Determinants of energy intensity in Russia

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Abstract: In the Soviet Union energy intensity levels remained high. After the Soviet Union breakdown Russia has also been very energy intensive. Although Russia's energy intensity has fallen by nearly 41%, primary energy consumption per capita has increased by 24% since 1998. The current study aims to investigate how different determinants have contributed to the decline in Russia's energy intensity. The cointegration methodology is applied to establish the long-run relationship among the variables influencing energy intensity in Russia. The results show that energy prices and the share of non-carbohydrate energy have significant impact being negatively correlated to changes in energy intensity. A 1% increase in real crude oil price is expected to reduce energy intensity by 0.26% approximately, as well as a 1% increase of the share of alternative energy sources is expected to reduce the energy intensity by 0.86%.

Keywords: energy intensity; energy efficiency; Russia; renewable energy; FMOLS.

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1 Introduction

Energy efficiency is accepted as one of the most cost-effective approaches that contribute to sustainable development and the reduction of escalating energy consumption level. It has become clear that lesser the primary energy intensity (EI) is the smaller energy is required to create a unit of gross domestic product (GDP). This in turn increases the economy's global competitiveness, provides an added incentive for environmental sustainability and energy security. The study of the dynamics of primary EI is needed for an effective energy policy implementation and for understanding how the energy demand varies under conditions of significant changes in the economy's structure and public policy.

Despite the considerable progress made in improving energy efficiency since the Soviet Union breakdown, Russia still belongs to the group of countries with a very high primary EI of GDP. That fact generates great risks, such as the decrease of country's energy security and competitiveness of domestic energy-intensive industries (Shi, 2015), a high level of environmental pollution and difficulties in complying with commitments undertaken in accordance with the 2015 Paris Climate Change Conference, as well as the necessity of large investments into the energy sector and other consequences of uncoordinated energy policy.

Russia's energy efficiency has been given very little attention. As noted in Thurner and Roud (2016), the domestic production driven by extractive industries and low-technology manufacturing has historically been very energy-intensive.

Reducing energy demand and increasing energy efficiency are seen as major elements of the ongoing transformation of energy system in Russia. The federal program for "Energy saving and energy efficiency improvement for the period till 2020" (Decree #2446-r) was drawn up in 2010, attempting to reduce EI of industrial production (per unit GDP) by 40% from 2007 to 2020. The total funding for this program is 9.5 billion Russian rubles. Expected results of program's implementation suggest achieving the total savings of primary energy of 110 million tonnes of oil equivalent (Mtoe) during 2011–2015 and 333 million tonnes over 2011–2020. Analysing the dynamics of energy intensity of the Russian economy after 2008 this aim seems doubtful. The program is going to join the list of projects burying taxpayers' money. As noted in Sheng et al. (2013), the increase of EI, together with the usual trend of growing energy demand due to economic growth, can create shock to the energy demand.

The primary goal of this study is to measure the importance of EI determinants for the Russian case. We follow the empirical literature on determinants of energy intensity that investigated developed and developing countries (Fisher-Vanden et al., 2004; Hübler and Keller, 2010; Hübler, 2011; Adom and Kwakwa, 2014; Adom, 2015a; Akal, 2016). We extend previous studies by paying special attention to the role of renewable energy sources in determining EI. The Russian case, where energy consumption is subsidised, provides an interesting case to study the issue.

The rest of the article is structured as follows. The second part reviews relevant literature on EI determinants. The third section provides an overview of the Russian energy sector. Data, model, estimation methodology and results are outlined in the fourth section. Some policy recommendations and conclusions are provided in the final section.

2 Literature review

Empirical studies on the determinants of EI are published every year. However, there is no well-defined conclusion. This may come from the different economic structures and samples analysed by these studies. Authors have defined several common determinants of EI. These factors are foreign direct investments (FDI) inflows, trade openness and export-import structure of trade, prices for primary energy resources, the role of industry in the economy and structure effects, as well as the technological level.

Adom (2015b) indicated that the energy saving potential of FDI inflows had been discussed along three lines: the scale effect (via GDP increase); the composition effect (changing sectors shares), and technical effect (adopting energy efficient technologies). Hübler (2011) found that FDI inflows were responsible for the fall in China's EI. In contrast, Hübler and Keller (2010) did not prove the significance of FDI inflows as an energy saving tool for a panel of 60 developing economies. The same result is proved in Adom and Kwakwa (2014). Paramati et al. (2016) found a significant positive impact of FDI inflows and stock market developments on clean energy consumption across emerging market economies.

The trade openness does not have a direct influence on EI, but it is based on the diffusion effect of technologies due to the trade openness. Lai et al. (2006) established the energy-reducing effect of trade openness in China. Cole (2006) established that the impact of trade openness on energy efficiency depends on the structure of country's import and export. Thus final influence of this determinant depends on relative weight of energy intensive exports and energy saving imports in total trade structure of the country. According to Shi (2002), the increasing of Chinese economy's energy efficiency was associated with the policy of country's trade openness. In contrast, Adom and Kwakwa (2014) concluded that trade openness had worsened energy efficiency in Ghana. Akal (2016) found the same result for the Turkish economy noting that the EI increases as the energy gap or import enlarges.

A rise in price for primary energy resources reduces consumption of goods and services and thereby affects energy consumption negatively. According to Birol and Keppler (2000), increased energy price with the help of economic instruments leads to energy efficiency. Lin and Moubarak (2014) confirmed the negative impact of energy price on EI for China in the period from 1985 to 2010. Adom (2015a) indicated that the influence of crude oil price on EI is negative and statistically significant. Cornillie and Frankhanser (2004) also confirmed the energy saving potential of energy price in 22 transition countries. Alam and Paramati (2015) proved a significant long-run equilibrium relationship among oil prices, financial development, industrialisation, trade openness and CO_2 emissions.

Industrial level activities are more energy intensive. Poumanyvong and Kameko (2010) found that the impact of industrial effects on EI to be positive and statistically significant for low and middle income groups. If high industrialisation is expected to increase EI, that structural or technical changes in the industrial sphere can produce energy saving effects. Lin and Moubarak (2014) concluded that changes in industrial structure have negative effect on energy intensity in China. Inglesi-Lotz and Pourishave (2012) investigated the determinants affecting energy efficiency in South Africa from 1993 to 2006. Their result showed that structural changes promoting economic growth had increased energy efficiency of the country. However, Voigt and Cian (2014) did not establish the statistical significance of these variables in reducing EI for 40 major economies.

The impotence of technological factor in reducing EI was thoroughly studied in several papers. The phenomenon of falling Chinese EI in the period from 1987 to 1992 was studied by Garbaccio and Ho (1999) who found that technology changes in the industry sectors were a main factor of EI decline. Kuper and van Soest (1999) argue that the effectiveness of policies to reduce the use of energy depend on the elasticity of substitution between the various inputs and on the rate of technological progress. Studying Dutch industry they showed that energy-saving technological progress in periods of high and increasing energy prices was also significantly higher than if energy prices were low and falling.

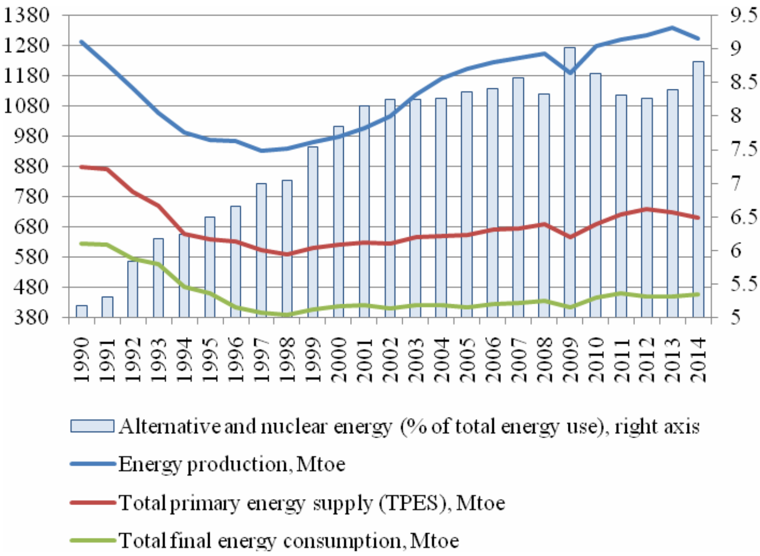
3 Russia's energy sector

As noted in Didenko and Kunze (2014), energy is an essential structural component of the Russian economy and is one of the key factors for the vital activity of the country. The energy sector produces more than a quarter of Russia's industrial output, thereby significantly affecting the formation of the country's budget.

Russia had experienced an impressive economic growth after a radical market transformation of 1990s. The average growth rate of GDP per capita was 7.0% per year from 1999 to 2008. Such a rapid economic growth caused an increase in demand for energy. According to The International Energy Agency (IEA, 2017), total primary energy supply (TPES) fell by 33.1% between 1990 and 1998, driven mainly by 41.9% and 47.1% decline in coal and oil use respectively. This downward trend in energy consumption went in line with primary energy production that fell by 27.3% between 1990–1998. After that period the total energy production increased from 939.7 Mtoe in 1998 to 1305.7 Mtoe in 2014 which is more than 38% increase as shown in Figure 1. Although being negatively affected by the crisis of 2008–2009 the total primary energy consumption has also risen by 20.9% from 587.9 Mtoe in 1998 to 710.9 Mtoe in 2014. The increase of production happened mainly by an increase in oil and nuclear energy production. So, the share of nuclear energy use has risen from 3.5% in 1990 to 6.67% in 2014. But economic crisis of 2008 interrupted the process of economic growth. The energy production as well as consumption has almost stopped growing since 2008.

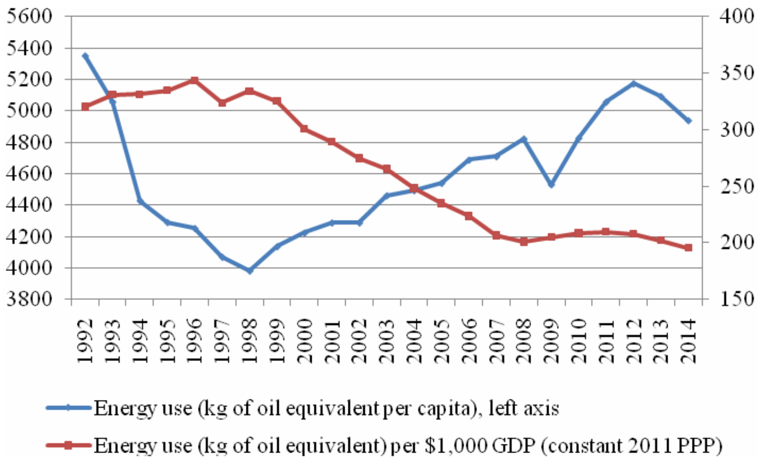
The country's energy use has risen faster than the population growth resulting in per capita energy use increase. We can also observe the growth of primary energy production and consumption while the country's EI increased due to a very weak dynamics of the real GDP after the global economic crisis of 2008–2009. The world's energy consumption was quite high, i.e., 1.89 toe per capita in 2014, Russia used 4.94 Mtoe per capita. Cui and Kuang (2014) investigated nine major economies between 2008 and 2012 concluding that only Russia and India had decreased their energy efficiency index. Although Russia's EI has fallen since 1996 to 2014, primary energy consumption per capita has significantly risen after the crisis of 1998 (Figure 2).

Figure 1 The Russian energy production and consumption, 1990–2014 (see online version for colours)



Source: The International Energy Agency (2017) and The World Bank (2017)

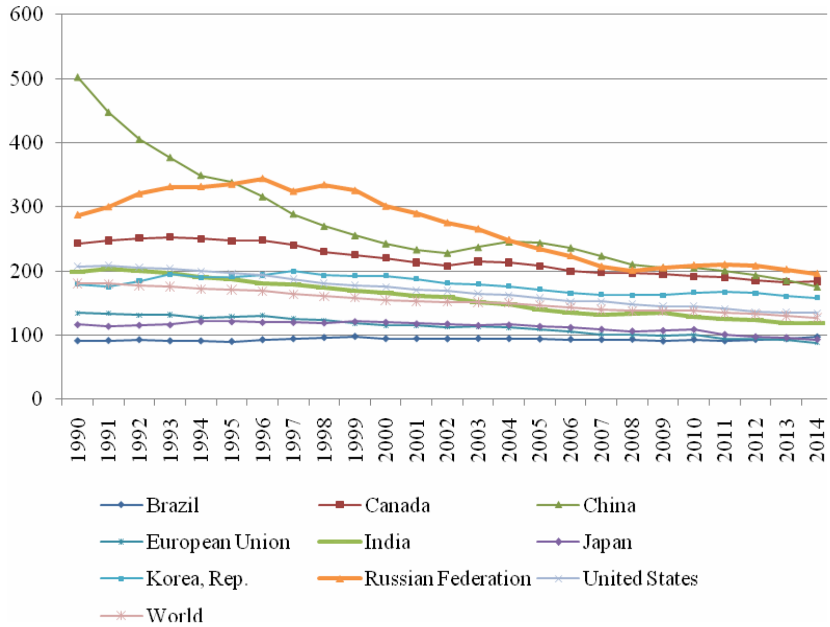
Figure 2 The Russian energy intensity, 1992–2014 (see online version for colours)



Source: The International Energy Agency (2017)

Russia ranks fourth in the primary energy consumption which is about 710.88 Mtoe in 2014. However, the country spent more energy per unit of GDP than any of the largest energy consumers globally. Russia is the 17th country from the bottom out of 133 in terms of EI. Primary EI in Russia is twice as high as the world average (Figure 3).

Figure 3 Russian and global energy intensity (kg of oil equivalent per $1,000 constant 2011 PPP GDP), 1990–2014 (see online version for colours)

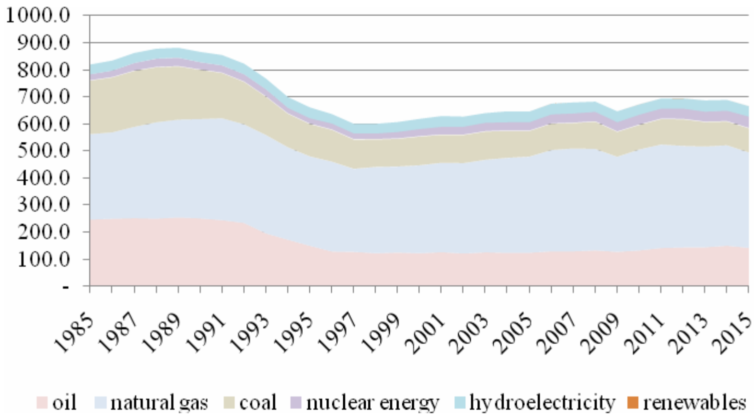


Source: The International Energy Agency (2017)

The average level of Russian EI decline was 1.26% annually for the period from 1998 to 2014. This reduction was attributable to structural changes in the economy, as the industry and residential sector did not develop as quickly as the services sector. We can conclude that the higher the GDP and the share of industry in total production, the larger its territory and the below average temperatures, the greater the consumption of primary energy sources is. All these factors explain most of the differences between energy consumption in various countries. Considering that Russia has the largest territory in the world, the harsh climate and it is one of the largest economies in the world, the country is obviously at the top in terms of EI.

Russia is a significant player in the world energy economy possessing a variety of abundant energy resources. The country’s energy consumption is dominated by fossil fuels such as crude oil, coal, natural gas and other combustible minerals. This share has not undergone significant changes being within 92% for the last 20 years (Figure 4). Key reason for this is the availability of mineral resources and poor renewable energy development. Russian energy sector is based mainly on natural gas making Russia the second in both its production and consumption. Russia is by far the largest natural gas net exporter (particularly in the form of pipeline gas) accounting together with Qatar and Norway for 43% of world gas exports in 2015 (British Petroleum, 2017). In 2015, Russia produced 540.7 million tonnes of crude oil, with a production growth rate of 1.2%. However, a large domestic oil production is used mainly for export.

Figure 4 Primary energy consumption structure in Russia, 1985–2015 (see online version for colours)



Source: British Petroleum (2017)

The main alternative energy source is nuclear energy and hydroelectricity. While the nuclear energy consumption has risen by 70% to 47.5 Mtoe in 2014, the hydro energy consumption has been stable at the average level of 14–15 Mtoe. The generation of wind, solar or geothermal energy in Russia is miserable reaching only 136 ktoe or just 0.1% of TPES in 2014.

The World Bank (2006) has noted several principal barriers to improved energy efficiency in Russia. The first barrier is a little appreciation of energy efficiency. For example, Russian banks rarely provide direct loan financing for energy servicing companies' energy efficiency projects perceiving higher risks. Currently, most energy servicing companies' projects are financed either through their own funds and direct loans to customers, or by the customers themselves. The second barrier is a lack of statistical data. Without proper statistics on energy consumption and production at the local, regional, national and, etc., levels, Russia will never be able to fully understand its energy efficiency challenges and potential. The next challenge is environmental externalities. Russian energy prices do not include the negative health effects of sulphur dioxide and nitrogen dioxide emissions artificially lowering the cost of consuming energy. Although recognised by the Government of Russia the need to develop the concept of transition to a green economy, investments in modernisation of traditional industries and the development of renewable energy sources and improvement of the energy sector's environmental efficiency, remains extremely low. The issue of preserving and protecting the natural environment of the Russian Arctic in the face of increasing energy production in the region is presented as a very actual challenge (Rudenko and Skripnuk, 2016; Romashkina et al., 2017; Vylegzhanina, 2017). And the fourth factor is no incentives to implement energy saving technologies.

4 Data, methodology and results

Following the empirical literature in energy economics, it is plausible to form a long-run relationship between EI and its factors in a linear logarithm form. We estimate the impact of oil prices and other factors on EI in Russia using a time series dataset covering the period from 1992 to 2015. Specifically the authors considered the following variables: EI, oil price, trade openness, FDI net inflows and a share of alternative and nuclear energy. All data except for oil prices were obtained from the World Development Indicators (World Bank, 2017). Data on international crude oil prices was sourced from the BP statistical review of World Energy (British Petroleum, 2017).

The baseline regression is represented by equation (1).

$$\ln EI_t = \alpha + \beta_1 \ln Oil_t + \beta_2 \ln FDI_t + \beta_3 \ln SVA_t + \beta_4 \ln AE_t \quad (1)$$

where *EI* is energy intensity, *Oil* is a real oil price, *FDI* is foreign direct investments per capita in constant 2010 prices, *AE* is a share of alternative and nuclear energy, *SVA* is services value-added.

EI is measured as the kg of oil equivalent per $1,000 GDP converted to 2011 constant international dollars using purchasing power parity rates. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.

The energy price being one of the most important factors in terms of energy consumption is measured as the real world price of crude oil in US dollar per barrel. According to The International Energy Agency (2017) data, crude oil constitutes almost 24% (about 42% of oil production is exported) of TPES in Russia. We include this variable to show the energy saving impact. The general position of the literature is that higher prices of energy will cause EI to fall. To capture the effect of policy changes (e.g., use of combined heat and electricity production methods) we replace real oil price by real tariff for heat and electricity for industrial organisations from Rosstat so the baseline regression is represented by equation (2).

$$\ln EI_t = \alpha + \beta_1 \ln Heat_t + \beta_2 \ln FDI_t + \beta_3 \ln SVA_t + \beta_4 \ln AE_t \quad (2)$$

where *Heat* is an average acquisition price in constant 2010 prices for heat energy and electricity purchased by industrial organisations.

Foreign direct inflows (FDI) are the net inflows of investment to acquire a lasting interest in or management control over an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. The FDI variable, as used in this study, is measured as the net inflow of FDI per capita in constant 2010 dollars. Generally, the effect of foreign direct investment on EI has been established to be negative.

Alternative and nuclear energy is non-carbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others. It is measured as a percentage of total energy use. In the current study a share of alternative and nuclear energy is a new, not previously analysed variable. The authors suppose that the higher this share is the less EI of the country is. Russia belongs to the group of countries with a high share of consumption of fossil fuels. The reduction of this share will allow decreasing an amount of primary energy used. Development of alternative and nuclear energy in Russia will reduce the EI of production, as well as provide energy to territories cut off from the centralised power supply. As a rule, these territories use coal and petroleum products for providing energy.

Services value-added include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, healthcare, and real estate services, imputed bank service charges and import duties. This determinant is measured as a percentage of GDP. The services have not been previously analysed. The services are considered as less energy intensive activity than any others, so the authors assume that the higher this share in the economy is the lower EI is. This indicator has been included to demonstrate the effect of structural changes in the country's energy consumption. During the period from 1998 to 2014, GDP in constant 2011 international dollars grew two times, while the demand for energy has risen only by 20%. In part, this is due to the fact that production has shifted towards less energy-intensive industries.

The focus of this study is to explore the long-run relationship among variables. The first step is to run the tests of stationarity. As mentioned in Lin and Moubarak (2014), the most common testing procedures used for such purposes are the augmented Dickey-Fuller (ADF), Phillips-Perron, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. We employ the Phillip-Perron test for unit root in time series assuming both constant and constant with trend. The results are presented in Table 1.

Table 1 Phillip-Perron unit root test

Null hypothesis: time series have a unit root		
Variable (log)	*Constant*	*Constant and trend*
EI	–0.3487	–1.9271
D (EI)	–3.2331**	–2.9608*
Oil	–1.1705	–1.9989
D (Oil)	–3.4766**	–3.3035*
AE	–2.8084	–1.7515
D (AE)	–4.9027***	–5.4543***
FDI	–1.7542	–0.9354
D (FDI)	–4.9401***	–5.5349***
SVA	–1.9313	–2.1722
D (SVA)	–5.1985***	–5.8608***
Heat	–1.1487	–3.0027
D (Heat)	–7.1570***	–8.9743***

Note: ***,**, * indicate 1%, 5% and 10% significance levels, respectively.

The unit root test shows that all series have unit root in levels under the model with trend and no trend. The unit root test reveals that the series are first difference stationary.

Next, we examine the direction of causality between the variables. The Hansen parameter instability is used to test the cointegration relationship. Cointegration implies that albeit series may be non-stationary there is as a systemic co-movement among variables over the long run. The Hansen parameter instability test shows that there is long-run equilibrium relationship (Tables 2 and 4). Thus, oil prices, alternative energy use, FDI and services output can be treated as the long run 'forcing' variables explaining EI in Russia.

Table 2 Cointegration test – Hansen parameter instability

Series: LOG(EI) LOG(OIL) LOG(AE) LOG(SVA) LOG(FDI)
Null hypothesis: Series are cointegrated
Cointegrating equation deterministics: C
Additional regressor deterministics: @TREND

Lc statistic	*Stochastic Trends (m)*	*Deterministic Trends (k)*	*Excluded Trends (p2)*	*Prob.**
0.501448	4	1	1	> 0.2

Note: *Lc (m2 = 4, k = 0) p-values, where m2 = m – p2 is the number of stochastic trends in the asymptotic distribution.

Table 3 Long-run estimates

Dependent variable: energy intensity (log)
Sample (adjusted): 1993–2015
Cointegrating equation deterministics: C
Additional regressor deterministics: @TREND
Long-run covariance estimate (Bartlett kernel, Newey-West automatic bandwidth = 2.3481, NW automatic lag length = 2)

Variable	*FM-OLS*	*DOLS*	*CCR*
Log(Oil)	–0.2660***	–0.2979***	–0.2657***
	(0.0291)	(0.0190)	(0.0288)
Log(AE)	–0.8073***	–1.4042**	–0.8151***
	(0.2196)	(0.1724)	(0.2342)
Log(SVA)	0.2381	1.4944***	0.2974
	(0.2668)	(0.2947)	(0.2823)
Log(FDI)	0.0147	0.0278	0.0060
	(0.0217)	(0.0153)	(0.0263)
C	7.2170***	3.3624**	7.0155***
	(0.8131)	(0.9339)	(0.8618)
Adjusted R-squared	0.9269	0.9940	0.9224
Lon-run variance	*0.002279*	*0.016282*	*0.002179*

Table 4 Cointegration test – Hansen parameter instability

Series: LOG(EI) LOG(HEAT) LOG(AE) LOG(SVA) LOG(FDI)
Null hypothesis: Series are cointegrated
Cointegrating equation deterministics: C
Additional regressor deterministics: @TREND

Lc statistic	*Stochastic Trends (m)*	*Deterministic Trends (k)*	*Excluded Trends (p2)*	*Prob.**
0.606975	4	0	0	> 0.2

Note: *Lc(m2 = 4, k = 0) p-values, where m2 = m – p2 is the number of stochastic trends in the asymptotic distribution.

We follow directly Adom and Kwakwa (2014) and employ the fully modified least squares (FM-OLS), the canonical cointegrating regression (CCR), and the dynamic least squares (DOLS) techniques to analyse the long run impact of selected variables on Russia's EI. As mentioned in Adom (2015b), "the Cointegration approach is known to be more robust to serial correlation and endogeneity compared to the johansen and ardl approach. hence, the estimates are more consistent and robust".

Table 5 Long-run estimates

Dependent variable: energy intensity (log)
Sample (adjusted): 1999–2015
Cointegrating equation deterministics: C
Additional regressor deterministics: @TREND
Long-run covariance estimate (Bartlett kernel, Newey-West bandwidth = 1.6266, NW automatic lag length = 2

Variable	*FM-OLS*	*DOLS*	*CCR*
Log(Heat)	–0.7759***	–0.7600***	–0.7815***
	(0.2177)	(0.2576)	(0.2595)
Log(AE)	–1.2446***	–1.1683**	–1.19***
	(0.3418)	(0.3065)	(0.2707)
Log(SVA)	–0.0606	-0.1407	–0.0701
	(0.4665)	(0.5856)	(0.5141)
Log(FDI)	–0.0805***	–0.0740***	–0.0805***
	(0.0198)	(0.0244)	(0.0255)
C	13.8152***	3.3624**	13.7742***)
	(0.9494)	(0.9339)	(0.9568
Adjusted R-squared	0.9177	0.9388	0.9174
Lon-run variance	*0.001518*	*0.002396*	*0.001518*

Models in Tables 3 and 5 show the estimate of equations (1) and (2) respectively. The effect of FDI and output structure on EI is not statistically significant. The effect of crude oil price and alternative energy use on EI is negative and statistically significant. The result is robust in all three regression models. A 1% increase in crude oil price is expected to reduce EI by 0.26% approximately. Lin and Moubarak (2014) estimate the effect of price to be 0.916, Adom (2015a, 2015b) found the price effect for Nigeria to be 0.383 and for South Africa to be 0.127. The relatively low oil price elasticity can be explained by the fact that Russia greatly subsidises fossil fuels consumption, which again is the reason why the consumption is high. According to Table 5, the effect of average acquisition price for heat energy and electricity purchased by industrial organisations is expected to be 0.78 that is much higher than real price for oil.

The effect of alternative energy usage on EI is positive and statistically significant. The estimated coefficient shows that for every 1% expansion in green energy reduce EI by 0.8% approximately.

Given the significance of natural gas as the low-emission source of energy, one of the main factors in energy costs reduction can be the development of pipeline infrastructure for adequate supply, reforming natural gas sector with a competitive price structure to combat excess demand in individual natural gas market in line with Alam et al. (2017).

The potential of development of wind, geothermal, solar energy, biomass and small hydro power stations depends on the region. However, nowadays, renewable energy in Russia, excluding large hydro power stations, is not used enough. As a result Russia significantly falls behind developed economies, as well as China, India, Brazil, Indonesia and South Africa.

5 Conclusions

The cointegration methodology was applied to investigate the impact of oil prices, energy usage structure, FDI alongside with services output on EI in Russia. The similar approach was adopted by Adom (2015a) who included only prices for energy, FDI inflow, industry value-added and economic integration (as the sum of exports and imports). The long run analysis based on a dataset with 24 observations showed that energy price as well as energy use structure have significant impact being negatively correlated to changes in EI in Russia. A 1% increase in real crude oil price is expected to reduce EI by 0.26% approximately, as well as a 1% increase of the share of alternative energy sources is expected to reduce the EI by 0.86%. Bearing in mind a very short period of time we understand that our results might not be robust.

Several policy implications emerge from this analysis. Firstly, international experience to establish the necessary regulatory conditions and investment climate necessary for the deployment of renewable energy sources is required. In line with Paramati et al. (2016), we argue that policy makers in Russia should initiate effective public-private-partnership investments in clean energy projects by providing lucrative incentives, which, in turn, will encourage both domestic and foreign investors to invest more in clean energy projects. Secondly, we should promote the spread of knowledge and best practices, especially based on the bioenergy technology platform and on the integration of renewable energy within heating and electricity systems. Thirdly, authorities have to simplify the existing certification procedure in order to establish sustainable market architecture for renewable energy. Russia has one of the highest energy subsidies that reduces incentives to energy efficiency of local companies. The government must indulge in activities that will lead to a rise in energy price. In other words, government subsidies on energy should be removed to enhance energy efficiency.

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