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Economic Growth, CO_2 Emissions and Energy Use in the South Caucasus and Turkey: a PVAR analyses

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Abstract – *The scope of the paper is to investigate the relationship among economic growth, carbon dioxide emissions and energy use for the South Caucasus area and Turkey in the 1992-2013 years. We estimate a 3-variable Vector AutoRegressions using a panel VAR technique. Empirical results show that the response of CO_2 emissions to energy use is negative and statistically significant in both the estimated coefficients and impulse responses. Moreover, the first lag of CO_2 (with a negative coefficient) is statistically significant in the real GDP equation. Instead, the energy use is only positively affected by its own lags. The forecast errors in real per capita GDP are mainly due to uncertainty in GDP itself and (marginally) in energy use emissions. The error variances in the carbon dioxide emissions are sensible to disturbances in all three equations. While the errors in predicting the energy use are sensitive to disturbances in its own equation. Thus, for the estimated sample, these results reinforced the VAR and IRFs analyses, suggesting that the "neutrality hypothesis" holds.*

Keywords – CO_2 emissions, economic growth, energy use, panel data, South Caucasus.

1. INTRODUCTION

South Caucasus is a strategic transit route connecting Caspian energy resources with European markets. The EU has a long-term interest in improving the energy security of the South Caucasus, since it can contribute to stability in the EU's neighborhood. Since the 1990s, the EU has provided technical and financial assistance to promote regulatory reform, energy efficiency and renewable energy, nuclear safety and the development of infrastructure and interconnections.

Armenia lacks indigenous resources and imports constitute around 75 per cent of the country's total energy supply. Natural gas, which accounts for two thirds of energy supplies, comes mainly from Russia through Georgia, and smaller volumes of Iranian gas are swapped for electricity. Armenia is also completely dependent on Russia for nuclear fuel.

With large oil and natural gas reserves, Azerbaijan is a major energy producer. Hydrocarbons are mainly exported to European markets, and to a lesser extent to Russia and other countries in the region. In 2013, energy accounted for 95 per cent of Azerbaijan's total export revenues, and 64 per cent of total fiscal revenues. These exports explain Azerbaijan's rapid economic growth over the last decade (34 per cent in 2006). However, in recent years economic growth has sharply slowed down (2.8 per cent in 2014), reflecting the decline in oil production (as a result of the drop in global oil prices) and slow growth in non-oil sectors.

Since the dissolution of the Soviet Union, its former member countries have been passing through a considerable transformation from socialism to a market economy.

Georgia is strategically located on the East-West and North-South energy trading routes, due to its access to the Black Sea and land transit links to major energy exporter and importer countries. In addition, Georgia lies within the EU's Southern Gas Corridor (Alieva and Shapovalova, 2015).

Turkey is a rapidly growing energy consumer in its own right. This country has experienced extremely sharp economic growth in recent years, which was largely achieved through a rapidly increasing population.

Because of the disruption of the Soviet energy and economic space and infrastructure during the 1990s, energy and economic potential of Azerbaijan, Georgia and Armenia were virtually nullified. Thus, the 1990s represented the period when the countries of the region had to rebuild their energy infrastructure that was damaged by political instability. At the same time, they had to determine which economic and energy spaces they saw themselves as being part of. Such an imbalance between the countries of South Caucasus with regards to energy dependence and political development poses the question as to how it would be possible to ensure the safety of energy transit and stable political relations between these differing spheres of European and Russian influence. Thus, taking the existing regional context into account, the transit potential of South Caucasus can play an important role in bringing the Caspian energy resources to the global market. It will be necessary to resolve issues that are vital for its stability and future development, which implies serious reforms.

If we compare the energy consumption of the leading developed countries, the result is alarming for Georgia: Georgia's energy consumption per capita is 10 times less than the same figure for the United States and 4-5 times less than the EU average (Aslanishvili, 2016).

The relationship between economic growth and energy use, as well as economic growth and environmental pollution, has been the subject of several research projects in the last years. Notwithstanding, the empirical results remains mixed and debatable. In addition, many studies concern the relation among energy consumption, CO_2 emissions and economic

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growth, but very few studies have been devoted to the South Caucasus case (Magazzino, 2016).

In this study, the nexus among economic growth, CO_2 emissions and energy use in three South Caucasus countries (Armenia, Azerbaijan and Georgia) and Turkey has been investigated for the period 1992-2013, using time-series methodologies. The results might help to define and implement the appropriate energy and environmental policies in this area. To our knowledge, this is the first study that investigates the relationship among economic growth, energy use, and CO_2 emissions in the area. In fact, the environmental degradation and economic growth relationship in the South Caucasus have not been researched empirically previously as far as this study is concerned. From an energy perspective, this represents a strategic area, linking to different continents and being rich of oil and gas.

Besides the Introduction, the outline of this paper is the following. Section 2 summarizes the survey of the literature. Section 3 contains an overview of the econometric methodology and a brief discussion of the data. Section 4 discusses the empirical results. Finally, Section 5 gives some conclusions and policy implications.

2. LITERATURE REVIEW

The relationship between carbon dioxide emissions, energy consumption, and real output is a synthesis of the Environmental Kuznets Curve (EKC) and the energy consumption growth literatures (Kuznets, 1955). The literature on the economic growth-energy consumption has been summarized in Magazzino (2014b) and Ozturk (2010), while Magazzino (2014a) and Payne (2010) report an overview of the electricity demand-GDP nexus. Bo (2011) contains a survey on the EKC literature.

The directions that the causal relationship between energy consumption (electricity consumption) and economic growth could be categorized into four types each of which has important implications for energy policy:

1. "Neutrality hypothesis": no causality between energy and GDP; it is supported by the absence of a causal relationship between energy consumption and real GDP.
2. "Conservation hypothesis": unidirectional causality running from GDP to energy; it is supported if an increase in real GDP causes an increase in energy.
3. "Growth hypothesis": unidirectional causality running form energy to economic growth; increases in energy may contribute to growth process.
4. "Feedback hypothesis": bidirectional causality between energy consumption and economic growth; It implies that energy consumption and economic growth are jointly determined and affected at the same time.

Table 1 presents the main features of the applied studies devoted to these four countries.

Moreover, Balat (2008) analyzed energy consumption and economic growth in Turkey during the 1980-2005 years, concluding that the country's energy strategy was aimed at satisfying demand without preventing economic growth. Turkey's renewable energy resources were the most important alternatives to fossil resources for the country's energy demand. Balat (2006) reviewed the energy policies in Turkey in the last decades, noting that Turkey had to adopt new long-term energy strategies to reduce the share of fossil fuels in the primary energy consumption. Kiliç (2006) investigated Turkey's main energy sources and importance of its usage in the energy sector. He pointed out that the Turkish energy policy has been mainly concentrated on assurance of energy supply in a reliable manner and sufficiently in time, under economic and clean terms, and in a way to support and orientate the target growth and social developments. Turkey's own energy sources are limited. Due to its growing economy and developing industries, this country is bound to experience an economic crisis in next future unless it finds alternative energy sources in addition to available ones. Yesevi and Tiftikcigil (2015) explored the Turkey-Azerbaijan energy relations, highlighting that the economic relations between these countries are below the expectations. In fact, neither a free trade area was not established, nor a visa-free regime was not implemented.

3. METHODOLOGY AND DATA

Our empirical strategy uses a panel-data Vector AutoRegression (VAR) methodology. This technique combines the traditional VAR approach, which treats all the variables in the system as endogenous, with the panel data approach, which allows for unobserved individual heterogeneity. Here, we follow a similar strategy of Magazzino (2014c, 2014d) and Cagala *et al.* (2014).

Our main objective is to compare the aggregate income to energy factors in countries on a different level of socio-economic integration.

We recover the PVAR parameters by estimating the reduced form PVAR model with a Least Squares Dummy Variable (LSDV) estimator (Bun and Kiviet, 2006) and then computing the Cholesky factorization of the reduced-form PVAR variance-covariance matrix of the residuals. The LSDV estimator is consistent when the number of time observations in the data set tends to infinity. To account for the endogeneity of economic growth, CO_2 emissions and energy use, we adapt a panel VAR model to our design.

The Impulse-Response Functions (IRFs) describe the reaction of one variable to the innovations in another variable in the system, while holding all other shocks equal to 0. To analyze the IRF we need an estimate of their confidence intervals. Since the matrix of IRF is constructed from the estimated VAR coefficients, their standard errors need to be taken into account.

Finally, we also present the Forecast Errors Variance Decompositions (FEVDs), which show the percent of the variation in one variable that is explained by the shock to another variable, accumulated over time. The variance decompositions show the magnitude of the total effect. We report the total effect accumulated over the 1, 5, and

10 years, as longer time horizons produced equivalent results.

Because of the length of our panel (22 periods for each selected country) the Nickell's bias (Nickell, 1981) is a minor concern.

We specify a first-order VAR model as follows:

$$z_{it} = \Gamma_0 + \Gamma_1 z_{it-1} + f_i + d_{ct} + e_t \quad (1)$$

where z_{it} is a three-variable vector {*RPCGDP*, CO_2, *PCEU*}. Our model also allows for country-specific time dummies, d_{ct}, which are added to model (1) to capture aggregate, country-specific macro shocks. We eliminate these dummies by subtracting the means of each variable calculated for each country-year. In applying the VAR procedure to panel data, we need to impose the restriction that the underlying structure is the same for each cross-sectional unit. Since this constraint is likely to be violated in practice, one way to overcome the restriction on parameters is to allow for "individual heterogeneity" in the levels of the variables by introducing fixed effects, denoted by f_i in the model (Love and Zicchino, 2006).

Table 1. Summary of existing literature on South Caucasus countries and Turkey.

Author(s)	Countries	Study period	Empirical analyses
Akbostancı *et al.* (2009)	Turkey	1968–2003	Stationarity and cointegration
Altinay and Karagol (2004)	Turkey	1950–2000	Stationarity and causality
Azgun (2011)	Turkey	1968–2008	SVAR
Erdal *et al.* (2008)	Turkey	1970–2006	Stationarity, cointegration and causality
Halicioglu (2009)	Turkey	1960–2005	Stationarity, cointegration and causality
Halicioglu and Ketenci (2016)	15 transition countries	1991–2013	Stationarity, cointegration and causality
Jobert and Karanfil (2007)	Turkey	1960–2003	Cointegration and causality
Kalyoncu *et al.* (2013)	Georgia, Azerbaijan and Armenia	1995–2009	Stationarity, cointegration and causality
Kaplan *et al.* (2011)	Turkey	1971–2006	Stationarity, cointegration and causality
Lise and Van Montfort (2007)	Turkey	1970–2003	Causality
Magazzino (2016)	South Caucasus and Turkey	1992-2013	Stationarity, structural breaks, cointegration and causality
Saatci and Dumrul (2013)	Turkey	1960–2008	Stationarity, cointegration and causality
Sentürk and Sataf (2015)	Turkey and Central Asian Republics	1992–2012	Stationarity, cointegration and causality
Soytas and Sari (2009)	Turkey	1960–2000	Stationarity and causality
Telli *et al.* (2008)	Turkey	2006–2020	CGE model
Tunç *et al.* (2009)	Turkey	1970–2006	LMDI method

Notes: CGE: Computable General Equilibrium; LMDI: Log Mean Divisia Index; SVAR: Structural Vector AutoRegressions.

Initially, we derived the log-transformation of our three variables. The empirical analysis uses yearly data of real per capita GDP, per capita CO_2 emissions, and per capita energy use, in the period 1992-2013 for Armenia, Azerbaijan, Georgia and Turkey. The data are obtained from the World Development Indicator (Table 2)[1]. In this paper, per capita GDP is expressed in constant 2005 US$ (RPCGDP), CO_2 emissions in metric tons per capita (CO_2), and per capita energy use in terms of kg oil equivalent (PCEU). In order to better understand and compare the emission trends in these four countries over time and in an international perspective, the measures of per capita emissions and GDP were used. The choice of the starting period was constrained by country's history and data availability.

Figure 1 shows the evolution of these variables for each country.

A visual inspection of the log-series shows an upward trend for all variables. Table 3 reports the summary statistics for our sample. Mean value of all variables is positive. These variables show similar values for mean and median in each country, indicating that a normal distribution emerges.

Given the fact that for each variable the Standard Deviation value is near to the Pseudo Standard Deviation, the Inter-Quartile Range (IQR) shows the absence of outliers in the observed sample.

As shown in Table 4 above, energy use and CO_2 emissions series are strongly correlated, since the

[1] See, for more details: http://www.econstats.com/wdi/wdic_ISR.htm.

corresponding correlation coefficients (*r*) exceed 0.83, and these pairwise correlations is significant at 1% level. Moreover, the correlation between real economic growth and energy use is negligible (0.13).

Table 2. Variable definitions.

Abbreviation	Description	Source
RPCGDP	GDP per capita (constant 2000 US$)	WDI
CO_2	CO_2 emissions (metric tons per capita)	WDI
PCEU	Per capita energy use, kg of oil equivalent	WDI

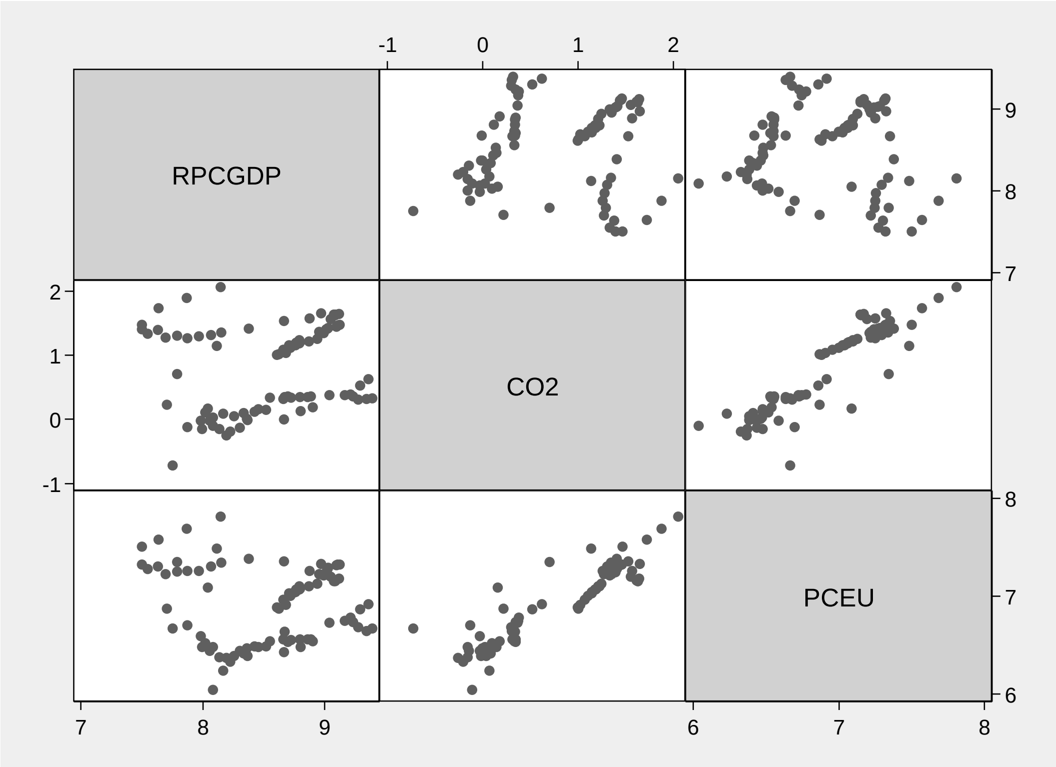


Fig. 1. Per capita real GDP, CO_2 emissions and energy use for South-Caucasian countries and Turkey (1992-2013, log-scale).
Sources: WDI data.

Table 3. Exploratory data analyses.

Variable	Mean	Median	IQR	Range	SD	CV	SE Mean
RPCGDP	8.5390	8.6671	0.8612	1.8901	0.5115	0.0599	0.0545
CO_2	0.7758	1.0053	1.2007	2.7765	0.6592	0.8496	0.0703
PCEU	6.9074	6.9374	0.7029	1.7719	0.3872	0.0561	0.0413
Country	**Variable**	**Mean**	**Median**	**IQR**	**Range**	**SD**	**CV**
Armenia	RPCGDP	8.7335	8.7354	0.9723	1.3931	0.5016	0.0574
	CO_2	0.1846	0.1537	0.3098	0.8202	0.2143	1.1607
	PCEU	6.5690	6.5127	0.3188	1.0500	0.2416	0.0368
Azerbaijan	RPCGDP	8.2602	8.1091	1.2763	1.6191	0.6131	0.0742
	CO_2	1.5140	1.5006	0.2965	0.7898	0.2085	0.1377
	PCEU	7.3281	7.2864	0.1302	0.6586	0.1726	0.0236
Georgia	RPCGDP	8.3061	8.2501	0.6489	1.1843	0.3818	0.0460
	CO_2	0.1658	0.1872	0.3683	1.8670	0.3692	2.2273
	PCEU	6.6221	6.5532	0.1591	1.1129	0.2797	0.0422
Turkey	RPCGDP	8.8563	8.7976	0.2976	0.5153	0.1657	0.0187
	CO_2	1.2389	1.2068	0.2488	0.4671	0.1511	0.1220
	PCEU	7.1106	7.0854	0.2177	0.4520	0.1441	0.0203

Notes: IQR: Inter-Quartile Range; SD: Standard Deviation; CV: Coefficient of Variation; SE Mean: Standard Error of Mean.
Sources: our calculations on WDI data.

Table 4. Correlation matrix.

Variable	RPCGDP	CO_2	PCEU
RPCGDP	1.0000		
CO_2	0.1269 (0.5590)	1.0000	
PCEU	-0.0545 (0.9425)	0.9142*** (0.0000)	1.0000

*Notes: Sidak's correction has been applied, P-Values in parentheses. ***p<0.01, **p<0.05, *p<0.10.*

Table 5. Main results of a 3-variable VAR model.

Response of	**Response to**					
	RPCGDP (*t*-1)	CO_2 (*t*-1)	PCEU (*t*-1)	RPCGDP (*t*-2)	CO_2 (*t*-2)	PCEU (*t*-2)
RPCGDP (*t*)	0.9478***	-0.1270**	-0.0349	0.4676***	-0.0103	-0.0368
	(0.0954)	(0.0558)	(0.0776)	(0.1066)	(0.0553)	(0.0646)
CO_2 (*t*)	0.1528	-0.3109**	-0.3488*	0.0890	0.0811	-0.1883
	(0.2177)	(0.1272)	(0.1772)	(0.2433)	(0.1262)	(0.1474)
PCEU (*t*)	0.1845	0.0784	0.9902***	0.1545	0.0834	0.2850***
	(0.1332)	(0.0778)	(0.1084)	(0.1489)	(0.0772)	(0.0902)
N obs.	80					
N countries	4					

Equation of RPCGDP		
F	RMSE	R^2
826.5379 (0.0000)	0.0548	0.9899
Equation of CO_2		
F	RMSE	R^2
21.9234 (0.0000)	0.1251	0.9672
Equation of PCEU		
F	RMSE	R^2
38.2424 (0.0000)	0.0765	0.9621

*Notes: Robust Standard Errors in parentheses. ***p<0.01, **p<0.05, *p<0.10.*

4. RESULTS

We estimate the coefficients of the system given in (1) after the fixed effects and the country-time dummy variables have been removed. In Table 4, we report the results of the model with three variables {RPCGDP, CO_2, PCEU}. Estimating a PVAR(2) model minimizes the Schwarz Bayesian Information Criterion (SBIC)[2].

We discuss general results of the 3-variable VAR model first, before proceeding to the ones of variance decompositions. For our selected sample, we observe that the response of CO_2 emissions to energy use is negative in the estimated coefficients and impulse responses. This is reasonable, since most of times, an increase in energy consumption is an effort to substitute non-renewable sources with renewable ones, resulting in lower level of CO_2 emissions (Shabbir *et al.*, 2014). The negative coefficient of CO_2 one period lagged (*t-1*) is statistically significant in the real GDP equation, showing that an increase in CO_2 emissions leads to a slower economic activity. Instead, the energy use is only positively affected by its own two lags. Thus, this variable simply seems to be driven by its own past values. Therefore, on the basis of our results, CO_2 emissions increase in response to an energy use shock (since higher energy intensity implies more environmental costs combined with negative externalities), whilst real per capita GDP is sensible to emissions' shocks. As concerns the economic growth-energy literature, for our sample countries the evidence is in favour of the "neutrality hypothesis". The implication of the neutrality hypothesis is that energy conservation policies will have no effect on economic growth. The IRFs presented in Figure 2 broadly confirm these results.

The variance decompositions for our panel, presented in Table 6, are in line with previous findings. In fact, CO_2 explains 11% of the economic growth variation 10 periods ahead, while the real GDP explains nearby 15% of variation of carbon dioxide emissions 5 periods ahead (in an increasing way); the energy use contributes to the CO_2 dynamic, too. Thus, the errors in predicting the carbon dioxide emissions are sensitive to disturbances both in the GDP and in energy use equations: after ten periods, almost 45% of the error variance in CO_2 forecasts is split between contributions from shocks to the GDP (29%) and energy (15%) equations. Moreover, as still highlighted in the comments of PVAR estimates, the variance decomposition of the energy use is mainly due to its own variation, since after 10 periods ahead only 1/5 of its variability is explained by two remaining variables.

[2] The dataset is available upon request.

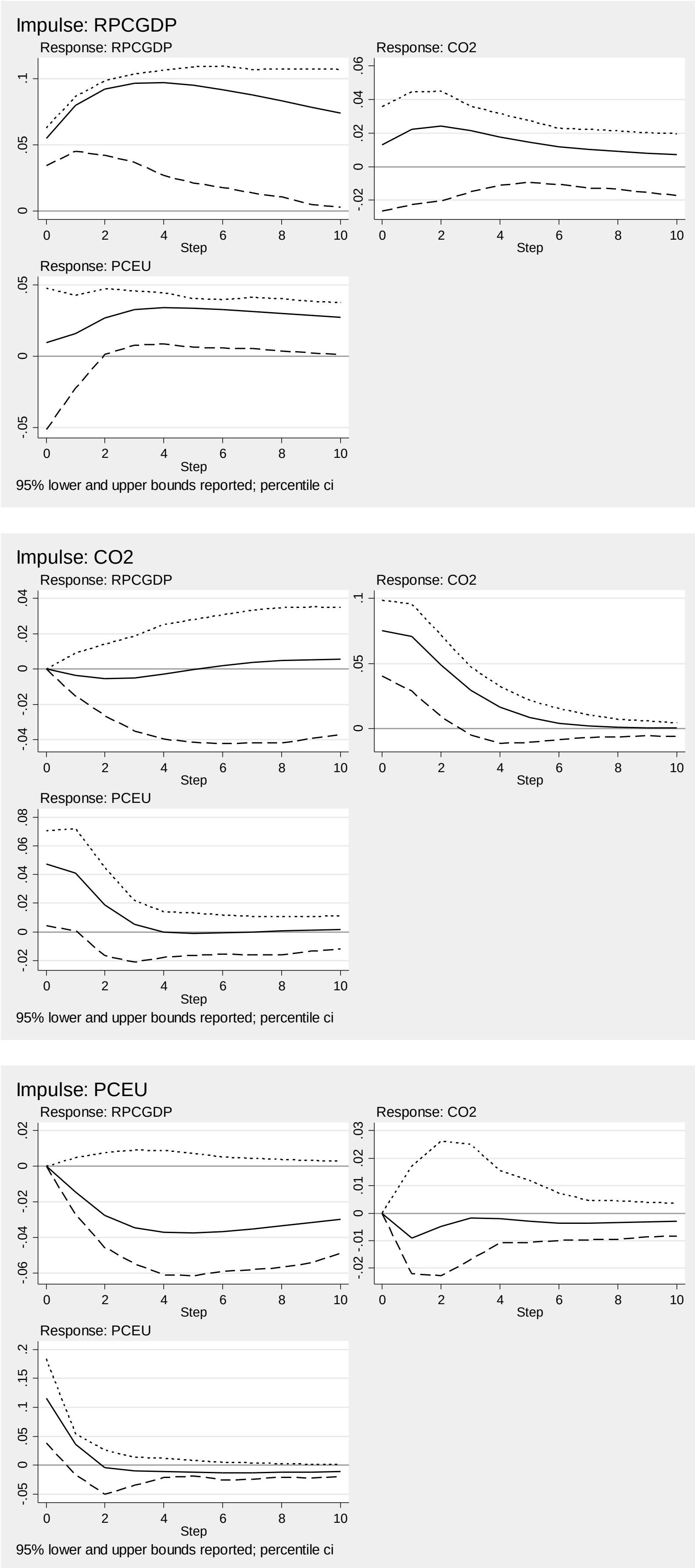
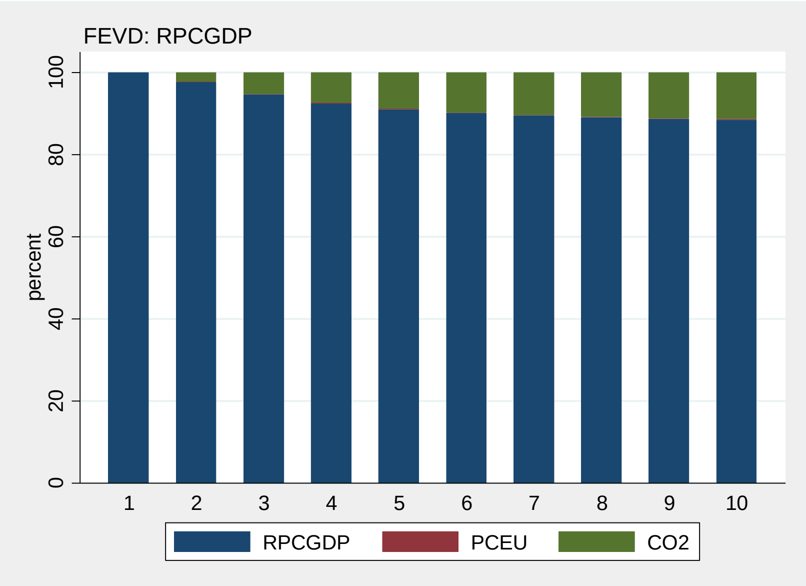


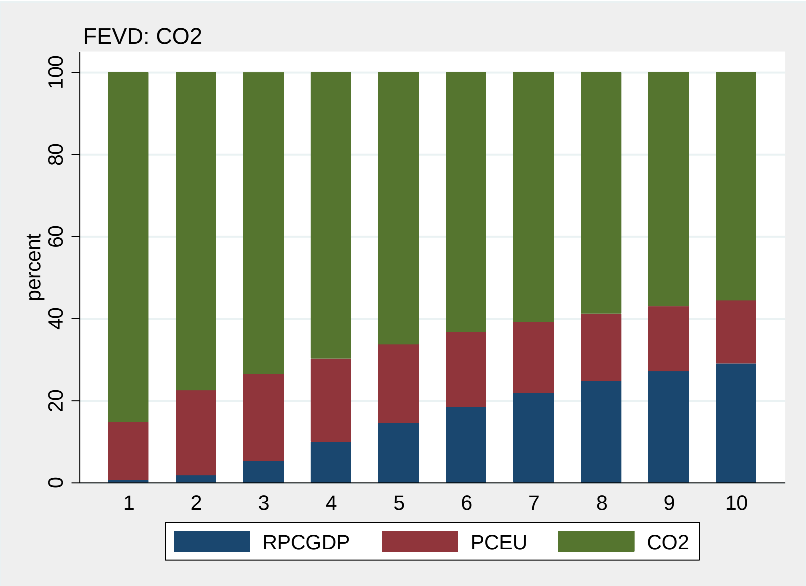
Fig. 2. Impulse-Response functions for 2 lags VAR of real GDP, CO_2 emissions and energy use.
Notes: Sample: Armenia, Azerbaijan, Georgia and Turkey.

Table 6. Variance decompositions.

Variable	RPCGDP	CO_2	PCEU
	1 period ahead		
RPCGDP	1.0000	0.0000	0.0000
CO_2	0.0058	0.8522	0.1420
PCEU	0.0285	0.0000	0.9715
	5 periods ahead		
RPCGDP	0.9102	0.0880	0.0018
CO_2	0.1453	0.6630	0.1917
PCEU	0.1227	0.0069	0.8704
	10 periods ahead		
RPCGDP	0.8847	0.1136	0.0017
CO_2	0.2911	0.5556	0.1533
PCEU	0.1524	0.0099	0.8377

Notes: Percent of variation in the row variable explained by column variable.





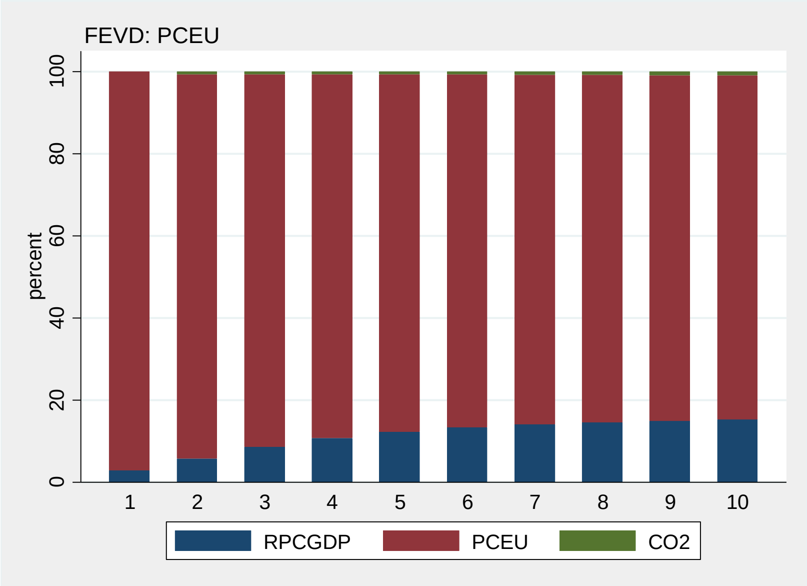


Fig. 3. Forecast errors variance decompositions for 2 lags VAR of real GDP, CO_2 emissions and energy use.

As discussed above, the FEVDs reported in Figure 3 roughly confirm the empirical findings reached by PVAR estimate and IRFs.

To sum up, for the four selected countries our panel empirical evidence is in line with the "neutrality hypothesis", since neither real GDP affects energy use nor *vice versa*. These findings are in line with previous results by Altinay and Karagol (2004), Halicioglu (2009), and Azgun (2011).

5. CONCLUSIONS AND POLICY IMPLICATIONS

This study explored the relationship among economic growth, carbon dioxide emissions and energy use in South Caucasus area (Armenia, Azerbaijan and Georgia) and Turkey over the period 1992-2013. The empirical strategy uses a panel VAR approach. The 3-variable VAR estimates underline that the real GDP is affected by its past (both two lags are statistically significant at 1% level) as well as by CO_2, with a negative sign, indicating that an increase in CO_2 emissions has a detrimental effect on economic activity. In the carbon dioxide emissions equation, the only statistically significant (both at 10%) coefficients are those related to its first lag and energy use. This might imply that an increase in energy is an effort to substitute non-renewable sources with renewable ones, resulting in lower level of CO_2 emissions. While the energy use is only affected by its own two lags. Therefore, for the selected countries the evidence is in line with the "neutrality hypothesis". It implies that energy is not correlated with GDP, which means that neither conservative nor expansive policies in relation to energy use have any effect on economic growth. Thus, the neutrality hypothesis is supported by the absence of a causal relationship between energy consumption and real GDP. The IRFs and variance decompositions findings confirm these results. In fact, CO_2 explains 11% of the economic growth variation 10 periods ahead, while the real GDP explains nearby 15% of variation of carbon dioxide emissions 5 periods ahead (in an increasing way); the energy use contributes to the CO_2 dynamic, too. Thus, the errors in predicting the carbon dioxide emissions are sensitive to disturbances both in the GDP and in energy use equations. Moreover, the variance decomposition of the energy use is mainly due to its own variation, since after 10 periods ahead only 1/5 of its variability is explained by two remaining variables. As noted in Payne (2010), the results for the specific countries surveyed show that 31.15% supported the neutrality hypothesis.

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