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Energy consumption and income in G-7 countries

Ugur Soytas [a,*], Ramazan Sari [b,1]

[a] *Department of Business Administration, Middle East Technical University, Ankara 06531, Turkey*
[b] *Department of Economics, Abant Izzet Baysal University, Bolu 14280, Turkey*

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Abstract

Several industrialized countries have signed the Kyoto Protocol, promising to reduce greenhouse gasses (GHG) emissions. To reduce or mitigate such emissions several policies including reducing energy consumption, increasing energy efficiency, decreasing energy intensity and forestation may be possible. The viability and effectiveness of each policy may differ due to country specific factors. This paper tries to assess the impact of a change in energy consumption on income and vice versa in G-7 countries. We employ multivariate cointegration, error correction models and generalized variance decompositions and uncover Granger causality relation between energy consumption and income in all countries. However, the direction of causality seems to differ across countries. This may suggest that although they are at the same level of economic development, different policy alternatives in support of the protocol may be available in each country.

JEL classification: Q 43

Keywords: Energy consumption; Economic growth; Global warming; Cointegration; Vector error correction; Generalized variance decompositions

1. Introduction

Energy conservation has been in the governments' agendas due to two main reasons. One reason is the 1973 oil crisis. The crisis started by OPEC's cutting crude oil production and placing embargo on shipments of crude oil to the Western countries. The outcome of the oil cut and embargo was

* Corresponding author. Tel.: +90 312 210 2010; fax: +90 312 210 1243.
E-mail addresses: soytas@ba.metu.edu.tr (U. Soytas), sari_r2@ibu.edu.tr (R. Sari).
[1] Tel.: +90 374 254 1465.

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economically severe all around the world, especially in oil dependent industrialized countries. The immediate effect of the crisis was higher unemployment and inflation rates, the stagflation. The crisis led to great interest in energy conservation, development of alternative energy sources and technologies that consume energy resources more efficiently. The aim was to decrease the dependence of the economy on imported energy. Another reason is the Kyoto Protocol which aims at decreasing global warming. According to the Kyoto Protocol the main reason for global warming is increased emissions of greenhouse gasses (GHG). Many industrialized countries have ratified the protocol, committing to reduce GHG emissions. The main policy to achieve it has been to reduce the domestic energy consumption (de Nooij, van der Kurk, & van Soest, 2003). However, if economic growth is influenced by the amount of energy as well as primary inputs (i.e. labor and capital) (Beaudreau, 2005; Stern & Cleveland, 2003), then increasing economic growth and reducing GHG emissions may appear to be two conflicting goals. On the other hand, there appears to be a wide variety of different policy options to fight global warming and to mitigate its adverse effects (see, for example, United Nations Framework Convention on Climate Change, UN FCCC, 2004). Such policies include decreasing energy intensity, switching from fossil fuels to cleaner sources, using fossil fuels more efficiently, increasing forestation to overcome affects of deforestation due to firewood consumption, changing life styles to promote energy conservation, developing a market for emissions trading, etc. (UN FCCC, 2004). The relevant action by each country is to choose the most appropriate option(s) according to the characteristics of its economy. To implement the most appropriate policy without hindering economic growth requires identifying the nature of the relationship between energy consumption and economic growth. This paper attempts to shed more light on the energy consumption and economic growth relations in G-7 countries that may provide more information to the policy makers in these countries in choosing from a wide variety of policy options in line with the Kyoto Protocol.

Several time series studies have investigated the relationship between energy consumption and income, but unanimous results were not reached. The lack of consensus may be largely due to the differences in the development stages of the various countries studied or the differences in the data and the methodologies employed. However, even studies focusing on the same countries sometimes yield different results. As for the differences in methodologies, they may be roughly categorized into two: use of either a bivariate or a multivariate framework. Although, bivariate Granger causality tests have been criticized due to a possible omitted variables bias, multivariate studies also yielded conflicting results. One possible reason for the lack of consensus in multivariate studies on the same countries may be that the choice of control variables was arbitrary.

In the light of these concerns, we investigate the relationship between energy consumption and income in each G-7 country, employing multivariate time series data, while controlling the changes in traditional factors of production. We were able to uncover Granger causality in all G-7 countries; hence, the policy makers should avoid evaluating economic growth, energy consumption, and emission reduction policies independent from each other.

If causality is running from energy consumption to growth, then energy conservation may harm economic growth. In such cases, countries may choose to invest in technology that discovers and makes alternative energy sources economically feasible, in the meantime following policies that mitigate carbon emissions such as increasing energy efficiency and decreasing energy intensity via substituting in cleaner (i.e. natural gas, solar, wind energy) sources for fossil fuels like coal and oil. On the other hand, if there is uni-directional causality running in the opposite direction, then decreasing domestic energy consumption and encouraging energy conservation may become the key actions in reducing domestic emissions. Finally, if there is bi-directional causality, then a carefully integrated mixture of alternative policy actions may be possible.

In the next two sections, we provide a brief review of the empirical literature and discuss the relevant theoretical background. Then we describe the data and data sources, and then we discuss the unit root and cointegration test results. We continue with the Granger causality tests in VEC framework and in generalized variance decompositions (as out of sample causality tests). The last section provides policy implications and conclusions.

2. Literature review

Most of the earlier work, starting with the pioneering paper by Kraft and Kraft (1978), conducted Granger causality tests between energy and income (Abosedra & Baghestani, 1991; Akarca & Long, 1980; Bentzen & Engsted, 1993; Erol & Yu, 1987; Glasure & Lee, 1997; Hwang & Gum, 1992; Yu & Choi, 1985; Yu & Hwang, 1984). The earlier studies were far from establishing stylized facts in that they reported different results for different countries and even different results for the same country for different time periods. More recent studies have incorporated relatively new time series techniques, such as cointegration and vector error correction modeling to overcome the stationarity problem inherent in the traditional tests (Altinay & Karagol, 2004; Asafu-Adjaye, 2000; Ghali and El-Sakka, 2004; Glasure, 2002; Lee, 2005, 2006; Masih & Masih, 1996, 1997, 1998; Narayan & Smyth, 2005; Oh & Lee, 2004; Sari & Soytas, 2004; Soytas & Sari, 2003; Stern, 1993, 2000; Wolde-Rufael, 2004, 2005; Yang, 2000). However, there still does not seem to be a consensus on whether causality exists between energy consumption and output or not, and on the direction of causality if it exists.

Stern (2000), Asafu-Adjaye (2000) and Glasure (2002) point out the importance of omitted variables and they suggest a multivariate empirical analysis. Although multivariate analysis is commonly used in the recent literature, there does not seem to be a theoretical background in most of the studies. Hence, a variety of macro variables have been considered in studies that investigate the relationship between income and energy. Probably a more formal treatment is provided in Ghali and El-Sakka (2004). They assume a neo-classical one sector production function with three inputs for Canada and find bi-directional causality between energy use and output. Their results do not seem to confirm the neo-classical assumption of neutrality of energy to growth.

3. Theoretical background

Beaudreau (2005) argues that the engineering and economic views of production have differences as well as similarities. He criticizes the traditional growth accounting for treating energy as a secondary factor and points out that for an engineer production is not possible without energy use. From an economist's perspective this calls for considering energy as an important input for production. Indeed several studies in the literature seem to support this belief. Beaudreau (1995), Ghali and El-Sakka (2004) and Stern (1997, 2000) all appear to incorporate energy consumption in a production function framework to analyze the relationship between energy consumption and output.

In this paper, we examine the relationship between energy consumption and output in a three factor (KLE) production function framework in G-7 countries. As it was formulized in Ghali and El-Sakka (2004):

$$Y_t = f(K_t, L_t, E_t) \tag{1}$$

where t is time trend, Y the real output, K the capital stock, L the total labor and E is the energy consumption. The differential of Eq. (1) is

$$dY_t = Y_K\, dK_t + Y_L\, dL_t + Y_E\, dE_t \tag{2}$$

where Y_K, Y_L and Y_E refers to the partial derivatives of Y with respect to capital stock, total labor and energy consumption, respectively. The division of Eq. (2) with Y_t and rearrangement of the results gives the following growth equation:

$$\dot{Y}_t = b_1\dot{K}_t + b_2\dot{L}_t + b_3\dot{E}_t \tag{3}$$

where the variables are in a growth rate form as indicated by the dots on top of them. Eq. (3) suggests that three is a long run equilibrium relationship between the variables. Hence, past observations on growth of inputs and energy consumption may improve the forecasts of economic growth. In the light of Eq. (3), we investigate the temporal relationship between energy consumption and economic growth while controlling for growth rates of traditional production factors.

4. Data

We use annual time series data sourced from the World Development Indicators (WDI) for all G-7 countries. The period of the data covered varies from as long as 44 years for most variables (1960–2004) to as low as 32 years (1971–2003 for some German data and 1970–2002 for some French data). We use total labor force and total energy use (kilotonnes of oil equivalent) and denote them as L and E, respectively. For income (Y) we use real GDP per capita (US$ 2000). The capital stock (K) data is difficult, if not impossible, to obtain. There is no readily available dataset for it. However, if I_t is the investment at time t and δ is depreciation rate, then the aggregate capital stock is calculated by $K_t = (1-\delta)\, K_{t-1} + I_t$, which is called perpetual inventory method (Jacob, Sharma, & Grabowski, 1997). This equation implies that the variance in capital is mostly related to the change in investment if the depreciation rate is constant. Thus, following Jin and Yu (1996) and Shan and Sun (1998) among others, we employ growth of real gross fixed capital formation (US$ 2000) as a reliable proxy for growth of capital stock. The variables employed in this paper are similar to those commonly used in the literature (see, for example, Beaudreau, 1995; Ghali & El-Sakka, 2004; Narayan & Smyth, 2005; Soytas & Sari, 2003). Note that all variables are in natural logarithms so that their first differences approximate their growth rates. We use L in front of each variable to indicate the natural logarithm.

5. Methods and results

We employ Johansen (1991, 1995) and Johansen–Juselius (1990) cointegration[2] test, vector error correction model (VECM) and generalized variance decomposition of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998). The time series properties of the series were checked by five different unit root tests.[3] And also, three different lag selection procedures

[2] See Gonzalo (1994) and Hubrich, Lutkepohl, and Saikkonen (2001) for a review and comparison of methods.

[3] Namely, augmented Dickey–Fuller (ADF) (Dickey & Fuller, 1979), Dickey–Fuller GLS detrended (DF-GLS) (Elliott, Rothenberg, & Stock, 1996), Phillips–Perron (PP) (Phillips & Perron, 1988), Kwiatkowski–Phillips–Schmidt–Shin (KPSS) (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) and Ng and Perron (2001) MZ_α test (NP) (see Maddala & Kim, 1998 for excellent treatment of ADF, PP, KPSS and DF-GLS; and Ng & Perron, 2001 for NP).

were employed.[4] There does not appear to be overwhelming statistical evidence to deny that all variables are integrated of order 1. The results of the cointegration tests, maximum eigenvalue and the trace statistics, for all seven countries show that for all countries there exists at least one cointegrating equation.[5] Existence of at least one cointegrating equation for each country suggests that Granger causality exists but it does not indicate the direction. In order to assess which variables Granger cause others and vice versa we refer to VEC modeling. If the variables in concern are cointegrated, a vector error correction model should be estimated rather than a VAR as in a standard Granger causality test. Following Engle and Granger (1987) and Granger (1969), we formulate the following VEC representation for each country as follows:

$$\Delta \mathrm{LY}_t = \mu_1 + \alpha_{1,1}\mathrm{ECT}_{1,t-1} + \alpha_{1,2}\mathrm{ECT}_{2,t-1} + \cdots + \alpha_{1,i}\mathrm{ECT}_{i,t-1} + \sum_{s=1}^{p}\gamma_{1,s}\,\Delta \mathrm{LY}_{t-s} + \sum_{s=1}^{p}\gamma_{2,s}\,\Delta \mathrm{LK}_{t-s} + \sum_{s=1}^{p}\gamma_{3,s}\,\Delta \mathrm{LL}_{t-s} + \sum_{s=1}^{p}\gamma_{4,s}\,\Delta \mathrm{LE}_{t-s} + \varepsilon_{1,t} \quad (4)$$

$$\Delta \mathrm{LE}_t = \mu_4 + \alpha_{4,1}\mathrm{ECT}_{1,t-1} + \alpha_{4,2}\mathrm{ECT}_{2,t-1} + \cdots + \alpha_{4,i}\mathrm{ECT}_{i,t-1} + \sum_{s=1}^{g}\lambda_{1,s}\,\Delta \mathrm{LY}_{t-s} + \sum_{s=1}^{g}\lambda_{2,s}\,\Delta \mathrm{LK}_{t-s} + \sum_{s=1}^{g}\lambda_{4,s}\,\Delta \mathrm{LL}_{t-s} + \sum_{s=1}^{g}\lambda_{5,s}\,\Delta \mathrm{LE}_{t-s} + \varepsilon_{4,t} \quad (5)$$

where ECT_i refer to error correction term(s) derived from long run cointegrating relationships, μ_1 and μ_2 the intercepts, and p, l, h, g and f are the lag lengths. The symbol (Δ) denotes the difference of the variable following it.

Sources of causation between the variables in one equation ((4) and (5)) can be identified through three channels: (i) the lagged ECTs (as) by a t-test; (ii) the coefficients of each explanatory variable in one equation (weak or short run Granger causality); (iii) the terms in (i) and (ii) jointly (strong or long run Granger causality). Table 1 presents the Granger causality test results.

The results for Canada imply bi-directional Granger causality between LE and LY both in the short and the long run, supporting Ghali and El-Sakka (2004). The results indicate that energy consumption, investment and labor adjust to restore the long run equilibrium relationship whenever there is a deviation from the equilibrium cointegrating relationship. For France although there does not appear to be short run causality between LE and LY, income appear to bear the burden of adjustment towards the long run equilibrium in response to a short run deviation. This result is consistent with findings reported in Soytas and Sari's (2003) bivariate analyses. The results imply uni-directional causality running from income to energy in both the short and long runs in Germany. Energy consumption seems to restore the long run equilibrium relationship alone. The direction of causality is from GDP to energy consumption in Italy in the short run as in Germany;

[4] The lag selection procedures used are the Akaike Information Criterion (AIC), the modified AIC (MAIC), and the general to specific methodology where we start with a maximum lag length of 12 and decrease the number of lags based on sequential t significance tests.

[5] The results of the unit roots and cointegration tests are not reported in order to conserve space. They are available from the authors upon request.

Table 1
Granger causality test results

Equation	Wald F-statistics				t-Statistics			Joint Wald F-statistics			
	ΔLY	ΔLE	ΔLK	ΔLL	$ECT_{1,t-1}$	$ECT_{2,t-1}$	$ECT_{3,t-1}$	$ECT_{i,t-1}$, ΔLY	$ECT_{i,t-1}$, ΔLE	$ECT_{i,t-1}$, ΔLK	$ECT_{i,t-1}$, ΔLL
Canada											
ΔLY	–	2.5117[c]	0.6753	3.0244[c]	−0.2150	1.1440	–	–	2.5071[c]	0.7842	1.9265
ΔLE	5.6004[a]	–	0.6678	2.2964	1.7694[c]	−1.8633[c]	–	3.9029[b]	–	2.7471[b]	2.1536
France											
ΔLY	–	1.7828	0.1442	1.0330	−1.7736[c]	1.7806[c]	−0.4013	–	1.9309	1.6205	1.5862
ΔLE	0.2822	–	0.1637	0.1587	1.3375	−1.1956	−0.3152	0.9834	–	0.8008	0.8461
Germany											
ΔLY	–	0.0191	1.2950	0.1894	0.8263	−1.1037	–	–	1.6060	2.6849[c]	1.7558
ΔLE	4.0647[b]	–	8.7711[a]	0.4151	4.1139[a]	−4.4128[a]	–	7.2202[a]	–	8.9678[a]	7.3717[a]
Italy											
ΔLY	–	0.1559	3.1722[c]	0.5394	0.3875	−2.4690[b]	–	–	5.0664[a]	4.6179[a]	4.0041[b]
ΔLE	4.7987[b]	–	4.0990[b]	1.3855	−0.4764	−3.7706[a]	–	8.2906[a]	–	7.4558[a]	6.4453[a]
Japan											
ΔLY	–	2.1129	1.9358	3.1589[c]	−1.3778	−0.7919	1.9064[c]	–	2.6474[c]	2.6822[c]	5.6410[c]
ΔLE	4.8131[b]	–	5.8941[b]	1.6362	−2.1714[c]	0.4767	2.3701[b]	8.4452[a]	–	9.4329[a]	5.8307[b]
UK											
ΔLY	–	1.1975	1.5728	3.4117[c]	0.6924	−1.2408	−0.3346	–	2.4667[c]	1.5983	1.7571
ΔLE	4.9699[b]	–	1.4169	1.0652	−2.4856[b]	−2.9858[a]	2.6453[b]	4.4771[a]	–	3.2092[b]	2.6158[c]
US											
ΔLY	–	4.2373[b]	0.7708	1.8711	−2.6112[b]	–	–	–	3.6018[b]	2.5716[c]	3.9217[b]
ΔLE	0.5167	–	0.2494	1.5905	0.7210	–	–	0.5645	–	0.7738	1.2085

[a] Significance at 1%.
[b] Significance at 5%.
[c] Significance at 10%.

however, in the long run there is strong evidence of bi-directional causality. The short and long run causality results of Japan are similar to those of Italy and Germany. Evidence from the UK support causality relationship only from income to energy in the short run, but in both directions in the long run. The results imply that causality is uni-directional and running from energy to income in US in both the short and the long runs. Investment and income act together to restore the long run equilibrium whenever a short run innovation shocks the system. Hence, we find evidence against the neutrality of energy. Only in the case of France, the relationship between energy and income appears to be weak and indirect, providing some support for Erol and Yu (1987) in the short run. Although our results support Erol and Yu (1987) and Soytas and Sari (2003) results partially for some countries, and Stern (1993, 2000) results fully, they seem to be contradicting Kraft and Kraft (1978), Erol and Yu (1987), Abosedra and Baghestani (1991), Yu and Jin (1992), Cheng (1995) and Lee (2006).

Short run causality runs from income to energy consumption in Germany, Italy, Japan and UK; from energy use to income in the US; and both ways in Canada. The only country in which we fail to identify short run causality is France. However, in the long run we were able to uncover causality in all countries. In four countries, namely Canada, Italy, Japan and UK, there is evidence of a bi-directional causality, suggesting that these countries may benefit from integrating energy and economic policies in the long run. In France and the US, the long run causality is reversed and running from energy consumption to income. This may be suggesting that the long run economic growth in these countries may be heavily relying on energy use but not vice versa. Only in Germany we were able to find uni-directional causality running from income to energy consumption. Note that by introducing investment and labor we uncover causality between income and energy consumption that went unnoticed in the bivariate analyses of Soytas and Sari (2003) for some countries. Hence, our results may be pointing out that empirical pursuits investigating the relationship between energy use and economic growth may benefit from the guidance of economic theory in reducing the omitted variables bias that may be affecting the Granger causality tests.

As a final analysis, we employ, *generalized forecast error variance decompositions* approach discussed in Koop et al. (1996) and Pesaran and Shin (1998). The unique feature of this approach is that the results are invariant to the ordering of the variables entering to VAR system.[6] The generalized variance decompositions (GVD) can be viewed as out of sample causality tests. To gauge the relative strength and dynamic interaction of the variables, we first shock the system and then decompose forecast error variances. The decomposed variances allow researchers to assess the relative importance of an individual variable due to its own shocks and the shocks of other variables.

The results of GVD are reported in Table 2. To conserve space, we report only the results for *per capita* GDP and energy equations, since our focus is on these two variables, and only the first and the fifth horizons, since the results seem to stabilize after 5 years.

The findings based on income equations show that the impact of energy consumption on *per capita* GDP initially ranges from 0.005% to approximately 65%. In France energy explains 0.005% of variation in *per capita* GDP, the lowest, while in Italy the initial impact of energy on

[6] In the literature, there are two basic approaches that decompose forecast error variances; standard *orthogonalized* method and *generalized* technique. The standard approach is developed by Sims (1980) which is based on Cholesky decomposition and orthogonalized shocks. The "orthogonality" feature of this approach is criticized in Lutkepohl (1991), since the results are sensitive to the order in which the variables are entered into the VAR. In the standard *orthogonalized* method, at least one variable has no contemporaneous effect on another and that variable depends on the ordering of the variables. The results of this method, therefore, are subject to serious shortcomings. To overcome the shortcomings, we use the *generalized forecast error variance decompositions* approach.

Table 2
Generalized forecast error variance decomposition results

	Horizon	LY	LK	LL	LE
Canada					
LY	1	0.83097	0.32241	0.00320	0.27818
	5	0.78907	0.31348	0.00360	0.28613
LE	1	0.14898	0.02677	0.01422	0.89829
	5	0.14327	0.03401	0.02640	0.86420
France					
LY	1	0.89061	0.69194	0.15832	0.07754
	5	0.77146	0.58908	0.25040	0.14772
LE	1	0.01522	0.02948	0.20429	0.97640
	5	0.08481	0.09913	0.20561	0.81394
Germany					
LY	1	0.95232	0.59712	0.01835	0.35738
	5	0.92198	0.60613	0.02302	0.34427
LE	1	0.38823	0.06246	0.01233	0.96871
	5	0.37635	0.07733	0.05220	0.92340
Italy					
LY	1	0.91946	0.45978	0.04596	0.66985
	5	0.88221	0.45349	0.05014	0.65718
LE	1	0.55843	0.24895	0.02673	0.90206
	5	0.48216	0.26976	0.13367	0.77491
Japan					
LY	1	0.87298	0.81482	0.12350	0.35887
	5	0.73607	0.66598	0.24410	0.31089
LE	1	0.49320	0.43104	0.07053	0.73538
	5	0.48136	0.40484	0.19498	0.58180
UK					
LY	1	0.99561	0.53295	0.08963	0.34232
	5	0.99136	0.52952	0.09032	0.34142
LE	1	0.34522	0.10717	0.01892	0.95639
	5	0.34693	0.10978	0.02008	0.95445
US					
LY	1	0.56971	0.43091	0.18233	0.43590
	5	0.37237	0.30974	0.30458	0.33034
LE	1	0.39350	0.24792	0.05116	0.89026
	5	0.30760	0.23256	0.24235	0.61295

forecast error variance of income is 65%, the highest reported. In Germany, Japan and UK, the impact of energy consumption on income is similar in magnitudes both in the short and the long runs. The impact is approximately 35% on average in these countries. In US, Canada and France, there is a considerable difference between initial impact of an innovation in energy on income and the impact by the 10th horizon. The results for US shows that initially energy explains more than 47% of variation in income and more than 33% in the 10th horizon, which is lower than the initial impact. In Canada and France, the longer the horizon is, the higher the impact of energy consumption on income. The results also reveal that income explains a considerable portion of volatility in energy consumption in all countries. Only in France and Canada the impact of income on energy consumption is less than 20%. In all other countries the impact is more than 30% in almost all horizons. In Japan, UK and Germany the impact of income on energy is greater than the impact of energy on income.

When assessing the relative strength of all inputs in the income equations, although the results appear to be mixed, in most cases the impact of energy on income is higher than the impact of employment. This is true for Canada, Germany, Italy, Japan and UK. In Italy, the impact of energy consumption is relatively higher than other variables in all horizons. In US, in the short run energy consumption explains more variation in income than labor, though in the longer horizons (after the 5th year) the impact of energy is higher than any other inputs. Similar results were reported in Sari and Soytas (2004) for Turkey and Beaudreau (2005) for US, Germany and Japan.

6. Conclusions and policy implications

This paper investigated the relationship between energy consumption and income in a production function framework utilizing annual data from G-7 countries. We uncovered long run causality between energy use and income in all G-7 countries. In four countries (Canada, Italy, Japan and UK) causality seems to run both ways, in two of them (US and France) from energy use to income, and only in one (Germany) from income to energy consumption. Therefore, Germany may contribute to the fight against global warming directly implementing energy conservation measures, whereas, US and France may focus on technological developments and mitigation policies. For Canada, Italy, Japan and UK a balanced combination of alternative policies seems to be appropriate. In the short run, energy conservation may significantly contribute to fight against global warming without hindering economic growth in Germany, Italy and Japan, since the causal relationship is from income to energy in these countries. It seems that US and Canada should implement energy policies that are similar both in the short and the long runs.

The GVD results along with the causality test results suggest that energy should be considered as a major factor that influences economic growth. According to our results, in the long run especially the US and the French economies may feel the negative impact of reduced energy consumption on growth. However, for Canada, Italy, Japan and UK energy use seems to be strongly endogenous as well. The only country that may not be affected negatively from energy conservation seems to be Germany.

Nevertheless, environmental policies aimed at decreasing energy intensity, increasing energy efficiency, increasing utilization of public transportation and establishing a price mechanism that may encourage the use of renewable and environmental friendly energy sources, developing a market for emissions trading, investing in technology that makes alternative energy sources more feasible may mitigate the pressure on the environment, although the potential of renewable and environmental friendly energy sources to fully replace the fossil fuels in the foreseeable future may be rather bleak.

As for policies considering the growth of economic output, our results imply that forecasts of economic growth would improve when energy use is incorporated in the forecasting equations. Policy makers should be cautious in designing energy conservation policies so as not to interfere with the economic growth goals (Lee, 2005), and should pursue sustainable energy supply in developing economic growth strategies. Another implication of the close link between energy use and economic growth in the long run may be that to achieve sustainable growth countries may need to rely more on renewable energy sources to ensure uninterrupted supply as traditional energy sources become scarcer.

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