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Energy consumption and economic growth: Evidence from the Commonwealth of Independent States

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ABSTRACT

This study examines the relationship between energy consumption and economic growth for eleven countries of the Commonwealth of Independent States over the period 1991–2005 within a multivariate panel data framework. Based on Pedroni's (1999, 2004) heterogeneous panel cointegration test and corresponding error correction model, cointegration is present between real GDP, energy consumption, real gross fixed capital formation, and labor force with the respective coefficients positive and statistically significant. The results of the error correction model reveal the presence of unidirectional causality from energy consumption to economic growth in the short-run while bidirectional causality between energy consumption and economic growth in the long-run. Thus, the results lend support for the feedback hypothesis associated with the relationship between energy consumption and economic growth.

1. Introduction

Formed in 1991, the Commonwealth of Independent States (CIS) is comprised of twelve countries of the former Soviet Union.[1] Though many of the countries within the CIS maybe considered transition economies, these countries play an important role in world energy markets both as producers of oil and natural gas and as transit centers for the distribution of these natural resources. In light of this region's importance within world energy markets, it is surprising there have been no published empirical studies which explore the relationship between energy consumption and economic growth for this group of countries.[2] The task of this study is to fill this void in the empirical literature. Such an investigation will not only provide insights with respect to the role of energy consumption in economic development for these countries, but also serve as a basis for discussion of energy and environmental policies.

Table 1 provides an overview of the composition of energy production and usage, the environmental impact of energy consumption, and level of economic development within the CIS region.[3] Russia dominates the CIS with respect to oil production and serves as a major oil producer in the world. While Russia, Kazakhstan, and Azerbaijan are net exports of oil, the remaining CIS countries are net importers. In regards to natural gas production, Russia has the world's largest natural gas reserves with 1,680 trillion cubic feet, nearly twice the reserves of Iran which has the second largest natural gas reserves.[4] Moreover, Russia is the world's largest natural gas producer as well as the world's largest exporter of natural gas. Though Turkmenistan and Uzbekistan follow Russia in terms of natural gas production, both of these countries have struggled to bring their sizeable oil and natural gas reserves to world markets due in large part to an insufficient pipeline infrastructure for the export of natural gas to end-use markets. In regards to natural gas consumption, over half of Ukraine's energy consumption is from natural gas.[5] The rest of the CIS countries rely upon natural gas imports from Russia to meet their natural gas consumption needs. Relative to oil and natural gas production, coal production and consumption in the CIS is not as significant. Coal production in the CIS is concentrated in Russia (who has the world's second largest recoverable coal reserves behind the U.S.), Kazakhstan, and the Ukraine.

The energy sources underlying electricity production varies quite a bit across CIS countries as well. The percentage of electricity production from oil ranges from 27.68% in Azerbaijan to 0.00% in

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[1] Georgia joined later in 1993. The Baltic countries of Estonia, Latvia, and Lithuania decided not to participate in the CIS, but instead pursue affiliation with the European Union.

[2] See Payne (forthcoming) for a survey of the international literature on the causal relationship between energy consumption and economic growth. Reynolds and Kolodzieji (2008) examine the former Soviet Union and focuses exclusively on the bivariate Granger-causality relationship between oil, coal, and natural gas production and GDP. Reynolds and Kolodzieji (2008) find unidirectional causality from oil production to GDP and unidirectional causality from GDP to coal production and natural gas production, respectively.

[3] Turkmenistan was excluded given the unavailability of data on the variables to be included in the panel data set for estimation of the causal relationship between energy consumption and economic growth.

[4] *Country Energy Briefs*, Energy Information Agency, www.eia.doe.gov.

[5] *Country Energy Briefs*, Energy Information Agency, www.eia.doe.gov.

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Table 1
Overview of energy production and consumption (Commonwealth of Independent States, 2005).

	Armenia	Azerbaijan	Belarus	Georgia	Kazakhstan	Kyrgyzstan	Moldova	Russia	Tajikistan	Ukraine	Uzbekistan
Petroleum											
Production	0.00	440.98	33.70	1.98	1337.90	1.96	0.00	9512.98	0.28	100.39	124.91
Consumption	40.00	115.00	156.00	13.40	234.00	12.00	14.50	2757.00	30.00	328.00	155.00
Natural gas											
Production	0.00	205.50	6.10	0.50	934.80	1.10	0.00	22,622.80	1.40	685.10	2108.00
Consumption	60.00	366.60	716.90	52.10	1075.30	26.10	86.50	16,153.10	50.50	3079.50	1702.20
Coal											
Production	0.00	0.00	0.00	0.00	95.40	0.40	0.00	320.60	0.10	66.50	3.30
Consumption	0.10	0.00	0.30	0.00	69.00	1.50	0.20	258.40	0.10	68.40	3.20
Electricity											
Production	6.32	21.22	30.96	7.27	67.92	16.42	3.86	951.16	17.09	185.92	47.71
% Oil	0.00	27.68	8.40	0.91	7.41	0.00	0.23	2.23	0.00	0.27	13.63
% Natural gas	28.94	58.14	91.38	13.28	10.68	9.52	98.14	46.16	2.35	18.65	68.85
% Coal	0.00	0.00	0.01	0.00	70.34	3.62	0.00	17.42	0.00	26.66	4.68
% Hydroelectric	28.07	14.18	0.11	85.81	11.57	86.87	16.30	18.15	97.65	6.65	12.84
% Nuclear	43.00	0.00	0.00	0.00	0.00	0.00	0.00	15.71	0.00	47.74	0.00
Consumption	4.20	19.20	29.50	7.40	58.00	8.20	5.60	779.40	14.70	142.20	40.90
Energy intensity	4.91	2.77	3.14	4.91	2.51	3.18	2.39	2.62	2.80	1.84	1.12
Carbon dioxide											
Emissions per capita	1.20	3.77	6.60	0.86	13.33	1.12	1.96	10.59	0.77	6.95	5.33
Real GDP											
Per capita	$4162	$4575	$8541	$3520	$8699	$1727	$2191	$11,858	$1478	$5583	$2008

Notes: Petroleum production and consumption measured in thousands of barrels per day. Natural gas production and consumption measured in billion cubic feet. Coal production and consumption measured in million short tons. Electricity production and consumption measured in billion kilowatt hours. Data on petroleum, natural gas, coal, and electricity consumption were obtained from the *Energy Information Agency–International Energy Data and Analysis* (www.eia.doe.gov). Data on electricity production, energy intensity measured in GDP per unit of energy use (constant 2005 PPP international dollars per kilogram of oil equivalent). Carbon dioxide emissions measured in metric tons per capita in 2004. Real GDP per capita measured in constant 2005 PPP international dollars. Data on electricity production, energy intensity, carbon dioxide emissions, and real GDP per capita were obtained from *World Bank Economic Indicators* CD-ROM.

Armenia, Kyrgyzstan, and Tajikistan; the percentage of electricity production from natural gas ranges from 98.14% in Moldova to 2.35% in Tajikistan; the percentage of electricity production from coal ranges from 70.34% in Kazakhstan to 0.00% in Armenia, Azerbaijan, Georgia, Moldova, and Tajikistan; the percentage of electricity production from hydroelectric power ranges from 97.65% in Tajikistan to 0.11% in Belarus; and the percentage of electricity production from nuclear power ranges from 47.74% in the Ukraine to 0.00% in Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, and Uzbekistan.

In addition to the variation in energy sources and consumption patterns across CIS countries, there is a great deal of variation in the efficiency of energy usage as measured by GDP per unit of energy use, ranging from 1.12 in Uzbekistan to 4.91 in Armenia and Georgia. As noted by the *Energy Information Agency*, the variation in the efficiency of energy usage is not surprising given that many of the CIS countries have an aging and inefficient energy infrastructure that are in critical need of capital investment and modernization. On the environmental front, CIS countries face tremendous challenges in the reduction of greenhouse gas emissions. As a measure of the environmental consequences of energy production and consumption, Table 1 reports carbon dioxide emissions in metric tons per capita. Carbon dioxide emissions per capita range from a low of 0.77 MT/capita in Tajikistan to a high of 13.33 MT/capita in Kazakhstan. It is interesting to note that the countries with the lowest carbon dioxide emissions per capita (Tajikistan 0.77, Georgia 0.86, and Kyrgyzstan 1.12) have the highest percentage of electricity production from hydroelectric power (Tajikistan 97.65%, Kyrgyzstan 86.87%, and Georgia 85.81%). Finally, the level of economic development in CIS countries exhibits a wide disparity in part due to the success to which individual countries have made the transition towards a market-based economy. As reported in Table 1, real GDP per capita ranges from $1,727 in Kyrgyzstan to $11,858 in Russia.

Given the brief overview of the composition of energy production and usage, the environmental impact of energy consumption, and the level of economic development within the CIS region, Section 2 discusses the four hypotheses associated with the causal relationship between energy consumption and economic growth. Section 3 discusses the data, methodology, and empirical results. Section 4 provides concluding remarks.

2. Survey of the energy consumption-growth hypotheses and the CIS

The relationship between energy consumption and economic growth has been synthesized into four testable hypotheses. First, the growth hypothesis asserts that energy consumption serves a vital role in economic growth both as a direct input in the production process and indirectly as a complement to labor and capital inputs. The growth hypothesis suggests that an increase in energy consumption causes an increase in real GDP (i.e. the economy is energy dependent). Under the growth hypothesis, energy conservation policies which reduce energy consumption may have an adverse impact on real GDP. However, Squalli (2007) suggests the possibility that an increase in energy consumption may have a negative impact on real GDP. Such a possibility could result from excessive energy consumption in relatively unproductive sectors of the economy, capacity constraints, or inefficiencies in energy production. Another possibility for the negative impact of energy consumption on real GDP could be attributed to the case of a growing economy which requires a decreasing amount of energy consumption as production moves toward less energy intensive sectors of the economy.

Second, the conservation hypothesis suggests that energy conservation policies designed to reduce energy consumption and waste may not have an adverse impact on real GDP. The conservation hypothesis is confirmed if an increase in real GDP causes an increase in