Management and Administration Research Center, METU

MARC Working Paper Series

Working Paper No. 2007-02

Energy Consumption, Economic Growth, and Carbon Emissions: Challenges Faced by an EU Candidate Member

Ugur Soytas
Dept. of Business Administration, Middle East Technical Univ.

Ramazan Sari
Dept. of Economics, Abant Izzet Baysal Univ.

Abstract

This paper investigates the long run Granger causality relationship between economic growth, carbon dioxide emissions and energy consumption in Turkey, controlling for gross fixed capital formation and labor. The most interesting result is that carbon emissions seem to Granger cause energy consumption, but the reverse is not true. The lack of a long run causal link between income and emissions may be implying that to reduce carbon emissions, Turkey does not have to forgo economic growth.

Key words: carbon dioxide emissions, economic growth, energy consumption, environmental Kuznets curve, Turkey

JEL codes: Q43, Q53, Q56

Please direct correspondence to Ugur Soytas soytas@metu.edu.tr .

Introduction

The Intergovernmental Panel on Climate Change (IPCC) (2007) report puts forward the fact that the most important environmental problem of our ages is global warming. The ever increasing amount of world wide carbon dioxide (CO_2) emissions seems to be intensifying this problem. Since the emissions mainly result from consumption of fossil fuels, reducing energy consumption seems to be the direct way of handling the emissions problem. However, due to the possible negative impacts on economic growth, cutting back from energy use is likely to be the "less traveled road". Furthermore, if the Environmental Kuznets Curve (EKC) hypothesis applies to the emissions and income link, economic growth by itself may become a solution to the environmental degradation problem (Rothman and de Bruyn, 1998). Indeed, according to Dinda and Coondoo (2006) both developing and developed economies must sacrifice economic growth. However, depending on the nature of the long run relationship between CO_2 emissions, income, and energy consumption in their economies, countries may resort to different policy options in contributing to the fight against global warming (Soytas and Sari, 2006a and 2006b). Hence, the emissions-energy-income nexus needs to be studied carefully and in detail for all economies.

In this paper, we investigate the relationship between energy consumption, economic growth, and CO_2 emissions in Turkey from a long run Granger causality perspective, in a multivariate framework controlling for gross fixed capital investment and labor. The analysis relies on recent time series techniques that offer potential solutions to the methodological problems listed in Stern (2004). The Toda and Yamamoto (TY hereafter) (1995) procedure eliminates the need for pre-testing for cointegration and therefore avoids pre-test bias and is applicable for any arbitrary level of integration for the series used. The most striking result may be that the long run Granger causality is running from CO_2 emissions to energy consumption in Turkey. That is, emissions improve the forecasts of energy consumption in Turkey, but not vice versa. This may have important policy implications for Turkey. We have chosen Turkey as a case study firstly because it is an emerging economy and a candidate country for full membership in the European Union (EU). Turkey needs to adjust her infrastructure, economy, and government policies (including environmental, energy, and growth policies) to make them inline with EU requirements. Secondly, with a 72.6% rise in GHG emissions in 2000-2004, Turkey has the fastest growing emissions in the world (UNFCCC, 2006), although her per capita emissions and per capita GDP are among the lowest ones of the countries in Annex 1 of the Kyoto Protocol. Thirdly, we want to examine whether Turkish concerns regarding negative effects of emission constraints on the economy may be justified, since this is the main reason why the country has not ratified the protocol. As the Turkish economy grows the pressure on energy security is also building up. Therefore, the country is in need of a sound long term plan that integrates energy, environment, and growth concerns.

The organization of the paper is as follows. In the next section we briefly review the literature. Then, we introduce the data definitions and discuss the time series properties of the variables in section 3. In section 4 we provide the empirical results and their discussions. The last section provides policy implications and concludes.

Income-Emissions-Energy Consumption Nexus

There are probably quite a few theoretical studies that formally model a direct link between the environment and growth, energy and growth, and energy and environment. The empirical literature seems to be more abundant. First, we briefly discuss the theoretical considerations. Then, secondly empirical investigations that relate to the transmission mechanisms within the energy-environment-growth nexus are introduced.

Theoretical Background

There has been a vast amount of theoretical work on economic growth, most of which relying on the Solow growth model. More recently growth models rely increasingly on the endogenous growth theory (see for a review Jones and Manuelli, 2005)[1]. There are also a considerable number of studies that model the relationship between the environment and economic growth, and natural resource management and environment (see for reviews Xepapadeas, 2005, and Kolstad and Krautkraemer, 1993 respectively). Jorgenson and Wilcoxen (1993) on the other hand seem to selectively cover theoretical work that focuses on modeling interrelationships between energy, the environment, and economic growth in an intertemporal general equilibrium framework and also discuss aggregate growth models.

According to Xepapadeas (2005) early works on economic growth failed to take environmental aspects of growth into account. Reviewing more recent studies he further argues that there is a "…necessity for growth theory to delve deeply into the analysis of the interrelationships between environmental pollution, capital accumulations and the growth of variables which are of central importance in growth theory." (Xepapadeas 2005, p. 1221). Kolstad and Krautkraemer (1993) point out the fact that there is a dynamic link between the environment, resource use and economic activity. They argue that while resource use (especially energy sources) yield immediate economic benefits, its negative impact on the environment may be observed in the long run. They argue that most theoretical work is dynamic, whereas

[1] Here we refrain from a detailed review of the vast theoretical literature; instead we briefly discuss points shown by surveys of the related literature.

empirical studies are largely static in nature, implying the need for dynamic empirical analysis. Jorgenson and Wilcoxen (1993) point out the common feature of some models as relying on the impact of policies on capital accumulation in modeling the interrelationships between energy, environment, and growth. Furthermore, they argue that intertemporal general equilibrium modeling is critical in accounting for the effects of oil price shocks on growth.

Ricci (2007) in his survey of theoretical work points out several transmission mechanisms through which environmental policy and economic growth may interact. This may be partly due to some models treating pollution as an input to production, and others as a negative by-product. Regarding the policy effects, he mentions that generally environmental policies are deemed to have negative effects on growth, because they are taken as additional constraints. However, if environmental improvement results in increased factor productivity and stimulate innovation, the growth prospects will be enhanced. Indeed, Dudek et al. (2003) show that the ancillary benefits from reduction of emissions will exceed the average cost of carbon reduction. Ricci (2007) also discusses how benefits may be achieved via reaching increasing returns to scale in abatement activity, and providing an urge to save more if environmental improvement is expected. Hence, empirical methodology employed should allow dynamic effects in the energy-environment-growth nexus. Furthermore, Ricci (2007) admits that the how the transmission mechanisms work may differ across countries at different stages of development.

Theoretical studies mainly consider policy tools that focus on pollution taxes, emissions trading, and conservation. They mention that any effective policy should take the dynamic nature of the relationships between energy, environment, and growth into account and should have a long term vision. Hence, understanding the intertemporal relationship between emissions, energy use, and economic growth in individual countries is essential in generating effective policies.

Empirical Studies

According to Brock and Taylor (2005) the contributions of theoretical work in understanding the relationship between growth and environment is not matched by empirical studies. They argue that the main regularity comes from EKC literature; however, in order to have progress other related data should also be examined. They call for a tighter connection between theory and data.

There seems to be two lines of well established empirical research areas dealing with energy-environment-income nexus. The first line of research mainly focuses on the relationship between the environment and economic growth (see for example Hill and Magnani, 2002; Dinda, 2004; and Stern, 2004 for a review). Although, the EKC studies that test linear (Shafik and Bandyopadhay 1992; Shafik, 1994; de Bruyn et al., 1998), as well as quadratic and cubic (de Bruyn et al., 1998; Heil and Selden, 2001; Holtz-Eakin and Selden, 1995; Moomaw and Unruh, 1997; de Bruyn and Opschoor, 1997; Roberts and Grimes, 1997; Han and Chatterjee, 1997; Gaelotti and Lanza, 1999; Friedl and Getzner, 2003; Canas et al., 2003) relationship between per capita income and CO2 emissions fail to yield unanimous results, a dynamic link between CO_2 emissions and income is suspected suggesting a time series approach. Furthermore, CO_2 emissions may precede economic growth from a production viewpoint. It may even be possible observe emissions to precede energy use if the energy production industry is responsible for a significant portion of a country's emissions. All these concerns point out a need for a flexible methodology that allows testing which way the precedence go as suggested by Coondoo and Dinda (2002), and Dinda and Coondoo (2006).

In the second line of research, there are a considerable number of studies that examine the link between energy consumption and economic growth. Following Kraft and Kraft (1978), earlier studies examined the Granger causality link between energy and income with diverse results (Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Choi, 1985; Erol and Yu, 1987; Abosedra and Baghestani, 1989; Hwang and Gum, 1992; Bentzen and Engsted, 1993; Glasure and Lee, 1997). The earlier studies suffered from a number of methodological problems, especially the omitted variables bias. Stern (1993) is probably the first study advocating and using a multivariate setting. The multivariate studies, following Stern (1993), employed recent and powerful time series techniques, (Stern, 2000; Masih and Masih,1996, 1997, and 1998; Asafu-Adjae, 2000; Yang, 2000; Glasure, 2002; Soytas and Sari, 2003, 2006a, 2006b; Altinay and Karagol, 2004; Sari and Soytas, 2004; Oh and Lee, 2004; Wolde-Rufael, 2004, 2005; Ghali and El-Sakka, 2005; Narayan and Smyth, 2005; Lee, 2005, 2006); however, this line of research also failed to achieve unanimous results.

Only recently scholars started investigating the inter-temporal relations in the energy-environment-income nexus employing recent time series techniques in a multivariate framework. For example, Soytas et al. (2006) study the long run Granger causality between carbon emissions, energy use, and income in the US, also accounting for labor and investment in capital. They find no evidence of a causal link between income and carbon emissions, and income and energy consumption, but confirm that energy use is the main source of emissions. Soytas and Sari (2006c) in a tri-variate model with energy, carbon emissions, and income failed to identify a significant Granger causality link between any of the variables.

In both lines of research, especially in the EKC literature, the bulk of the work was on developed economies. There are even a more limited number of studies that study the link between economic growth and environmental degradation in Turkey, yet alone the inter-temporal link between CO_2 emissions and income. Kumbaroglu (2003) employs a computable general equilibrium approach to assess the economic impact of an emission tax on SO_2, NO_x, and sulphur contained fuels in a disaggregated Turkish economy. According to the results of his model, an emission tax on SO_2 reduces GDP, but on NO_x may increase GDP, since NO_x emissions largely arise from imported fuels. Hence, it is possible to improve both the environment and the economy. Akbostanci et al (2006) apply both time series and panel data techniques to test for EKC hypothesis for carbon emissions in Turkey. Their results do not confirm EKC, but imply an N-shaped link between income and emissions. Using energy consumption as an indicator of environmental degradation, Lise (2006) employing simple OLS in levels and Lise and van Montfort (2006) in first differences both conclude that the relation between carbon emissions and income in Turkey is linear rather than following an EKC path. Say and Yucel (in press) model energy use as a function of income and population; and emissions as a function of energy use to forecast carbon emissions in Turkey. They argue that energy use can significantly explain carbon emissions in Turkey. However, they fail to account for the stationarity of the series therefore their OLS results may be spurious. In terms of environmental efficiency Turkey is among the worst five performers of OECD countries (Zaim and Taskin, 2000). Hence, there is a need and potential for environmental improvement in Turkey.

Following the suggestions in Dinda (2004), Stern (2004), Coondoo and Dinda (2006), in this paper we investigate the dynamic relationship between energy consumption, income, and CO_2 emissions (as suggested by Xepapadeas, 2005, Kolstand and Krautkraemer, 1993, and Jorgenson and Wilcoxen, 1993) in an emerging economy, accounting for possible affects of labor and investment in fixed capital (to account for capital accumulation as suggested by Jorgenson and Wilcoxen, 1993). The paper attempts to make a contribution to the existing empirical literature by combining the two lines of empirical research in an emerging economy, using relatively new time series methodologies that overcome some of the methodological concerns of recent studies. We examine a single country which allows us to use a framework that allows us to account for country specific issues such as economic crisis. Furthermore, the selection of the variables is not arbitrary but relies on theory (as suggested by Brock and Taylor, 2005), which may be lacking from many empirical studies. The empirical results may be helpful in guiding policy makers in devising long term sustainable plans.

Data Properties and the Empirical Model

Our analysis is confined to the period 1960-2000 due to data availability. The energy consumption (E), carbon dioxide emissions (C), labor (L), and gross fixed capital investment (K) data are sourced from World Development Indicators. The real GDP per capita chain series (Y) data is from the Penn World Tables. E is in kilo tons of oil equivalent; whereas, C is measured in metric tons per capita. All data are used in natural logarithms. We also account for the financial crisis in 1994, via a possible inclusion of a dummy variable receiving a value of 1 after 1993 (0 otherwise).

The Toda-Yamamoto (TY) procedure requires the knowledge on the maximum order of integration that the series in concern have. In order to assess the stationarity properties of the variables employed, we utilized 5 different unit root tests augmented Dickey and Fuller (1979) (ADF), Phillips and Perron (1988) (PP), Elliot, Rothenberg, and Stock's (1996) Dickey-Fuller GLS detrended (DF-GLS) and Point Optimal (ERS-SPO), Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS), and

Ng and Perron's (2001) MZ_α (NP) (see Maddala and Kim (1998) for an excellent treatment of ADF, PP, KPSS, and DF-GLS; and Ng and Perron (2001) for more on NP). The unit root test results are reported in Table 1.

(Table 1 about here)

The results in Table 1 are only slightly contradictory. Hence, we can safely assume that the maximum order of integration is 2 (*d=2*). Since, all series do not appear to be *I(1)*, cointegration tests common in the literature may not be applied. The TY procedure does not need the knowledge on cointegration. The procedure involves a VAR in levels; therefore, there is no loss of information due to differencing. A Wald test is conducted on the first *k* parameters of the augmented VAR(*k+d*) model and the statistic follows an asymptotic Chi-square distribution with *k* degrees of freedom ($c^2(k)$). All criteria, used in determining the optimum lag length, including final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), Hannan-Quinn (HQ) information criterion, and likelihood ratio test (LR) point out a lag length of 1. Hence, when we augment the VAR with the maximum order of integration the lag length becomes 3 (*k+d=3*). The VAR(3) satisfies the stability condition in that no roots are outside the unit circle[2].

The estimated VAR(3) system is as below:

$$V_t = a_v + ß_1 V_{t-1} + ß_2 V_{t-2} + ß_3 V_{t-3} + e_{vt} \quad (1)$$

where $V_t=(Y_t, E_t, C_t, L_t, K_t)'$, α_v is a (5x1) vector of constants, $ß_1$, $ß_2$, $ß_3$ are (5x5) coefficient matrices, and ε_{vt} denotes white noise residuals.

In addition to checking the stability of the VAR, we subject all equations in the VAR to a series of diagnostic tests to assess the conformity to common assumptions. The diagnostic test results are summarized in Table 2.

[2] The dummy for 1994 crisis does not seem to be significant and its inclusion makes the VAR unstable. Hence, we estimated the VAR(3) without the dummy.

(Table 2 about here)

As Table 2 shows there are no serious violations of normality or heteroscedasticity assumptions. Furthermore there is no evidence of an ARCH effect. Only the Breusch-Godfrey tests for serial correlation and the Ramsey RESET tests with one component for parameter instability seem to indicate problems. However, when we consider the correlograms of residuals and squared residuals and the Q-statistics, we can conclude no serial correlation. We also subjected all equations to the CUSUM and CUSUM of squares tests for any hint of parameter instability, but we could not find any[3]. Therefore, we continue with the Granger causality tests and generalized impulse response analysis.

Long Run Granger Causality and Generalized Impulse Responses

The Granger causality framework allows for testing the existence and the direction of causality between the variables. The TY procedure allows us to conduct long run Granger causality tests without any need for testing cointegration and estimating the cointegrating equation. Table 3 summarizes the results of long run Granger causality tests.

(Table 3 about here)

We observe from Table 3 that there are only three significant results. Income and capital investment Granger cause labor in the long run. Hence, knowledge of income level and gross fixed capital formation may improve the forecasts of the labor force. The reverse does not hold, since the causality is not bi-directional. However, probably the most interesting outcome is that there is evidence of a uni-directional causality running from carbon emissions to energy consumption in Turkey. Intuitively one may tend to expect the reverse, since the most important source of carbon dioxide

[3] All unreported results are available from the authors upon request

emissions is energy consumption. This may be arising due to the fact that energy production and mining sectors account for 30% of Turkish carbon emissions, with manufacturing sector accountable for only a slightly higher portion (Tunç et al., in press). Carbon dioxide emissions may appear to precede energy consumption, if a bulk of the emissions is arising from electricity production. Furthermore, Turkey is a net importer of oil and natural gas that account for a significant portion of electricity generation. Hence, it is not counterintuitive for past emissions to improve forecasts of energy consumption.

The TY procedure is a way to examine the long run Granger causality relationship among the series. However, it does not provide information on how each variable responds to innovations in other variables, and whether the shock is permanent or not. This can be done via generalized impulse response analysis by Koop, et al. (1996) and Pesaran and Shin (1998). Note that unlike the standard approach, the generalized approach is not sensitive to the ordering of variables in the VAR system. The generalized IR overcomes the orthogonality problem inherent in traditional out-of-sample Granger causality tests. Figures 1-3 show the responses of income, energy use, and carbon emissions to one standard deviation shocks to other variables in the VAR[4].

(Figures 1-3 about here)

Although all initial impacts in Figures 1-3 seem to be significant except for the response of emissions to an innovation in labor, they tend to die off rapidly after 2 or 3 periods. A one standard deviation shock in labor has significant negative initial impacts on income and energy. A plausible explanation is that in the short run energy and labor tend to be substitutes, but a temporary substitution away from energy to

[4] Only responses of income, energy, and emissions are displayed and self shocks are not included in order to conserve space. All omitted responses are available from the authors upon request.

labor is in turn transmitted to income as a negative first impact. Labor also has a similar impact on investments in gross fixed capital (not shown here). Shocks in gross fixed capital investment have identical impacts on income, energy, and emissions. Initially they are positively significant, but become insignificant in the third horizon. Although the affects seem to be transitory, the generalized impulse responses of income, energy, and carbon dioxide emissions provide some evidence of an interactive nexus. A shock in one of the three variables in the nexus has positive and significant first impacts on the other two, with the innovation in emissions having a slightly larger effect on energy consumption than on income. In fact, this is the largest initial impact one can observe in all impulse responses throughout Figures 1 to 3. Hence, although in the short run all three variables seem to significantly interact, in the long run Granger causality can be established only from emissions to energy use.

The long run Granger causality and impulse response results may have important implications for the Turkish economy. In the light of the empirical results, the next section briefly discusses the policy implications.

Policy Implications and Conclusions in the Light of EU's Energy Policy

The energy-environment-income nexus poses important challenges to Turkish policy makers, considering the high economic growth rate and high CO_2 growth rate this emerging market experiences as a candidate member to the EU. The short run dynamics of generalized impulse responses may be implying flexible short run policy options, without having a significantly detrimental effect on the long run growth.

In line with the theory, capital accumulation appears to be driving energy use, emissions, and growth according to the generalized IR analysis.

The EU has set ambitious targets in reducing the GHG emissions by about 60-80% by 2050 compared to 1990 (Commission of the European Communities (CEC), 2007). Although emission reduction does not yet seem to be a membership criterion, it is highly likely that the EU will require Turkey to take some measures in line with the union's goals. In the light of the uni-directional causality running from carbon emissions to energy use, one may argue that the main contribution in meeting the GHG emission targets would come from reducing the share of fossil fuels in energy consumption, since coal fired power plants are important sources of electricity supply in Turkey. In order to reduce the dependence of the economy on imported energy and to meet growing energy demand, Turkey cannot overlook its coal reserves. This is exactly what the government seems to be doing via opening bids for coal fired plants. However, since coal emits twice as much CO_2 as natural gas, sustainable coal technologies should be imposed on the new coal power plants with CO_2 capture and storage facilities. Gradually existing plants should also install carbon capture and storage. This may prove to be costly and dependence on imports may rise, especially if the technology is imported. Hence, significant investment is needed in improving the sustainable fossil fuel technologies.

Another much debated option for Turkey is nuclear power. Nuclear power is the cheapest carbon free energy source and is not subject to fuel price changes (CEC, 2007). Probably due to the low probability but high risk scenarios and possible public opposition, the EC leaves the nuclear power option to the discretion of member states. High standards of safety, security, and nuclear waste management may push the costs up, not to mention the dependence on imported technology in the case of Turkey. Furthermore, at current consumption levels the proven reserves of uranium will last about 85 years (CEC, 2007). However, according to the World Nuclear Association's (2006) information paper on uranium, if the energy prices rise enough (ten times), the technologies to retrieve uranium from sea water may become economically feasible.

This argument may also hold for other environment friendly energy sources as well. Although renewable energy sources are not perfect substitutes for fossil fuels as of now, technological improvements may make them on par with traditional energy sources. Furthermore, the reason why they have not become more common is partly due to the lack of "coherent and effective policy framework …and stable long term vision" (CEC, 2007, p. 13). A long term Turkish energy policy needs sound forecasts of energy demand. Our results suggest that Turkish policy makers take carbon emissions into account when forecasting energy consumption.

Turkey may have a big potential in improving her energy efficiency as an emerging market and a big responsibility as a future member of the EU. The EU target is to reduce energy use by 20% by 2020 (CEC, 2007). According to our results, energy consumption does not seem to be Granger causing income in Turkey in the long run. Hence, Turkey can take direct measures at reducing energy consumptions may also be taken without much concern for long run economic growth. Increased competition in the Turkish energy market will contribute to the country's energy efficiency. Indeed, according to the CEC (2007), there should be three internal energy market targets: competitiveness, sustainability, and energy security. CEC argues that the latter two can be achieved by increased competitiveness in the EU energy market. The Turkish energy market does not seem to be meeting these targets very well. The government policies tend to view privatization as equivalent to competitiveness. However, as Ercan and Oz (2004) note, after privatization the long term purchase guarantees of the Turkish government at fixed prices may not make economic sense, if the aim is to promote competitiveness and efficiency. CEC (2007) states that generalized price caps may have negative effects because they tend to suppress price signals that may be pointing out a need for changes in investment plans; hence, leading to wrong policy changes such as underinvestment, jeopardizing the future energy security and discouraging more efficient firms to take part in clean energy production.

In addition to the carbon constraint, energy security, dependence on imported energy and exposure to oil and gas price changes are important issues that need to be addressed. The CEC (2007) states that even with extreme efficiency measures, a significant amount of investment is required to meet the growing energy demand in the EU. Hence the CEC (2007) points out the need for EU members to invest in renewable energy as well as in energy efficiency. The commission argues that such investments are likely to lead to a knowledge based economy via encouraging innovation and also lower unemployment through job creation. Whether similar arguments may hold for Turkey or not may only be assessed after careful studies that consider the environment-income-energy nexus as a whole.

Turkey is facing an investment problem. Regardless of which alternative energy sources she wants to develop or utilize, a large portion of this investment would be through accumulating capital based on imported technology. In order to reduce dependence on imports, Turkey needs to adopt a strategic long term plan in technology development. In this paper we only accounted for gross fixed capital investments. It may be worthwhile for future work to take investments in technology into account as well.

References

Abosedra, S. and Baghestani, H. (1989). "New evidence on the causal relationship between United States energy consumption and gross national product." *Journal of Energy and Development* 14, 285-292.

Akarca, A.T. and Long, T.V., (1980). "On the Relationship between Energy and GNP: A Reexamination." *Journal of Energy and Development* 5: 326-331.

Akbostanci, E., Turut-Asik, S. and Tunc, G.I. (2006) "The Relationship Between Income and Environment in Turkey: Is There an Environmental Kuznets Curve?." International Conference in Economics-Turkish Economic Association Sept. 11-13, Ankara, Turkey.

Altinay, G. and Karagol, E., (2004). "Structural break, unit root, and the causality between energy consumption and GDP in Turkey." *Energy Economics* 26: 985-994.

Asafu-Adjaye, J., (2000). "The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries." *Energy Economics* 22: 615-625.

Bentzen, J. and Engsted, T., (1993). "Short- and Long-run Elasticities in Energy Demand." *Energy Economics* 15: 9-16.

Brock, W. A., and Taylor, M.S. (2005). "Economic Growth And The Environment: A Review Of Theory And Empirics." In Aghion, P. and Durlauf, S. N. (ed.s), *Handbook of Economic Growth,* vol. 1B, pp. 1749-1821.

Comission of the European Communities (2007). "Communication from the Commission to the European Council and the European Parliament: An Energy Policy for Europe." COM (2007), 1 final, Brussels.

Coondoo, D. and Dinda, S., (2002). "Causality between income and emission: a country group-specific econometric analysis." Ecological Economics 40:351-367.

de Bruyn, S.M., van den Bergh, J.C.J.M., and Opschoor, J.B., (1998). "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves." Ecological Economics 25: 161-175.

Dickey, D. A., and W. A. Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." Journal of the American Statistical Society 75: 427-431.

Dinda, S., (2004). "Environmental Kuznets curve hypothesis: A survey." Ecological Economics 49: 431-455.

Dinda, S., and Coondoo, D. (2006). "Income and emission: A panel data-based cointegration analysis." Ecological Economics 57: 167-181.

Dudek, D., Golub, A., and Strukova, E. (2003). "Ancillary Benefits of Reducing Greenhouse Gas Emissions in Transitional Economies." World Development 31(10): 1759–1769.

Elliott, G., Rothenberg, T. J., and Stock, J. H. (1996) "Efficient Tests for an Autoregressive Unit Root," Econometrica 64: 813-836.

Ercan, H. and Oz, G. (2004) "Avrupa Birligi ve Türkiye elektrik piyasalarina iktisadi ve hukuki bir bakis." in UPAV, Europa Bilgi Köprüleri Programi, *AB'nin Enerji Politikasi ve Türkiye*, pp. 169-214.

Erol, U. and Yu, E.S.H., (1987). "On the Causal Relationship between Energy and Income for Industrialized Countries." *Journal of Energy and Development* 13: 113-122.

Friedl, B. and Getzner, M., (2003). "Determinants of C emissions in a small open economy." Ecological Economics 45: 133-148.

Ghali, K. H. and El-Sakka, M. I. T., (2004). "Energy use and output growth in Canada: a multivariate cointegration analysis." Energy Economics 26(2): 225-238.

Glasure, Y.U., (2002). "Energy and national income in Korea: further evidence on the role of omitted variables." Energy Economics 24: 355-365.

Glasure, Y.U., Lee, A.R. (1997) "Cointegration, error-correction, and the relationship between GDP and energy: The case of South Korea and Singapore", Resource and Energy Economics, 20: 17-25.

Han, X. and Chatterjee, L. (1997). "Impacts of Growth and Structural Change on CO_2, Emissions of Developing Countries." World Development 25(3): 395-407.

Hamilton, C. and Turton, H., (2002). "Determinants of emissions growth in OECD countries." Energy Policy 30: 63-71.

Hill, R.J. and Magnani, E., (2002). "An exploration of the conceptual and empirical basis of the environmental Kuznets curve." Australian Economic Papers 42: 239 - 254.

Hwang, D.B.K., Gum, B. (1992), "The causal relationship between energy and GNP: the case of Taiwan", The Journal of Energy and Development, 16: 219-226.

IPCC (2007). "Climate Change 2007: The Physical Science Basis." Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Paris.

Jones, L.E., and Manuelli, R.E. (2005). "Neoclassical Models of Endogenous Growth: The Effects of Fiscal Policy, Innovation and Fluctuations." In Aghion, P. and Durlauf, S. N. (ed.s), *Handbook of Economic Growth*, vol. 1A, pp. 13-65.

Jorgenson, D.W., and Wilcoxen, P.J. (1993). "Energy, The Environment, And Economic Growth." In Kneese, A.V. and Sweeney, J.L. (ed.s), *Handbook of Natural Resource and Energy Economics*, vol. III, pp. 1267-1349.

Kolstad, C.D., and Krautkraemer, J.A. (1993). "Natural Resource Use and the Environment ." In Kneese, A.V., Sweeney, J.L. (ed.s), and *Handbook of Natural Resource and Energy Economics*, vol. 3, pp. 1219-1265

Koop, G., Pesaran, M.H., and Potter, S.M., (1996). "Impulse Response Analysis in Nonlinear Multivariate Models." Journal of Econometrics 74: 119-147.

Kraft, J. and Kraft, A., (1978). "On the Relationship between Energy and GNP." Journal of Energy and Development 3: 401-403.

Kumbaroglu, G.S. (2003). "Environmental taxation and economic effects: a computable general equilibrium analysis for Turkey." Journal of Policy Modeling 25: 795–810.

Kwiatkowski, D., P. C. B. Phillips, P. Schmidt and Y. Shin Y (1992) "Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root." Journal of Econometrics 54: 159-178.

Lee, C.-C. (2005). "Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysis." Energy Economics 27: 415-427.

Lee, C.-C. (2006). "The Causality Relationship between Energy Consumption and GDP in G-11 Countries Revisited." Energy Policy 34: 1086-1093.

Lise, W., (2006). "Decomposition of CO_2 emissions over 1980–2003 in Turkey." Energy Policy 34: 1841-1852.

Lise, W., and van Montfort, K. (2006) "Energy consumption and GDP in Turkey: Is there a co-integration relationship?" Energy Economics, doi:10.1016/j.eneco.2006.08.010.

Maddala, G. S. and I. Kim (1998) Unit Roots, Cointegration, and Structural Change. Cambridge: Cambridge University Press.

Masih, A.M.M. and Masih, R., (1996). "Energy Consumption, Real Income and Temporal Causality: Results from a multi-country study based on cointegration and error-correction modeling techniques." Energy Economics 18: 165-183.

Masih, A.M.M. and Masih, R., (1997). "On the Temporal Causal Relationship Between Energy Consumption, Real Income, and Prices: Some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error-correction approach." Journal of Policy Modeling 19: 417-440.

Masih, A.M.M. and Masih, R., (1998). “A multivariate cointegrated modeling approach in testing temporal causality between energy consumption, real income and prices with an application to two Asian LDCs.” Applied Economics 30: 1287-1298.

Narayan, P.K. and Smyth, R. (2005). “Electricity Consumption, Employment and Real Income in Australia: Evidence from Multivariate Granger Causality Tests.” Energy Policy 33: 1109-1116.

Ng, S. and P. Perron (2001) “Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power.” Econometrica 69: 1519-1554.

Oh, W., Lee, K. (2004), “Causal relationship between energy consumption and GDP revisited: the case of Korea 1970-1999”, Energy Economics, 26: 51-59.

Pesaran, M. H. and Shin, Y., (1998). “Generalized Impulse Response Analysis in Linear Multivariate Models.” Economics Letters 58: 17-29.

Phillips, P.C.B. and Perron, P., (1988). “Testing for a Unit Root in Time Series Regressions.” Biometrica 75: 335-346.

Ricci, F. (2007). “Channels of transmission of environmental policy to economic growth: A survey of the theory.” Ecological Economics, doi: 1016/j.ecolecon.2006.11.014.

Rothman, D.S. and de Bruyn, S.M., (1998). “Probing into the environmental Kuznets curve hypothesis.” Ecological Economics 25: 143-145.

Sari, R., and Soytas, U. (2004). “Disaggregate Energy Consumption, Employment, and Income in Turkey.” Energy Economics 26: 335-344.

Say, N.P., and Yucel, M. (in press). “Energy consumption and CO_2 emissions in Turkey: Empirical analysis and future projection based on an economic growth.” Energy Policy.

Soytas, U. and Sari, R., (2003). “Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets.” Energy Economics 25: 33-37.

Soytas, U. and Sari, R., (2006a). “Energy Consumption and Income in G-7 Countries.” *Journal of Policy Modeling* 28(7): 739-750.” Energy Economics 25: 33-37.

Soytas, U. and Sari, R., (2006b). “Can China contribute more to the fight against global warming?” *Journal of Policy Modeling* 28(8): 837-846.

Soytas, U. and Sari, R., (2006c). “Energy Consumption, Economic Growth, and Carbon Emissions in Turkey”, International Conference in Economics-Turkish Economic Association Sept. 11-13, Ankara, Turkey.

Soytas, U., Sari, R., and Ewing, B.T. (2006). “Energy Consumption, Income, and Carbon Emissions in the United States” forthcoming in Ecological Economics, doi:10.1016/j.ecolecon.2006.07.009

Stern, D.I. (1993). “Energy use and economic growth in the USA: a multivariate approach.” Energy Economics 15: 137-150.

Stern, D.I. (2000). “A multivariate cointegration analysis of the role of energy in the US macroeconomy.” Energy Economics 22: 267–283.

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

Toda, H.Y., and Yamamoto, T., (1995). “Statistical inference in vector autoregression with possibly integrated processes,”Journal of Econometrics 66: 225--250.

UNFCCC (2006). “National greenhouse gas inventory data for the period 1990–2004 and status of reporting.” Subsidiary Body for Implementation, Twenty-Fifth Session, Nairobi.

Wolde-Rufael, Y. (2004). “Disaggregated Energy Consumption and GDP, the Experience of Shangai 1952-1999.” Energy Economics 26: 69-75.

Wolde-Rufael, Y. (2005). “Energy Demand and Economic Growth: The African Experience 19 Countries.” Journal of Policy Modeling 27(8): 891-903.

World Nuclear Association (2006). “Supply of uranium.” WNA Information Papers.

Xepapadeas, A. (2005) “Economic Growth and the Environment.” In Mäler, K.-G., and Vincent, J.R. (ed.s), *Handbook of Environmental Economics*, vol. 3, pp. 1219-1271.

Yang, H. Y. (2000). “A note on the causal relationship between energy and GDP in Taiwan.” Energy Economics 22: 309-317.

Yu, E.S.H. and Hwang, B.K., (1984). “The relationship between energy and GNP: further results.” Energy Economics 6: 186-190.

Yu, E.S.H. and Choi, J.Y., (1985). “The Causal Relationship between Energy and GNP: An International Comparison.” Journal of Energy and Development 10: 249-272.

Zaim, O. and Taskin, F., (2000). “A Kuznets curve in environmental efficiency: An application on OECD countries.” Environmental and Resource Economics 17: 21-36.

Table 1. Unit Root Test Results

		ADF	DF-GLS	PP	KPSS	NP-Z_a
				LEVELS		
Intercept	E	-1.229467 (0)	0.684142 (1)	-1.268738	0.788642[a]	0.98020 (1)
	Y	-1.134767 (0)	0.902675 (0)	-1.158398	0.782212[a]	1.39950 (0)
	C	-2.217958 (0)	0.603650 (0)	-6.418732[a]	0.771913[a]	1.20370 (0)
	L	1.138552 (1)	-0.325013 (1)	5.410207	0.783965[a]	-16.3723[a] (1)
	K	-1.862716 (0)	0.285598 (0)	-1.972424	0.732557[b]	0.98389 (0)
Intercept and Trend	E	-1.732277 (0)	-1.680907 (0)	-1.732277	0.178518[b]	-4.99276 (0)
	Y	-2.540750 (0)	-2.449590 (0)	-2.539598	0.130002[c]	-8.98046 (0)
	C	-2.273832 (0)	-1.684001 (0)	-2.205761	0.190755[b]	-3.92257 (0)
	L	-1.872755 (1)	-2.037895 (1)	-0.482027	0.208383[b]	-29.5930[a] (1)
	K	-2.345629 (1)	-1.915468 (0)	-2.167999	0.118363	-5.60780 (0)
				FIRST DIFFERENCES		
Intercept	E	-5.476278[a] (0)	-5.106520[a] (0)	-5.458145[a]	0.157366	-19.6329[a] (0)
	Y	-6.761734[a] (0)	-6.791674[a] (0)	-6.765712[a]	0.099217	-19.5913[a] (0)
	C	-6.912886[a] (0)	-6.180916[a] (0)	-6.891365[a]	0.392701[c]	-25.5210[a] (0)
	L	-1.167168 (1)	-0.977303 (0)	-1.271355	0.643876[b]	-2.01627 (0)
	K	-5.271773[a] (0)	-4.668951[a] (0)	-5.227365[a]	0.212303	-16.5561[a] (0)
Intercept and Trend	E	-5.646708[a] (0)	-5.271926[a] (0)	-5.616628[a]	0.050409	-17.7557[b] (0)
	Y	-6.813617[a] (0)	-6.796866[a] (0)	-6.852033[a]	0.046854	-19.5026[b] (0)
	C	-7.776836[a] (0)	-6.721280[a] (0)	-8.276917[a]	0.412445[a]	-18.4935[b] (0)
	L	-2.100313 (0)	-2.069162 (0)	-2.462433	0.080376	-7.22313 (0)
	K	-5.322104[a] (0)	-5.393318[a] (0)	-5.286056[a]	0.072294	-18.6625[b] (0)
				SECOND DIFFERENCES		
Intercept	L	-5.006411[a] (0)	-4.862767[a] (0)	-5.001696[a]	0.087400	-18.3479[a] (0)
Int. and trend	L	-4.939516[a] (0)	-5.023348[a] (0)	-4.933414[a]	0.086956	-18.9603[b] (0)

All variables in natural logs, lag lengths are determined via SIC and are in parentheses. Superscripts a, b, and c indicate significance at 1, 5, and 10% respectively. The null of all tests except KPSS are unit roots. KPSS null hypothesis states stationarity.

Table 2. Diagnostic test results

Equation	Adj. R^2	B-G test	J-B test	ARCH LM	White test	Ramsey RESET
E	0.994707	11.20464[a]	1.3992	0.071307 (2)	28.96633	6.655552[a]
Y	0.973779	9.741740[a]	0.3853	2.814109 (2)	30.04365	2.433994
K	0.969649	3.382939	1.2339	1.228807 (2)	30.05886	3.636697[c]
L	0.999944	0.411039	0.8306	1.095344 (2)	26.86769	6.398974[b]
C	0.974285	9.025563[b]	3.2636	0.996988 (2)	21.47874	14.58314[a]

The first column gives the adjusted R^2. The rest of the entries are the relevant test statistics. B-G test null is no serial correlation. J-B test null is normality. ARCH LM null is no ARCH up to the selected lag, determined via AIC from a maximum of 2. White test is without cross terms due to insufficient degrees of freedom and the null is no heteroscedasticity. Ramsey RESET test null is no specification errors and is conducted for one fitted term using LR. Superscripts a, b, and c represent significance at the 1, 5, and 10% respectively.

Table 3. Granger causality test results

Dependent Variable	E	Y	K	L	C
E	-	0.006123	0.043130	1.161628	3.244861[c]
Y	0.001124	-	1.037964	0.732147	1.035411
K	1.243155	0.181574	-	0.245269	2.554063
L	2.218683	13.21135[a]	6.120106[b]	-	1.309600
C	0.258188	0.136207	0.161202	0.201034	-

Superscripts a, b, and c represent significance at the 1, 5, and 10% respectively. Significance implies that the column variable Granger causes the row variable.

Figure 1. Generalized Impulse Responses of Income to other Variables

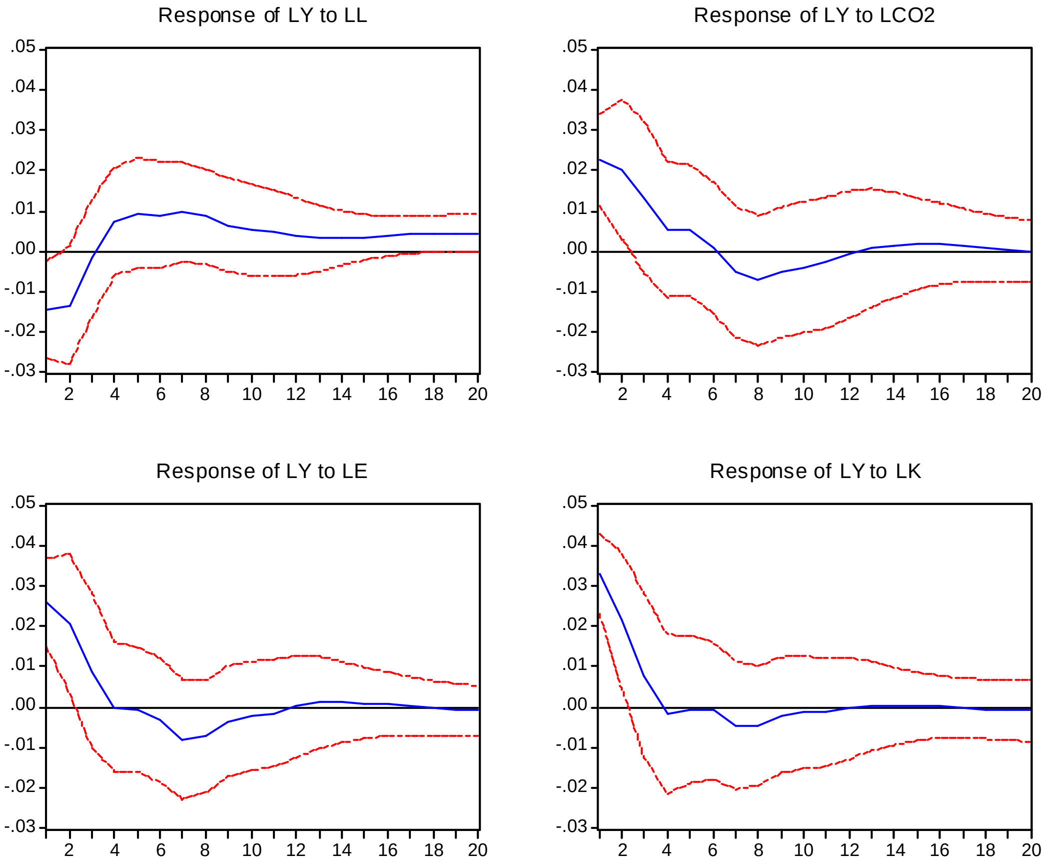

Figure 2. Generalized Impulse Responses of Energy to other Variables

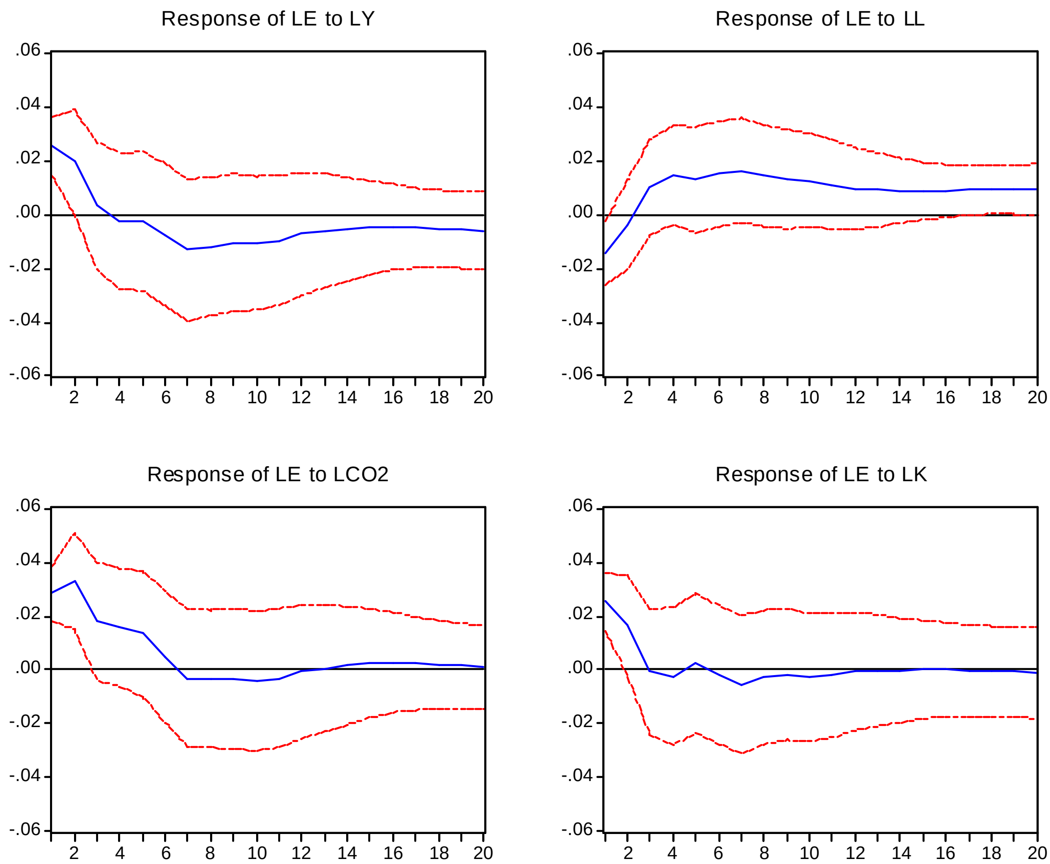

Figure 3. Generalized Impulse Responses of CO_2 to 1 Std. Dev. Innovations