc of socialist countries are used for the estimations of CO2 emissions drivers of post-communist economies. The research covers such Eastern European countries as Bulgaria, Czech Republic, Hungary, Russian Federation, Poland, Romania, Slovak Republic, and Ukrainian territory as treated by international law and such Central Asian states as Kazakhstan and Uzbekistan during the period 1996-2018. The main goal of the research is to identify common drivers that determine carbon dioxide emissions in selected states. To control for the time fixed affects (like EU membership) random effect model was used for the analysis of panel data set.

Results. It is found that energy efficiency has a negative influence on per capita CO2 emissions and an increase in GDP by 100 USD per 1 ton of oil decreases per capita CO2 emissions from 17 to 64 kg per capita. That is the more energy efficient the economy becomes, the less CO2 emissions per capita it produces. Unlike energy efficiency, an increase in GDP per capita by 1000 USD increases CO2 emissions by 260 kilograms per capita, and the richer the economy becomes, the more CO2 emissions per capita it generates. The increase in life expectancy by one year lead on average to increase in CO2 emissions per capita 200 to 370 kilograms per capita, with average values of 260 kilograms per capita. It was found that energy consumption per capita is a factor that positively adds to the CO2 emissions per capita. Oil prices, and foreign direct investment came as statistically insignificant factors.

Conclusions. Among the main policy reconditions are the promotion of energy efficiency policy in accordance with EU policies and programs that stimulate a reduction in energy consumption and consequently CO2 emissions per capita. The other measure is the promotion of less energy-intensive service sector instead of building up an industrial sector characterized by high energy and carbon intensity.

Background

Environmental aspects of economic growth and development of national economies are closely intertwined with economic and social problems. All of the above-mentioned problems can be addressed using the framework of sustainable development (SD). The SD concept has received significant attention during last 40 years and is now recognized by the world leading countries as a means to reach harmonious co-existence of human society and natural systems (Report 1987). The SD concept involves analysis of environmental performance in all key processes of international and national development. It turns out that the combustion of fossil fuels for energy production is the largest contemporary source of environmental pollution. It produces carbon dioxide CO_2, water, and energy. Problems of rational energy use have been given considerable attention by politicians and scientists in different countries in the context of sustainable development. Over the past decades, many researchers focused on studying the range of factors that influence CO_2 emissions. Climate change mitigation is gradually gaining momentum in the global economy. However, to ensure that environmental projects are realized with maximum efficiency, it is necessary to clarify the nature, directions, and strength of certain impacts from CO_2 emissions.

Despite a significant number of scientific studies devoted to the study CO_2 emission drivers, there is no consensus among researchers regarding all determinants of these processes. Many scientists have empirically tested the impact of green-house gas emissions on national economies as well as a proper relationship between various factors that cause those emissions. According to their findings, economic growth (Alam et al. 2016; Alshehry & Belloumi 2015; Bilan et al., 2019; Grubb et al. 2004; Lau et al. 2014; Muangthai et al. 2014; Ozturk & Acaravci 2013; Shahbaz et al. 2013; Sharma 2011; Shrestha et al. 2009; Chiu 2017), energy prices (Allowance 2018; Allaire & Brown 2012; Alshehry & Belloumi 2015; McCollum et al. 2018; Rapanos & Polemis 2005; Yiia & Geetha 2017), electricity consumption (Alam et al. 2016; Alshehry & Belloumi 2015; Heidari et al. 2015; Kurbatova & Khlyap 2015; Sapkota & Bastola 2017; Sbia et al. 2014; Shahbaz et al. 2013; Sharma 2011; Chiu 2017), energy efficiency (Auffhammer 2013; Emissions 2004; Lin et al. 2016; Chiu 2017), institutional reforms and structural changes (Auffhammer 2013; Everett et al. 2010; Freitas & Kaneko 2011; Lyulyov et al., 2017; Nepal et al. 2017; Yiia & Geethab 2017), investment and trade openness (Chygryn et al., 2018; Hitam & Borhan 2012; Lau et al. 2014; Leonov et al., 2012; Omri et al. 2014; Ozturk & Acaravci 2013; Vasylyeva et al., 2014; Sapkota & Bastola 2017; Sbia et al. 2014; Shahbaz et al. 2013; Sharma 2011; Chiu 2017), population dynamics and urbanization (Alam et al. 2016; Hitam & Borhan 2012; Lin et al. 2016; Martínez-Zarzoso & Maruotti 2011; Sapkota & Bastola 2017; Sharma 2011) are recognized as the most important factors influencing CO_2 emissions. These research results are based on empirical studies conducted in various countries over different periods of time.

A large number of papers treat the analysis of factors that cause CO_2 emissions in emerging economies, particularly in post-communist states (Alshehry & Belloumi 2015; Heidari et al. 2015; Hitam & Borhan 2012; Kasman & Duman 2015; Vasylieva et al., 2019; Sineviciene et al., 2018; Lau et al. 2014; Lyeonov et al., 2019; Lin et al. 2016; Liobikiene et al. 2016; Nepal et al. 2017; Omri et al. 2014; Ozturk & Acaravci 2013; Sbia et al. 2014; Karintsheva 2017; Shahbaz et al. 2013; Sharma 2011; Yiia & Geetha 2017; Yevdokimov et al., 2018). Decarbonization and greening of national economies became urgent issues for post-communist states, which have historically inherited highly energy-intensive economies. In this regard, the identification of factors associated with CO_2 emissions and policy recommendations for environmental improvement are of

great importance. However, the research outcomes of empirical studies are quite different, which complicates the formation of recommendations for local environmental policies.

This study focuses on the main drivers of Carbone dioxide emissions using a panel of 10 post-communist states in Eastern Europe as well as Central Asia during 1996-2018. A particular feature of research is analysis of three different geographical groups of countries (as defined by the UN (Standard Country 1999)) which belonged to the former bloc of socialist countries. These groups include countries of Eastern European countries (Bulgaria, Czech Republic, Hungary, Russian Federation, Poland, Romania, Slovak Republic, and Ukrainian territory as treated by international law) and Central Asian states (Kazakhstan, Uzbekistan). Over our study period, some of the analysed states have made great progress in terms of environmental sustainability through reduction of CO_2 emissions per capita (for example, Slovak Republic) or just preserved their positions (like Hungary, Romania, Ukraine, Uzbekistan). The other states like Kazakhstan, Russian Federation were not very successful in the reduction of their CO_2 emissions over our study period. The contribution of research is the key drivers identification that influenced CO_2 p.c. emissions in the countries mentioned above as well as the formulation of policy recommendations for efficient energy use and environmental improvements. To achieve comparability of results, we have chosen the 1996-2018 period. The chosen period is also characterized by data availability provided by the World Bank and EBRD.

The main hypotheses tested in this study can be specified as follows:

- CO_2 emissions in post-communist countries depend on economic progress, which means a better economic achievements is related to higher p. c. levels of CO_2 emissions;
- an increase in natural gas and crude oil prices improve energy efficiency and therefore reduce c. CO_2 emissions;
- foreign direct investment has an ambiguous influence: a) if foreign direct investment in post-communist countries is associated with the so-called “pollution haven industries”, then such investment increases the level of pollution and per capita CO_2 emissions levels; b) if foreign direct investment is associated with financial or service sphere, then such investment decreases CO_2 emissions per capita;
- energy efficiency improvements are negatively correlated with per capita levels of CO_2 emissions indicators;
- higher shares of the urban population and population growth are correlated with higher rates of CO_2c. emissions since per capita energy usage in cities is higher than in rural areas;
- institutional changes such related to EU accession increase energy efficiency and reduce per capita levels of CO_2 emissions;

The rest of the paper has such structure. Section 2 critically reviews recent literature with regard to the existing factors that influence CO_2 emissions in national economies. Section 3 presents the methodological contribution for our analysis and describes data sources. Section 4 discusses results of our empirical estimation. Section 5 summarizes our findings and policy implications.

Literature Review

Sustainable development goals achievements as proclaimed in Agenda 21 (United Nations 1992) involve a systematic reduction of the carbon intensity of national economies. The last includes measures on rationalizing energy consumption, declining fossil fuels utilization, switching to renewable energy, activating macro- and microeconomic mechanisms of CO_2 reduction. A basic measure for assessing the degree of national economies decarbonization is CO_2 emissions indicator, which is applied in a number of international environmental documents. For instance, the United Nations uses variations of this indicator to evaluate the current state and formation of global plans on decreasing the carbon intensity of countries and regions (CLP's Climate Vision 2016). The Intergovernmental Panel on CC and UN Environment Programme (UNEP) uses indicators related to CO_2 emissions and carbon intensity in its reports (Intergovernmental Panel 2017) as well. OECD analyses energy issues in close connection with CO_2 problems that is reflected in the titles and contents of relevant reports (for example, (Recent trends 2016)). The International Energy Agency considers carbon intensity as one of the key indicators to measure the efficiency of economic and energy development and includes it to annual documents such as IEA World Energy Balances, reports on World Energy Statistics, and others (International Energy, 2017). Various carbon intensity indicators are included to internationally recognized economic and environmental ratings and form a separate international and regional ranking (for example, ET Carbon Rankings, Global Carbon Atlas, Ranking Global Warming Contributions by Country) (2016 ET Carbon Rankings 2017; CO2 emissions 2017; Global Carbon Atlas 2016; Ranking 2014).

Along with documents and reports of international organizations, the reason for including carbon intensity index to international rankings is a number of scientific studies that confirm a close relationship between energy development, economic growth and the dynamics of CO_2 emissions. Given the importance of CO_2 intensity tracking to prevent global climate change a significant number of papers are devoted to studying factors affecting the CO_2 emissions volume.

Several studies (e.g., Lin and Chang 1996; Muangthai et al. 2014; Nag and Parikh 2000; Shrestha et al. 2009) use decoupling and decomposition methods to estimate CO_2 emissions in national and sectoral economies such as industry, power and transportation sectors. The authors

conclude that fast economic development is the key driver in increasing CO_2 emission for all considered countries.

The report (Emissions 2004) based on the top 25 emitting countries data for 1990-2002, suggests that CO_2 intensity are not related to economy size or number of inhabitants. A large state may have lower greenhouse gases intensity, and other way round. Thus, carbon intensity is affected by two fundamental drivers – energy intensity and sort of fuel. The authors concluded that relative indicators of CO_2 efficiency are similar for developing and developed economies. Everett et al. (2010) have examined the link between economic growth and environment (concerning CO_2 emissions) as well as a role of ecopolicy of renewable and non-renewable resources usage. The authors have proved that the links between economic achievements and the environmental situation are at high level of complexity. They distinguished some CO_2 factors, e.g. the scale and structure. Changes in technological efficiency and innovations reduce environmental impacts, while promoting economic growth.

Grubb et al. (2004) have studied the attitude between CO_2 emissions and economic achievements for different types of economic systems during 1950-2002. The research result is that beyond initial industrialization the relationships between per capita incomes and CO_2 are not vivid. Moreover, there is no strong link between GDP and progressive CO_2 increasing since a number of developed economies has shown a divergence between GDP and emissions. As of transition economies, they have grown with little or no emissions increase in the “post-transition” period and resumed economic growth has been accompanied by continued emission reductions.

The ambiguous influence of economic and energy development on CO_2 in transitive economies raises many scientific discussions regarding key drivers of CO_2 emissions in these states. In general, recent publications on carbon emissions drivers in post-communist and developing countries, have determined the following essential factors affecting the dynamics of CO_2 emissions:

- energy consumption whose influence was discovered for 15 European states (EU states and candidate states) over the period 1992-2010 (Kasman & Duman 2015), 5 ASEAN countries over the period 1980-2008 (Heidari et al. 2015); Indonesia over the period 1975-2011 (Shahbaz et al. 2013); the Baltic states over the period 1990-2012 (Liobikiene et al. 2016); Brazil, China, India and Indonesia over the period 1970-2012 (Alam et al. 2016); 14 Latin American states in 1980-2010 (Sapkota & Bastola 2017); UAE over the period 1975–2011 (Sbia et al. 2014); 69 states over the period 1985-2005 (Sharma 2011); Saudi Arabia over the period 1971–2010 (Alshehry & Belloumi 2015);

- trade openness whose influence was discovered for 15 European states (EU states and candidate states) during 1992-2010 (Kasman & Duman 2015); Indonesia over the period 1975-2011 (Shahbaz et al. 2013); Malaysia over the period 1970-2008 (Lau et al. 2014); 69 states over the period 1985-2005 (Sharma 2011); Turkey over the period 1960-2007 (Ozturk & Acaravci 2013); 28 European and Central Asian transitive economies over the period 1990-2012 (Nepal at al. 2017);

- economic growth whose influence was discovered for Turkey over the period 1960-2007 (Ozturk & Acaravci 2013); 5 ASEAN countries over the period 1980-2008 (Heidari et al. 2015); Indonesia over the period 1975-2011 (Shahbaz et al. 2013); Brazil, China, India and Indonesia over the period 1970-2012 (Alam et al. 2016); Malaysia over the period 1970-2008 (Lau et al. 2014); 69 states over the period 1985-2005 (Sharma 2011); Saudi Arabia in 1971–2010 (Alshehry & Belloumi 2015);

- financial development and foreign direct investment whose influences were discovered for Malaysia over the period 1970-2008 (Lau et al. 2014); UAE over the period 1975–2011 (Sbia et al. 2014); 54 states in 1990–2011 (Omri et al. 2014); Malaysia over the period 1965-2010 (Hitam & Borhan 2012); Indonesia over the period 1975-2011 (Shahbaz et al. 2013);

- population growth, population density and urbanization whose influences were discovered for India and Brazil over the period 1970-2012 (Alam et al. 2016); 15 European states (EU states and EU candidates) in 1992-2010 (Kasman & Duman 2015); 88 developing states in 1975-2005 (Martínez-Zarzoso & Maruotti 2011); 69 states over the period 1985-2005 (Sharma 2011); Malaysia over the period 1965-2010 (Hitam & Borhan 2012); 5 African states (Egypt, Kenia, Nigeria, DR Congo, South Africa) over the period 1980-2010 (Lin et al. 2016);

- energy efficiency and relevant encouraging energy policy, whose influence was discovered for the Baltic states over the period 1990-2012 (Liobikiene et al. 2016); 5 African states (Egypt, Kenia, Nigeria, DR Congo, South Africa) over the period 1980-2010 (Lin et al. 2016); Asia Pacific Economic Cooperation members over the period 2001–2010 (Wang et al. 2016); 99 countries over the period 1971-2010 (Chiu 2017); 28 European and Central Asian transitive economies over the period 1990-2012 (Nepal et al. 2017);

- institutional reforms and structural changes, whose influence was discovered for 28 European and Central Asian transition economies over the period 1990-2010 (Nepal et al. 2017); Brazil over the period 2004-2009 (Freitas & Kaneko 2011); Malaysia over the period 1971-2013 (Yiia & Geethab 2017); the Baltic states over the period 1990-2012 (Liobikiene et al. 2016);

- energy prices, whose influence was discovered for Saudi Arabia over the period 1971–2010 (Alshehry & Belloumi 2015); Malaysia over the period 1971-2013 (Yiia & Geetha 2017); OECD countries (CO2 Allowance 2018).

At the same time, while the influence of the abovementioned determinants on CO_2 emissions is confirmed for some countries and periods, it seems to be ambiguous for other states and time series. The reason is that scientists consider mixed groups of national economies which are on different stages of their market transformation. In this regard, the drivers affecting carbon emissions for transitive economies require further research.

Methodological Section And Data Description

It is used the World Bank and European Bank for Reconstruction and Development's data (EBRD, 2020; The World Bank, 2020) on countries' economic and energy development it is estimated the impact of key drivers on the dynamics of CO_2 emissions per capita for 10 selected post-communist states of Eastern Europe and Central Asia during the 1996-2018. To choose a number of states, we considered such arguments. Firstly, our research focuses on studying tendencies of CO_2 emissions per capita for post-communist states in order to investigate how these countries have coped with environmental problems through processes of their economic transformations and recent reforms. Thus, all selected countries belong to the former communist bloc, which finally ceased to exist with the Soviet Union collapse in 1991. Secondly, we have considered three different geographical regions, which represent the largest number of post-communist countries, and the majority of them shares European values and environmental goals in particular. Thirdly, all selected states were characterized by centrally planned economies with close economic relations for several decades. Therefore, studying long-run environmental transformations in these countries accompanied by radical changes in their economic models allows us to understand successes of some countries and failures of the other ones in decarbonizing their economies (tab. 1). Based on this analysis, it is possible to form policy recommendations to make post-communist and former economies in transition more environmentally friendly.

Table 1. Grouping of the studied countries according to levels of per capita CO_2 emissions in 1996 and 2018

CO_2 emissions per capita/ year	1996	2018
The lowest levels among the set of the studied countries	Bulgaria, Hungary, Romania, Ukraine, Uzbekistan	Bulgaria, Hungary, Romania, Slovak Republic, Ukraine, Uzbekistan
Medium levels among the set of the studied countries	Kazakhstan, Poland, Slovak Republic	Czech Republic, Poland, Russian Federation
High levels among the set of the studied countries	Czech Republic, Russian Federation	Kazakhstan

Calculations based on (EBRD, 2020; The World Bank, 2020)

Fourthly, in order to construct an adequate econometric model, we needed a comprehensive database for each country. Therefore, an important reason for choosing the presented states was the availability of data for each country from the list of post-communist countries in the World Bank and EBRD databases. That is why we have excluded some countries from consideration if their data were missing or incomplete.

The study span period was chosen for the according to such arguments:

- The end of the 1980s and early 1990s were marked by the communist bloc collapse in Europe. Those are the countries such Eastern European countries (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovak Republic, Ukraine,) and Central Asian states (Kazakhstan, Russian Federation, Uzbekistan). In addition, in 1993 the Czech-Slovak republic split into two states: the Czech Republic and Slovakia. Therefore, statistics for a number of countries were available only after 1991-1993 period;
- After the Eastern bloc of socialist economies and the USSR collapse, most of the newly-formed states have been in deep economic crisis over the next few years because of the loss of economic ties and transition to world energy prices. Since 1996, a tendency to stabilize economies appeared in the majority of states. It led to economic development and increase in their CO_2c. emissions. For such reason, we did not consider the 1991–1995 period in this study because this period does not reflect steady economic trends and cannot be used to obtain reliable statistical results;
- Comprehensive sets of data for the selected countries and indicators in the World Bank and EBRD databases were found for the period 1996-2018.
- The method of random-effect GLS estimations was used for panel data analysis. To identify key factors that should be included in the econometric model, we have analyzed the main determinants that influence c. CO_2 emissions according to the research results described in the Literature Review section.

The focus on the service sector in the post-industrial era should reduce CO_2 emissions. One more reason is the development of housing and communal services. It was associated with the widespread use of centralized heating systems in cities instead of individual ones, which was applied mainly in rural areas. Compared to individual heating systems, centralized heating systems produce lower CO_2 emissions per capita. It is mostly due to the use of more advanced equipment and technologies. Thus, because of the multidirectional influence of the urbanization trends on CO_2 emissions, it requires a more detailed empirical analysis.

We added a dummy variable for states that are linked the common EU energy policy. EU energy policy dummy is null for all non-EU countries, and one for EU members. It is expected that Common European energy policy and EU 2020 Energy Strategy are strong political reasons for

energy efficiency improvements. To be more specific, according to EU 2020 Energy Strategy (Communication, 2010), EU has to reduce its GHG to at least 20% of consumption.

EBRD estimates progress in emerging economies with progress in large and small-scale privatization as well as governance and enterprise restructuring. In our study, these indicators have been used to estimate the reform developments in selected states.

Given the above discussion, the following model was specified:

$$CO_{2it} = F\ (LE_{it};\ Y_{it};\ GDP\_E_{it};\ FA_{it};\ EC_{it};\ AFF_{it};\ IN_{it};\ EXP_{it}; MS_{it};\ FDI_{it};\ MT_{it};\ GF_{it};\ EU;\ PG_{it};\ Op_{it};\ T_t) \qquad (1)$$

Where:

LE_{it} – Life expectancy (years at birth);

Y_{it} – GDP per capita (USD);

GDP_E_{it} – GDP per unit of energy (USD per 1 ton);

$FA_{i\,t}$– Forest area (percentage);

EC_{it} – Energy consumption (toe) per capita;

AFF_{it} – Agriculture, forestry, and fishing (% of GDP);

IN_{it} – Industry (including construction) (% of GDP);

EXP_{it} – Exports of goods and services (% of GDP);

MS_{it} – Mobile cellular subscriptions (per 100 people);

FDI_{it} – FDI per capita;

MT_{it} – Merchandise trade (% of GDP);

GF_{it} –Gross fixed capital formation (% of GDP);

EU – European Union dummy (1 EU member, 0 – otherwise);

PG_{it} – Population growth (annual %);

Op_{it} – Oil price ($/bbl);

T_t – time dummy (annual 1996-2013).

Research Results And Discussion

Using our random effect model, we have obtained the following results (Table 2), and energy efficiency has a negative influence on per capita CO_2 emissions and it is one of the most important factors to reduce CO_2 pollutions. Thus, an increase in energy efficiency by 100 USD per 1 ton of oil decreases per capita CO_2 emissions from 17 to 64 kg. per capita (Models 1, 3). It means that the more energy efficient the economy becomes, the less CO_2 emissions per capita it produces. Thus, energy efficiency improvement is a powerful driver for environmentally friendly changes in post-communist economies. This conclusion is also confirmed by other theoretical and empirical studies (Chiu 2017; Liobikiene et al. 2016; Nepal et al. 2017).

Table 2. The random-effects general least square regression of CO_2 emissions (metric tons per capita) for the panel of 10 countries during the 1996-2018

	CO2 emissions (metric tons per capita)			
VARIABLES	*Model 1*	*Model 2*	*Model 3*	*Model 4*
Life expectancy	0.203*** (0.0456)	0.374*** (0.0958)	0.241*** (0.0450)	0.280*** (0.0419)
GDP per unit of energy (USD per 1 ton of oil)	-0.00064** (0.000247)		-0.000176** (6.91e-05)	-0.00021*** (6.22e-05)
Forest area (percent)	-0.0842*** (0.00636)	-0.0296*** (0.0108)	-0.0903*** (0.00589)	-0.0919*** (0.00538)
Energy consumption (toe) per capita	2.849*** (0.131)		3.019*** (0.114)	3.073*** (0.106)
Agriculture, forestry, and fishing (% of GDP)	-0.134*** (0.0182)	-0.202*** (0.0301)	-0.0999*** (0.0155)	-0.0677*** (0.0144)
GDP per capita (USD)		0.00026*** (4.80e-05)		
Industry (including construction) (% of GDP)	0.0373** (0.0165)	0.110*** (0.0336)	0.0378** (0.0169)	0.0692*** (0.0161)
Exports of goods and services (% of GDP)	-0.0401*** (0.00421)	-0.0402*** (0.00878)	-0.0395*** (0.00405)	
GDP per unit of energy squared (USD per 1 ton)	5.35e-08* (2.89e-08)			
Mobile cellular subscriptions (per 100 people)	-0.00650* (0.00379)	0.0210*** (0.00697)	-0.0105*** (0.00365)	-0.00839*** (0.00325)
FDI per capita	-1.36e-05 (5.99e-05)	6.90e-06 (0.000124)	-1.33e-05 (6.12e-05)	
Merchandise trade (% of GDP)				-0.0239*** (0.00205)
Gross fixed capital formation (% of GDP)				-0.0553*** (0.0141)
EU	1.082*** (0.410)	-5.499*** (0.573)	0.721 (0.377)	1.318*** (0.355)
Oil price ($/bbl)	0.00627 (0.0142)	-0.159*** (0.0252)	0.0124 (0.0143)	0.0127 (0.0130)
Population growth (annual %)	0.365*** (0.112)			
y1997	0.221 (0.370)	0.216 (0.371)	0.212 (0.370)	0.232 (0.340)
Rest time year dummies 1998-2017				
y2018	-0.142 (0.414)	-0.171 (0.413)	-0.105 (0.411)	-0.216 (0.379)
Constant	-14.17*** (2.870)	--11.03* (6.475)	-14.14*** (2.866)	-17.32*** (2.665)
Observations	230	230	230	230
Number of id	10	10	10	10

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Similar to the previous factor, GDP per capita plays a significant role for per capita CO_2 emissions. However, unlike energy efficiency, per capita GDP growth has a positive effect: an increase in GDP per capita by 1000 USD per capita increases CO_2 emissions 260 kilograms per capita. The richer the economy becomes, the more CO_2 emissions per capita it generates. All these activities increase energy consumption and cause higher levels of CO_2 emissions. These results are similar to such studies (Chiu 2017; Kasman & Duman 2015; Nepal et al. 2017; Sharma 2011; Melnyk et al. 2013).

The increase in life expectancy by one year lead on average to increase in CO_2 emissions per capita 200 to 370 kilograms per capita, with average values of 260 kilograms per capita. Thus, it is not the life expectancy itself that increase in CO_2 emissions per capita, it is the way of life which is more common to more developed economies (e.g. elderly people may have more traveling during retirements).

Countries with larger forest area (percentage of territory) tend to have smaller CO_2 emissions per capita. The last is rather policy appealing results, since countries with smaller forest area (percentage of territory) don't have reasonable instruments to compensate the CO2 emissions.

Energy consumption (toe) per capita is a factor that positively adds to the CO_2 emissions per capita, and in a group of selected economics one additional ton of energy consumption in terms oil equivalent lead to the 3 tons increase in carbon dioxide.

It is appeared to be that structure of the economy has a significant influence on carbon dioxide emissions. Thus, industrial share growth (% of GDP) increase the CO2 emissions per capita, while the growth of agriculture, forestry, and fishing (% of GDP) reduses it. It was found that an incrase in agriculture, forestry, and fishing sector by one percentage lead to the decrease of CO2 emissions per capita from 67 to 200 kg per capita. While an increase in industrial share sector by one percentage lead to the increase of CO2 emissions per capita from 37 to 110 kg per capita.

Exports of goods and services (% of GDP) incrae by one percentage leads to the decrease of CO2 emissions per capita by 40 kg per capita.

Mobile cellular subscriptions (per 100 people) is an indicator of digital economy and an increase in Mobile cellular subscriptions by 10 person per 100 people) leads to decrease of CO2 emissions from 37 to 110 kg per capita

The next factor influencing CO_2 emissions is EU energy policy, and countries that became members of EU are characterized by lower CO_2 emissions, as stated by model 2. However the first and third model show the other results, and more of research have to be done in this direction, comparing the whole set of EU states with not EU ones.

Results in Table 2 show a insignificant influence of gas and oil prices on CO_2 p.c. emissions. This outcome can be explained that world energy prices did not have any influence on selected countries (Carvalho 2016; Nepal et al. 2017; Sineviciene et al., 2017).

Foreign direct investment is another statistically insignificant factor for CO_2 emissions in our model. The reason is its dual effect on those emissions. On the one hand, investment in a national economy is responsible for faster economic growth and, as a rule, for an increase in fossil fuels consumption that causes an increase in CO_2 emissions. On the other hand, investment in energy efficiency, development of environmentally friendly technologies and service sector expansion may significantly contribute to a reduction in per capita CO_2 emissions. Those are two mutually exclusive trends affecting the dynamics of CO_2 p.c. emissions. The dominance of one of these tendencies at a particular stage of development determines the direction of impact on CO_2 emissions. These results are in accordance with other papers (Nepal et al. 2017; Omri et al. 2014; Melnyk et al. 2014). However, the survey by Bae J.H. et al. (2016) on post-Soviet Union independent states proves a positive influence of foreign direct investment on CO_2 emissions.

The incresse in polulation for the panel of 10 countries has no positive impact on the decarbonization of national economies. Its multidirectional influence on CO_2 emissions can explain this result as it had been discussed in the Methodology and data section, which is consistent with other studies (Lin et al. 2016; Martínez-Zarzoso & Maruotti 2011).

To sum up, the obtained results support the majority of hypotheses concerning the influence of various factors on CO_2 emissions in pre-selected post-communist countries. Among confirmed hypotheses are:

1) The positive impact from GDP p.c., share of industry (including construction) (% of GDP), life expectancy and population growth on per capita CO_2 emissions;

2) Negative impact from energy efficiency, share of agriculture, forestry, fishing (% of GDP), progress in digital economy (Mobile cellular subscriptions) on p. c. CO_2 emissions;

3) The ambiguous impact from FDI as well as Oil prices, EU energy policy access, on per capita CO_2 emissions. Contrary to other views, our study shows the insignificant influence of these factors on CO_2 emissions due to their ambiguous consequences.

Conclusions

This paper considers the key drivers of p.c. CO_2 emissions for the panel of 10 post-communist countries in Eastern Europe and Central Asia. Significant findings of our study can be summarized as follows:

1. Economic growth, increase in Energy consumption per capita, and population growth are the main determinants that positively affect per capita CO_2 These outcomes are quite logical because economic development requires additional resources as well as primary energy. Since fossil fuels are primary energy resources for selected countries, their use in the production of various goods and services leads to an increase in carbon dioxide emissions..
2. Energy efficiency; share of Agriculture and forestry; share of Exports of goods and services; progress in digital economy (Mobile cellular subscriptions) appear to be significant factors for decarbonizing in selected countries. Positive changes in these determinants lead to a reduction in CO_2 pollution due to a decrease in energy use through energy-efficient innovations, development of less energy intensive service sector, and relevant national energy efficiency programs.
3. Oil prices, foreign direct investment came as statistically insignificant factors. These results are explained by the ambiguity of their effects in the selected set of countries. During our study period, investments in some countries have been made in the development of energy-efficient industries (for example, Czech Republic, Poland) while in other countries (in particular, Russia, Ukraine, Uzbekiston) they have been aimed at energy-intensive industries rebuilding. The presence of contradictory tendencies in those countries led to the leveling off the investment factor impact on CO_2 emissions per capita.

4. In terms of policy recommendations, energy and environmental policy in post-communist countries of Eastern Europe and Central Asia should be aimed at decarbonization and green economy development with the help of the following measures:

– Promotion of energy efficiency policy in accord with EU policies and programs that stimulate a reduction in energy consumption and consequently CO_2 emissions per capita;

– Promotion of the predominant development of less energy-intensive service sector instead of building up an industrial sector characterized by high energy and carbon intensity. Moreover, it requires a well-balanced investment policy that directs investment into innovative technologies with lower CO_2 emissions;

– State control over privatization. It should focus on small privatization since the it is based on more innovative energy-efficient and environment-friendly technologies that provide lower CO_2 emissions;

–Most of the studied countries have switched to the world prices for oil and natural gas over last 5-7 years, we expect an increase in energy efficiency with a reduction in CO_2 emissions. In this regard, state policy in the energy sector in these countries should include the formation of higher prices for fossil fuels due to the adverse impact of their use on the environment as well as the introduction of preferential policies for renewable energy to ensure a smooth transition to a green economy with lower CO_2 emissions.

The policy recommendations requires further research to identify optimal policy instruments and to assess their effectiveness for all post-communist countries concerning their national specifics.

Abbreviations

CO2: carbon dioxide; GDP: gross domestic product; FDI: foreign direct investment; EBRD: European Bank for Reconstruction and Development ; IEA: International Energy Agency;

Declarations

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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