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Does Financial Development Matter for Environmental Kuznets Curve in Russia? Evidence from the Autoregressive Distributed Lag Bounds Test Approach

Alexander Bass[1]*, Dmitry Burakov[2], Max Freidin[3]

[1]Department of Financial Markets and Banks, Financial University under the Government of the Russian Federation, Moscow, Russia, [2]Department of Banks, Monetary Circulation and Credit, Moscow State Institute of International Relations (MGIMO-University), Moscow, Russia, [3]Department of Marketing, Belarusian State Agricultural Academy, Mogilev region, Gorki, Belarus.
*Email: alexbass1947@gmail.com

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ABSTRACT

This study explores the relationship between carbon dioxide emissions and their main determinants, which include real income and energy consumption in Russia, employing data for the period 1990-2016. The hypothesis of financial development being an important determinant of environmental quality in Russia is also tested. For estimating the short-run and long-run relationships the autoregressive distributed lag bounds test approach is employed in this study. The results are consistent with the Environmental Kuznets Curve hypothesis and show that the real income and energy consumption have a statistically significant positive impact on the carbon emission and its square has a significant negative effect on the carbon emissions both in the short-run and long-run. Financial sector is found to be significant determinant of carbon emission in Russia as well. The pairwise Granger causality test also reveals unidirectional causality running from financial development to the carbon emissions.

Keywords: Financial Development, Environmental Kuznets Curve, Pollution, Autoregressive Distributed Lag Bounds Test, Carbon Emission
JEL Classifications: 016, 044, Q43

1. INTRODUCTION

Environmental pollution is one of the main areas of research in the field of the environmental economics. The problems of climate changes, global warming and worsening quality of environment, brought to life by an increased industrial output, are related to an increased greenhouse gases emission, which include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well. Financial sector and its development play an important role in economic growth. Yet, it's role in environmental pollution is not so obvious. In some cases, investment and lending for renewable energy projects may help in decreasing the level of CO_2 emissions. In other circumstances, financial sector helps in sustaining the existing energy structure of the economy, which might be not so environment friendly. The heterogeneity of the financial development's role in environmental pollution, then, should be viewed as an interesting question and area of research.

Concerning the studied country, one should notice, that Russia takes the 4th place among other countries, contributing in the world CO_2 emissions, after China, the United States of America and India in total kilotons (kt). Yet, in terms of kilogram (kg) of CO_2 emission per GDP, measured in 2010 US dollars, in 2014, according to the World Bank data (2018), Russia with 0.999 kg outplaced the US with 0.324 kg. According to the world tendency among developed countries, CO_2 steadily declines. However, in Russia CO_2 emissions continue to rise. Since 1998 minimum, the level of CO_2 emissions has increased on 14% up to 2014. If the

GDP is taken into account, the picture changes: CO_2 emissions, measured as kg per 2010 US dollars of GDP, decline from 1.839 in 1998 to 0.999 in 2014. This tendency is the result of using more friendly-environmental technologies in some sectors of the national economy. Yet, the share of renewable energy consumption continues to decline.

Overall, the world's share of renewable energy consumption is steadily growing, beginning from 16.908% in 2007 up to 18.054 in 2015, according to the data of the World Bank. E.g., in the USA the share of renewable energy consumption steadily grows beginning from 4.67% in 2001 up to 8.71% in 2015. In case of Russia, the dominant state of oil and hydrocarbons sector with its monopolistic power and government support, neutralizes on the one hand the stimulus to engage in renewable energy projects and given the high bureaucratic and shadow barriers and transaction costs, initially helps in declining the share of the renewable energy market. According to the data of the World Bank, the share of renewable energy consumption has declined from 4% in 1993 down to almost 3% in 2015. According to the Bank of Russia, financial development in Russia, measured as a percentage share of commercial, industrial and consumer credit to GDP, accounts only for 46% at the beginning of 2018. The existing growth rates of financial development are not high enough to support the intensification of the national economic growth on the one hand. On the other hand, the share of credit resources, provided to the energy sector and energy distribution sector accounts for only 2.5% of total loans provided to the non-financial sector in 2012, growing up to 5.1% in 2018. However, most of these loans are used for financing oil-driven energy supply: The share of loans provided to the oil sector has increased from 1.6% in 2012 up to 3.2% in 2018. Even the figures show that the stimuli for using renewable energy sources are quite weak in Russia, that is supported by the findings of Burakov and Freidin (2017). The similar logic of argumentation of high costs may be found in a paper by Shahbaz et al. (2013).

2. LITERATURE REVIEW

The problem of environmental pollution has already received much attention in the literature. Most empirical studies are based on the theoretical hypothesis of the environmental Kuznets curve (EKC). The EKC framework underlines the importance of energy consumption in producing the national GDP and assumes the existence of an inverted U-shaped relationship between environmental degradation and real income per capita. As national income rises, environmental pollution initially is rising as well. However, achieving a certain threshold in national economic development, the level of emissions declines and pollution is assumed to decrease. (Kuznets, 1955).

The initial wave of empirical studies tested the EKC hypothesis in narrow sense, aiming to describe and explain environmental pollution solely by economic factors, including different proxies for economic growth (Grossman and Krueger, 1995; Heil and Selden, 1999; Akbostanci et al., 2009; Poudel et al., 2009; Narayan and Narayan, 2010; Onafowora and Owoye, 2014).

The second wave of the studies is different in a more deeply oriented approach, taking into consideration the structural issue: These studies seek for additional or structural factors that may amplify or accelerate the environment pollution process. Some studies accentuate importance of energy consumption as a leading factor of environmental degradation (Soytas and Sari, 2009; Acaravci and Ozturk, 2010; Pao and Tsai, 2010; Alam et al., 2012; Dagher and Yacoubian, 2012; Saboori and Sulaiman, 2013; Shahbaz et al., 2015; Benavides et al., 2017; Shahbaz et al., 2018). These studies bring evidence in favor of energy-induced EKC both for developed and developing countries, yet in some cases the results are heterogeneous due to differences in econometric techniques used.

The third wave of empirical research is aimed at mitigating the omitted variables bias and include various additional proxies for incorporation of changes in international environment and globalization processes. Recently, the importance of changes in energy prices and terms of international trade gain attention in testing the EKC. The issue of trade liberalization and globalization has led to a rise in international trade, which spurred the total output, leading to a rise in environmental pollution (Rabi et al., 2015; Halicioglu and Ketenci, 2016; El-Aasar and Hanafy, 2018). An increased volatility of energy prices and the export-import status of the country relative to energy resources also gained attention in empirical research. (Richmond and Kaufmann, 2006; He and Richard, 2010; Al-Mulali and Ozturk, 2016) In case when the country is an importer of energy resources and in times of rising energy prices, the stimulus to substitute energy-intensive technologies by renewable energy resources or more environmentally friendly ones, is supposed to be greater. In case of exporting countries, rising global energy prices lead to increased profit and greater output, which, in turn, may lead to higher level of pollution (He and Richard, 2010).

Also empirical research on the EKC hypothesis may be divided for developed and developing countries. The results of the studies are heterogeneous in nature. In some papers, authors find evidence in favor of the inverted U-shaped curve, while in others the N-shaped. e.g., Halicioglu and Ketenci (2016) provided evidence in favor of the existence of EKC only in three out of fifteen transition countries. Onafowora and Owoye (2014) found the N-shaped trajectory in six out of eight studied countries and only in two countries the inverted U-shaped curve was detected. The ambiguity of results may be the consequence of using total pollution as a proxy for environmental degradation, neglecting the differences in the emissions structure in the economy (Stern, 2004).

Although empirical studies, testing the EKC hypothesis, are common today, yet the results of studies, devoted to assessing the role of financial development in the environmental pollution in the EKC framework are mixed. Ozatac et al. (2017) investigates the EKC hypothesis for the case of Turkey from 1960 to 2013 by considering energy consumption, trade, urbanization, and financial development variables. The results of the bounds test and the error correction model under autoregressive distributed lag mechanism suggest long-run relationships among the variables as well as proof of the EKC in Turkey. A conditional Granger causality test reveals that there are causal relationships among the variables. Zambrano-Monserrate et al. (2016) provides empirical evidence on the existence of the EKC hypothesis for Singapore by applying the autoregressive distributed lag bounds testing approach for the period of 1971-2011. The results, along with this the Granger causality test, show that the causal variables of CO_2 emissions are the GDP per capita, energy consumption, population density, financial development and trade openness. Moghadam and Dehbashi (2018) show that financial development accelerates the degradation of the environment; however, an increase in trade openness reduces the damage to the environment in Iran. Furthermore, the results did not agree with the EKC hypothesis in Iran. Chang (2015) focuses on nonlinear effects of financial development and income on energy consumption. Energy consumption increases with income in emerging market and developing economies, while in advanced economies energy consumption increases with income beyond a point at which the economy achieves a threshold level of income. In addition, in the non–high income regime, energy consumption increases with financial development when both private and domestic credit are used as financial development indicators. Halkos and Polemis (2017) investigate the relationship of financial development and economic growth to environmental degradation on the sample of the OECD countries. The empirical findings do indicate that local (NOx per capita emissions) and global (CO_2 per capita emissions) pollutants redefine the EKC hypothesis when they account for the presence of financial development indicators. Specifically, in the case of global pollution an N-shape relationship is evident in both static and dynamic frameworks, with a very slow adjustment. Nasreen and Anwar (2015) demonstrate that financial development reduces environmental degradation in the high-income panel and increases environmental degradation in the middle- and low-income panels. Hypothesis of the EKC is accepted in all income panels. Granger causality results show the evidence of bidirectional causality between financial development and CO_2 emission in the high-income panel, and unidirectional causality from financial development to CO_2 emission in the middle- and low-income panels. Haseeb et al. (2018) examine the impact of energy consumption, financial development, globalization, economic growth, and urbanization on carbon dioxide emissions in the presence of EKC model for BRICS economies. The results show that energy consumption and financial development contribute to the carbon dioxide emissions whereas globalization and urbanization have negative but insignificant relationship with carbon dioxide emissions and support the EKC hypothesis in BRICS economies.

Despite the interest in testing the EKC hypothesis, empirical research of the EKC in Russian case is almost absent. Pao and Tsai (2010), testing the EKC hypothesis for BRIC countries, found that emissions are "output inelastic" and the EKC is not supported. Halicioglu and Ketenci (2016) and Yang et al. (2017) found support for the EKC in Russia, where the economy-related greenhouse emissions are presented by energy consumption, emissions from industrial process, from animal husbandry and fugitive emissions. Ketenci (2018) also find support for the EKC in Russia, stressing importance of energy consumption, real income, education and urbanization levels for environmental pollution in Russia. Also mixed results for Russian case are found by Mihalischev and Raskina (2015), Rudenko (2018) on macro, regional and city-levels. The results of testing the EKC hypothesis are controversial, even when Russia is included in the panel of BRIC countries. The results of Pao and Tsai (2010) speak in favor of the EKC in Russia, while the results of Chang (2015) speak in favor of the U-shaped curve, which is controversial to conventional results.

3. MATERIALS AND METHODS

Given the heterogeneity of the obtained results on the EKC hypothesis, discussed in the previous section, we aim to fill the gap by enquiring into the nature of the relationship between CO_2 emission and financial development as a share of GDP in the EKC framework. Following methodology for the Russian case, proposed by Ketenci (2018), the basic EKC hypothesis then can be presented as follows:

$$c_t=\beta_0+\beta_1 e_t+\beta_2 i_t+\beta_3 i_t^2+\beta_4 f_t+\varepsilon_t$$

Where c_t represents CO_2 emission per capita in the sampled country; e_t is commercial energy use per capita; i_t is the real income, measured as national GDP per capita; i_t^2 represents the square of per capita income; f_t is the financial development, measured as a percentage share of loans, provided to the energy sector.

The theoretical foundation of the EKC hypothesis states that the energy consumption is the primary source of shifts and changes in emissions. Then, it is expected the regression coefficient β_1 to have a positive sign. (Suri and Chapman, 1998) Also the EKC hypothesis states that β_2 is positive, while β_3 is negative in sign, demonstrating a rise in CO_2 emissions goes alongside the economic growth till the certain threshold, after achieving of which, the emission declines due to technological changes, leading to increasing environment quality. Coefficient β_4 may be positive or negative, depending on the current stage of development of the national economy, political and institutional factors, stimulating introduction of environment-friendly technologies in the economy.

In this study we employ the autoregressive distributed lag (ARDL) bound test approach, which allows for I(0), I(1) or fractionally integrated variables. Yet, if the variables are I(2) integrated, the use of this methodology is unacceptable. That is why the first step of this study is to check the stationarity of the sampled variables and determine whether it us achieved without second differencing procedure. For this we employ four alternative unit root tests: The Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979), the Dickey–Fuller generalized least squares (DF-GLS) test proposed by Elliot et al. (1996), the Phillips and Perron (1988) PP test and the KPSS (Kwiatkowski et al., 1992) test. The null hypothesis of the ADF, DF-GLS and PP tests states that the there exists a unit root, while the alternative hypothesis states that the series are generated by a stationary process. The null hypothesis of the KPSS test is of reverse nature – it states that the series are stationary, while the alternative hypothesis states that the unit root is present.

After determining the stationary character of the series, the study employs the bounds testing approach, proposed by Pesaran et al. (2001) for cases with low span of data. The bounds testing approach is also known as the ARDL model, which has some important advantages over the Johansen cointegration test (Pesaran and Shin, 1999). The most important advantage of the ARDL approach is that the ARDL approach can be used regardless the integration order of variables I(0), I(1) or both. Yet, the approach is invalid in case when the I(2) integrated variables are present. Also of great importance is that the ARDL approach allows differences in lags of the sampled variables in the data generating process. Endogenuity problem is absent in the ARDL approach because it also corrects for residual serial correlation. Also the ARDL approach allows to estimate short-run parameters by the means of the error correction model (ECM) adjustments.

The first step in the ARDL procedure is the determining the co-integration existence between the sampled variables. The bounds test examines long-run relationships, where the ARDL framework of the model (Equation 1) is expressed in Equation 2:

$$\Delta c_t = \gamma_0 + \sum_{i=1}^{p}\gamma_{1i}\Delta c_{t-i} + \sum_{i=0}^{p}\gamma_{2i}\Delta e_{t-i} + \sum_{i=o}^{p}\gamma_{3i}\Delta i_{t-i} + \sum_{i=0}^{p}\gamma_{4i}\Delta i_{t-i}^{\;2}$$

$$+\sum_{i=0}^{p}\gamma_{5i}\Delta f_{t-i} + \gamma_{6i}c_{t-i} + \gamma_{7i}e_{t-1} + \gamma_{8i}i_{t-1} + \gamma_{9i}i_{t-1}^{\;2} + \gamma_{10i}f_{t-1} + \mu_t$$

Where $\gamma_{1i}, \gamma_{2i}, \gamma_{3i}, \gamma_{4i}, \gamma_{5i}$ represent short-term coefficient of the sampled variables and $\gamma_{6i}, \gamma_{7i}, \gamma_{8i}, \gamma_{9i}, \gamma_{10i}$ represent the long-term coefficients. Presence or absence of short-run relationship is tested by employing the joint F or statistics of the Wald test. The null hypothesis of the Wald test states that there is no cointegration between the variables of Equation 2: H_0:γ_7=γ_8=γ_9=γ_{10}=0,while the alternative hypothesis states that the variables are co-integrated (H_0:$\gamma_7 \neq \gamma_8 \neq \gamma_9 \neq \gamma_{10} \neq 0$). To test the significance of the obtained results, the critical values for the bound test, reported in Pesaran et al. (2001) are used. The critical bounds are set as if the variables are of I(0) and are of I(1). If the F-statistics is above the upper bound of the critical values, the null hypothesis is rejected. If the F-statistics is below the lower critical bound, the null hypothesis is accepted. If the F-statistics is between the bounds, the results of the test are inconclusive.

In case of the presence of co-integration between the variables, the next stage is the estimation of the ECM of the following type (Equation 3):

$$\Delta c_t = \theta_0 + \sum_{i=1}^{p}\theta_{1i}\Delta c_{t-i} + \sum_{i=0}^{p}\theta_{2i}\Delta e_{t-i} + \sum_{i=o}^{p}\theta_{3i}\Delta i_{t-i} + \sum_{i=0}^{p}\theta_{4i}\Delta i_{t-i}^{\;2}$$

$$+\sum_{i=0}^{p}\gamma\theta_{5i}\Delta f_{t-i} + \delta_1 EC_{t-1} + \varphi_t$$

Where EC_{t-1} represents the error correction term and δ_1 is the coefficient, estimating the speed of variables adjustment towards the equilibrium. This coefficient has to be statistically significant and negative in sign.

The study aims to test the short and long-run relationships between carbon emission and their determinants in the framework of the EKC hypothesis. The variables include energy consumption, real income and financial development in the Russian case for the period 1990-2016. The study employs annual data. The data are collected from the World Bank's World Development Indicators database and Russian statistical database when and where needed. Carbon emissions are measured by CO_2 emissions per capita in the sampled country, metric tonnes; energy consumption is measured by commercial energy use in Russia per capita, kg of oil equivalent; real income is represented by Russian GDP per capita, constant 2010 US dollars; financial development is measured as a percentage share of loans, provided to the non-financial sector. All variables are transformed in natural logarithms.

4. RESULTS AND DISCUSSION

Descriptive statistics for the sampled variables are presented in Table 1. Carbon emissions in Russia amounts 11.77 metric tonnes per capita for the period from 1990 to 2016. Commercial energy consumption is 4711.48 kg of oil equivalent per capita. The average share loans granted to the energy sector amounts to 3.749% with a growing trend up to 5.2%.

The study is based on the use of Russian data for the sampled variables for the period 1990-2016 and aimed to explore the long and short-run relationships between CO_2 emissions and variables which have the potential to affect the changes in the environmental pollution process under the EKC hypothesis. These include energy consumption, real income and financial development. For the purposes of the study the ARDL bounds test approach is employed, that assumes the use of the variables with different order of integration, except integration of order above I(1). The first goal, then, should be the investigation of the order of sampled variables integration, achieving which supposes testing the variables for stationarity in order to determine if the ARDL approach suits the study. We employ four different unit root tests, including the ADF, the DF-GLS, the PP and the KPSS tests. The results of testing the variables for stationarity are presented in Table 2.

The results of the tests for stationarity show that all the sampled variables of the study are generated by a stationary process. Given the results of the different unit root tests, we can assume that the variables in the study are integrated of the order 0 or 1 and none is integrated of the order above 1.

Given that the variables of the study are not integrated of the order 2 we can proceed with the ARDL cointegration approach. The first

Table 1: Descriptive statistics

Variable	Mean	Max.	Min.	St. dev.	Obs.
c	11.77003	16.08000	10.12730	1.339353	27
e	4711.481	5928.661	3981.502	497.5094	27
i	8707.101	11803.712	5505.628	2226.278	27
f	3.749	5.178	2.401	3.70432	27

Max. is the abbreviation for maximum value of a variable, Min. is for the minimum value, St. dev. is referred to a standard deviation, Obs. is the number of observations, c is the abbreviation for carbon emission, e is for energy consumption, r is for real income and f is for percentage share of loans to energy sector step in the ARDL co-integration analysis requires identification of the optimal lag length under the unrestricted vector autoregression. For these purposes we use the Schwarz Criterion (SC), the Akaike Information Criterion (AIC) and the Hannan-Quinn Information criterion (HQ). All the information criteria stand for the lag length of 2 years (Table 3).

Then we can proceed to determining the long-run relationships between the variables of the study. To check the variables on the existence of the long-run relationship we employ the bound F-test for Equation 2. The results of the bounds test for the estimated equation are presented in Table 4.

The estimated equation includes both dependent and independent variables. Dependent variables include energy consumption, real income and square of the real income, while financial development stands as an independent variable. The results of the cointegration F-test show that the resulting F-statistics are above the upper bound and statistically significant at 10%, 5% and 1% significance level. The results show that the sampled variables are cointegrated and the long-run relationship between the variables exists in the Russian case. The obtained results are in line with the results of Ketenci (2018).

Given that the sampled variables are cointegrated in the long-run, we can proceed to the next stage, that requires estimation of the long and short-run coefficients. The estimates for the short-run relationships are presented in Table 5.

As can be seen from the results of the short-run relationship estimation, the error correction term is negative in sign and statistically significant at 1% level. This result confirms the presence of the co-integration. The value of the ECM coefficient is 0.796, that allows to assume that in Russia about 79% of the CO_2 emissions disequilibrium in the short-run is rectified. The diagnostic test results imply the acceptable fit of the model, given the appropriate R^2 and significant F-statistic. Durbin-Watson statistics coefficient shows that the error terms are not correlated. The absence of autocorrelation in the disturbance of the error term is proved by the Breusch-Godfrey test. The normality criterion of the model is also met.

Given the results of the short-run estimates, we obtain evidence in favor of the EKC hypothesis in Russia. Particularly, the energy consumption and the real income have a positive effect on the CO_2 emissions during the sampled period. The square of the real income coefficient has a negative sign that speaks in favor of the EKC hypothesis in Russia, confirms the results of Ketenci (2018) and supports the results of Halicioglu and Ketenci (2016) as well as Yang et al. (2017) and Chang (2015). Another finding indicates that financial development plays a statistically significant role in environmental pollution in Russia, given the positive sign of the β coefficient, that confirms the importance of financial development sector as a short-run source of environmental pollution in Russia, given that most of the energy loans, provided by the banking sector, go to producers of the non-renewable and environmental unfriendly energy sources.

The estimates of the long-run relationship between the studied variables are presented in Table 6.

Table 2: Results of unit root tests

Variable	ADF	DF-GLS	PP	KPSS
c	−3.852911*	−3.003408*	−3.655386**	0.174587
e	−3.207594**	−3.280949*	−3.216722**	0.369353
i	−3.687551**	−2.261857**	−2.358914**	0.308785
f	−3.120864*	−4.039318*	−3.083471*	0.542141

The null hypothesis of ADF, DF-GLS and PP unit root tests is the presence of the unit root. The null hypothesis of the KPSS test is the stationarity of an estimated variable.
* and **denote the rejection of the null hypothesis at the 1% and 5% significance levels, respectively

Table 3: Results of optimal lag length selection

Lag	AIC	SC	HQ
0	−12.57210	−13.94036	−11.40503
1	−14.78423	−14.25931	−15.02542
2	−14.98415*	−15.19537*	−15.69266*

*Indicates lag order selected by the criterion AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion

Table 4: Cointegration F-Test, F ($c|e, i, i^2, f$)

F-statistics	90% LB	90% UB	95% LB	95% UB	99% LB	99% UB
8.64	2.45*	3.52*	2.86*	4.01*	3.74*	5.06*

Null hypothesis of the ARDL bounds test is: No long-run relationship exists. LB: Low bound, UB: Upper bound. If the F test statistic falls between lower and upper bounds the result is inconclusive. If it is below lower bound, the null hypothesis cannot be rejected. If the test statistics is above upper bound, the null hypothesis of no co-integration is rejected (*)

Table 5: ARDL short-run results

Regressor	β coefficient	*t*-statistics
Δe	0.626	5.911*
Δi	0.011	3.934*
Δi^2	−0.014	−4.135*
Δf	0.049	3.827*
ECM_{t-1}	−0.796	−6.605*
Diagnostic test statistics		
R^2	0.9827	
DW-statistic	2.95	
F-statistic	4.88	
RSS	0.01	

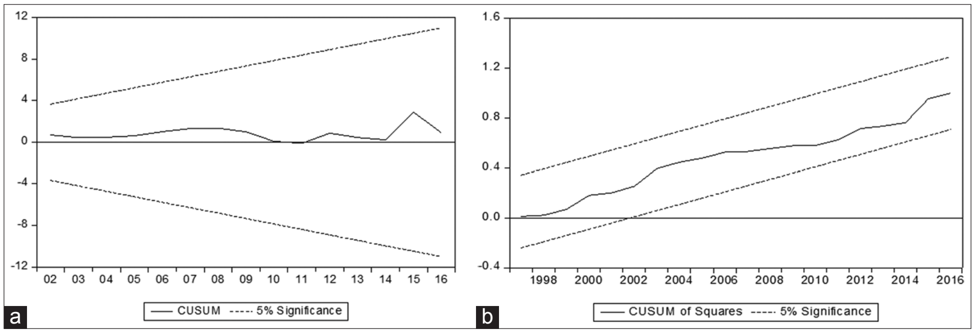
* and **denote the rejection of the null hypothesis at the 1% and 5% significance levels respectively. β column reports estimated coefficients

Table 6: ARDL long-run results

Regressor	β coefficient	*t*-statistics
e	0.841	8.572*
i	0.009	1.944*
i^2	−0.012	−3.086*
f	0.052	2.943*
c	5.943	5.662*
Diagnostic test statistics	***t*-statistics**	**P-value**
x^2SC	1.94	0.246
x^2FF	0.14	0.885
x^2N	3.68	0.642
x^2H	0.99	0.794

* and **denote the rejection of the null hypothesis at the 1% and 5% significance levels respectively. β column reports estimated coefficients. x^2SC, x^2FF, x^2N, x^2H present the Breusch–Godfrey serial correlation LM test, the Ramsey RESET test of functional form misspecification, the Jarque–Bera normality test and the Breusch –Pagan-Godfrey heteroscedasticity test, respectively

Figure 1: (a and b) Results of the stability tests



As can be seen from the results, presented in Table 6, the estimates of the ARDL model are found to be significant. The long-run estimates, as the short-run ones, of the energy consumption, real income and financial development positively affect the CO_2 emissions in Russia. The impact of the energy consumption is stronger than that of the GDP, which supports the energy-induced pollution hypothesis. An increase in energy consumption per capita in Russia by 1% leads to an increase in the CO_2 emissions per capita by 84.1%, while an increase of the real income in 1% causes only 1% of environmental pollution. A 1% increase in financial development leads to a 5% increase in the CO_2 emissions in Russia. These results need interpretation. First, a strong impact of the commercial energy consumption in Russia leading to reaction in environmental pollution almost 90 times greater is also found by Ketenci (2018), yet logical explanation of such results is absent. A serious impact of energy consumption on CO_2 emissions in Russia is quite logical, given low energy efficiency and high energy intensity of the Russian economy. Second, the low impact of the GDP on environmental pollution is achieved because of the structure of the Russian economy, where energy intensive and "toxic" sectors (such as oil and gas industry, agriculture and metal industry) account for less than 50% of the GDP: The share of agriculture being around 5%, the share of oil and gas industry being around 10% on average, while the impact of the agriculture on CO_2 emissions is around 10%. The low impact of financial development, yet statistically significant, may be explained by the fact that most of the energy loans are used for financing the working capital and the need for materials, not for developing new plants or green and environmental friendly projects, which require long-term financing. Then the low impact of the β-coefficient of financial development becomes quite clear.

Given the above results, the EKC hypothesis finds support: The positive sign of the real income is changed by the negative sign of the squared real income, showing an inverted U-shaped relationship between CO_2 emissions and the real income in the Russian case, as well as supporting the importance of the financial sector as a source of environmental pollution and necessity to increase the level of environment-friendly technologies used in the Russian economy.

Another important aspect of the long-run estimates is the magnitude of the positive and negative impacts of the real income and the square of the real income on the CO_2 emissions. The magnitude of the positive impact of the GDP on CO_2 emissions in Russia is less than the negative impact of the squared GDP per capita. This implies that the environmental improvement takes its place in the Russian economy after achieving a certain threshold, compared to the initial environment degradation process. This result is confirmed by the World Bank (2018), according to which CO_2 emissions, measured as kg per 2010 US dollars of GDP, have declined in Russia from 1.839 in 1998 to 0.999 in 2014.

Table 7: Pairwise granger causality test

Null hypothesis	F-statistic	P-value
e does not Granger cause *c*	3.495	0.000
c does not Granger cause *e*	8.254	0.002
i does not Granger cause *c*	4.564	0.013
c does not Granger cause *i*	4.358	0.037
i^2 does not Granger cause *c*	4.255	0.001
c does not Granger cause i^2	5.156	0.033
f does not Granger cause *c*	4.812	0.004
c does not Granger cause *f*	0.741	0.635

Another important test to explore the relationships between the sampled variables is the pairwise Granger causality test. The results of the causality test are presented in Table 7.

According to the results of the pairwise Granger causality test, the unidirectional causality running from financial development to the CO_2 emissions in Russia exists. Moreover, the bidirectional causality between CO_2 emissions and energy consumption, real income and real income squared has been revealed.

The last step in the ARDL approach is estimating the stability of the model. For this purpose, we employ the cumulative (CUSUM) and the cumulative sum of squares (CUSUMSQ) stability tests, proposed by Brown et al. (1975). The results of the CUSUM and CUSUMSQ tests are presented in Figure 1a and b.

As can be seen from Figure 1a and b, the plots of the CUSUM and the CUSUMSQ statistics are located within the 5% significance critical bounds, which proves the stability of the developed model.

5. CONCLUSION

This study explores the relationship between carbon dioxide emissions and their main determinants, which include real income and energy consumption in Russia, employing data for the period 1990-2016. The hypothesis of financial development being an important determinant of environmental quality in Russia is also tested. For estimating the short-run and long-run relationships the

ARDL bounds test is employed in this study. To check the causal relationship, the pairwise Granger causality test is employed.

The results of the cointegration F-test show that the resulting F-statistics are above the upper bound and statistically significant at 10%, 5% and 1% significance level. The results show that the sampled variables are cointegrated and the long-run relationship between CO_2 emissions, energy consumption, real income and financial development exists in the Russian case. According to the results of the short-run relationship estimation, the value of the ECM coefficient is 0.796, that allows to assume that in Russia about 80% of the CO_2 emissions disequilibrium in the short-run is rectified, which also gives evidence in favor of the EKC hypothesis in Russia. Another empirical finding is that financial development plays a statistically significant role in environmental pollution in Russia, that confirms the importance of financial sector as a short-run source of environmental pollution in Russia. The long-run estimates, as the short-run ones, of the energy consumption, real income and financial development positively affect CO_2 emissions in Russia. E.g., an increase in energy consumption per capita in Russia by 1% leads to an increase in the CO_2 emissions per capita by 84.1%, while an increase of the real income in 1% leads causes only 1% of environmental pollution. A 1% increase in loans granted to the energy sector leads to a 5% increase in the CO_2 emissions in Russia. The results of the pairwise Granger causality test also confirm the unidirectional causality running from financial development to the CO_2 emissions in Russia.

Given above, the present study supports the existence of the inverted U-shaped relationship between CO_2 emissions, real income an energy consumption, providing evidence in favor of the EKC hypothesis in Russia. Moreover, financial sector in Russia is found to be a statistically significant variable in explaining environmental pollution.

REFERENCES

Acaravci, A., Ozturk, I. (2010), On the relationship between energy consumption, CO2 emissions and economic growth in Europe. Energy, 35(12), 5412-5420.

Akbostanci, E., Asik, S., Tunc, G.I. (2009), The relationship between income and environment in Turkey: Is there an environmental Kuznet curve? Energy Policy, 37, 861-867.

Alam, M.J., Begum, I.A., Buysse, J., Huylenbroeck, G.V. (2012), Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. Energy Policy, 45, 217-225.

Al-Mulali, U., Ozturk, I. (2016), The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. Renewable and Sustainable Energy Reviews, 54, 1622-1631.

Benavides, M., Ovalle, K., Torres, C., Vinces, T. (2017), Economic growth, renewable energy and methane emissions: Is there an environmental Kuznets curve in Austria? International Journal of Energy Economics and Policy, 7(1), 259-267.

Brown, R.L., Durbin, J., Evans, J.M. (1975), Techniques for testing the constancy of regression relations over time. Journal of the Royal Statistical Society Series B Methodological, 37, 149-163.

Burakov, D., Freidin, M. (2017), Financial development, economic growth and renewable energy consumption in Russia: A vector error correction approach. International Journal of Energy Economics and Policy, 7(6), 39-47.

Chang, M.C. (2015), Room for improvement in low carbon economies of G7 and BRICS countries based on the analysis of energy efficiency and environmental Kuznets curves. Journal of Cleaner Production, 99, 140-151.

Chang, S.C. (2015), Effects of financial developments and income on energy consumption. International Review of Economics and Finance, 35, 28-44.

Dagher, L., Yacoubian, T. (2012), The causal relationship between energy consumption and economic growth in Lebanon. Energy Policy, 50, 795-801.

Dickey, D.A., Fuller, W.A. (1979), Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427-431.

El-Aasar, K.M., Hanafy, S.A. (2018), Investigating the environmental Kuznets curve hypothesis in Egypt: The role of renewable energy and trade in mitigating GHGs. International Journal of Energy Economics and Policy, 8(3), 177-184.

Elliot, G., Rothenberg, T., Stock, J. (1996), Efficient tests for an autoregressive unit root. Econometrica, 64(4), 813-836.

Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. The Quarterly Journal of Economics, 112(2), 353-378.

Halicioglu, F., Ketenci, N. (2016), The impact of international trade on environmental quality: The case of transition countries. Energy, 109, 1130-1138.

Halkos, G., Polemis, M. (2016), Examining the Impact of Financial Development on the Environmental Kuznets Curve Hypothesis. MPRA Paper 75368, University Library of Munich, Germany.

Haseeb, A., Xia, E., Danish, Baloch, M.A., Abbas, K. (2018), Financial development, globalization, and CO2 emission in the presence of EKC: Evidence from BRICS countries. Environmental Science and Pollution Research, 25(31), 31283-31296.

He, J., Richard, P. (2010), Environmental Kuznets curve for CO2 in Canada. Ecological Economics, 69(5), 1083-1093.

Heil, M.T., Selden, T.M. (1999), Panel stationarity with structural breaks: Carbon emissions and GDP. Applied Economics Letters, 6, 223-225.

Ketenci, N. (2018), The environmental Kuznets curve in the case of Russia. Russian Journal of Economics, 4(3), 249-265.

Kuznets, S. (1955), Economic growth and income inequality. American Economic Review, 45, 1-28.

Kwiatkowski, D., Phillips, P., Schmidt, P., Shin, Y. (1992), Testing the null hypothesis of stationarity against the alternative of a unit root. Journal of Econometrics, 54, 159-178.

Mihalischev, S., Raskina, Y. (2015), Environmental Kuznets Curve: The Case of Russia. EUSP Department of Economics Working Paper Series Ec-03/15, European University at St. Petersburg, Department of Economics.

Moghadam, H.E., Dehbashi, V. (2018), The impact of financial development and trade on environmental quality in Iran. Empirical Economics, 54(4), 1777-1799.

Narayan, P.K., Narayan, S. (2010), Carbon dioxide emissions and economic growth: Panel data evidence from developing countries. Energy Policy, 38(1), 661-666.

Nasreen, S., Anwar, S. (2015), The impact of economic and financial development on environmental degradation: An empirical assessment of EKC hypothesis. Studies in Economics and Finance, 32(4), 485-502.

Onafowora, O.A., Owoye, O. (2014), Bounds testing approach to analysis of the environment Kuznets curve hypothesis. Energy Economics, 44, 47-62.

Ozatac, N., Gokmenoglu, K.K., Taspinar, N. (2017), Testing the EKC hypothesis by considering trade openness, urbanization, and financial development: The case of Turkey. Environmental Science and Pollution Research, 24(20), 16690-16701.

Pao, H.T., Tsai, C.M. (2010), CO2 emissions, energy consumption and economic growth in BRIC Countries. Energy Policy, 38, 7850-7860.

Pesaran, M.H., Shin, Y. (1999), An autoregressive distributed lag modeling approach to cointegration analysis. In: Strom, S., editor. Econometrics and Economic Theory in the 20th Century. Cambridge: Cambridge University Press. p371-413.

Pesaran, M.H., Shin, Y., Smith, R. (2001), Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16, 289-326.

Phillips, P.C., Perron, P. (1988), Testing for a unit root in time series regression. Biometrika, 75(2), 335-346.

Poudel, B.N., Paudel, K.P., Bhattarai, K. (2009), Searching for an environmental Kuznets curve in carbon dioxide pollutant in Latin American countries. Journal of Agricultural and Applied Economics, 41(1), 13-27.

Richmond, A.K., Kaufmann, R.K. (2006), Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecological Economics, 56, 176-189.

Rudenko, D. (2018), Environment and economic growth in the Russian Arctic. International Journal of Global Environmental Issues, 17, 163-174.

Saboori, B., Sulaiman, J. (2013), Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. Energy Policy, 60, 892-905.

Shahbaz, M., Destek, M., Polemis, M. (2018), Do Foreign Capital and Financial Development affect Clean Energy Consumption and Carbon Emissions? Evidence from BRICS and Next-11 Countries. MPRA Paper 89267. University Library of Munich, Germany.

Shahbaz, M., Dube, S., Ozturk, I., Jalil, A. (2015), Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy, 5(2), 475-481.

Shahbaz, M., Ozturk, I., Ali, A. (2013), Revisiting the environmental Kuznets curve in a global economy. Renewable and Sustainable Energy Reviews, 25, 494-502.

Soytas, U., Sari, R. (2009), Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. Ecological Economics, 68, 1667-1675.

Stern, D.I. (2004), The rise and fall of the environmental Kuznets curve. World Development, 32(8), 1419-1439.

Suri, V., Chapman, D. (1998), Economic growth, trade and energy: Implications for the environmental Kuznets curve. Ecological Economics, 25(2), 195-208.

World Bank. (2018), World Development Indicators. Available from: http://www.databank.worldbank.org/data/views/re-ports/tableview.aspx?isshared=true.

Yang, X., Lou, F., Sun, M., Wang, M., Wang, Y. (2017), Study of the relationship between greenhouse gas emissions and the economic growth of Russia based on the environmental Kuznets curve. Applied Energy, 193, 162-173.

Zambrano-Monserrate, M.A., Carvajal-Lara, C., Urgiles-Sanchez, R. (2016), Is there an inverted U-shaped curve? Empirical analysis of the environmental Kuznets curve in Singapore. Asia-Pacific Journal of Accounting and Economics, 25, 145-162.