ENERGY CONSUMPTION AND ECONOMIC GROWTH: EVIDENCE FROM MICRO DATA

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ABSTRACT
Although almost all the states in the USA have the similar economic size to the other world countries, no study has investigated the relationship between energy consumption and economic growth subject which has been extensively examined in the literature. Unlike previous energy consumption-growth studies, this study examines the relationship between energy consumption and economic growth for 47 US states over the period 1997-2009. Heterogeneous panel cointegration test reveals there is a long-run equilibrium relationship between real GDP and energy consumption. In addition, panel granger causality test results illustrate that feedback hypothesis (bidirectional relationship between energy and economic growth in which causation runs in both directions) is confirmed in these states.

Keywords: US States, Energy Consumption, GDP, Panel Granger.
JEL: C33, Q4, Q43

INTRODUCTION

The relationship between energy consumption and economic growth has been investigated comprehensively by using econometrics techniques over the past three decades. According to the controversial and inconsistent evidence, the directions of causality between energy consumption and economic growth can be categorized into four testable hypotheses: growth, conservation, feedback, and neutrality (Belke et al., 2011 and Ozturk 2010).

The “growth” hypothesis postulates that energy consumption plays a significant role in economic growth. The empirical support for the growth hypothesis is based on the presence of unidirectional causality from energy consumption to economic growth. In this case, energy conservation policies that decrease energy consumption will negatively impact economic growth. The conservation hypothesis states that energy conservation policies designed to reduce energy consumption and waste will not adversely impact real GDP. The conservation hypothesis is supported if there is unidirectional causality from economic growth to energy consumption. Third, the feedback hypothesis depends upon the interdependent relationship between energy consumption and economic growth. The feedback hypothesis postulates that there is a bidirectional causal relationship between energy consumption and real GDP. If this is the case energy policy efficiency would not adversely affect economic growth. Finally, the neutrality hypothesis states that neither conservative nor expansive energy consumption polices have any effect on economic growth.

However the empirical findings of these studies are mixed and have not reached a consensus (Yalta, 2011). The studies in Table 1 differ even on the direction of causality and the long-term versus short-term impact on energy policy.

Table 1. Summary of literature review

Study	Methodology	Period	Subject	Causal Relationship
Aggregate Energy Consumption				
Soytas and Sari (2003)	Co-integration tests	1950-1992	G7 and 10 emerging markets	Mixed
Fatai et al., (2004)	Causality test	1 960–1999	New Zealand, Australia	GDP → EC
Huang et al., (2008)	GMM	1972- 2002	82 countries	Low-income panel, EC≠ GDP Middle-income panel GDP→EC (+) High-income panel, GDP → EC (-)
Lee and Chang (2008)	Panel ECM	1971–2002	16 Asian countries	EC→GDP (in the long run) GDP≠ EC (in the short run)
Lee et al., (2008)	Panel co-integration tests	1960-2001	OECD Countries	EC ↔ GDP
Apergis and Payne (2009)	Panel co-integration tests	1980–2004	6 Central American countries	EC → GDP
Payne (2009)	Toda-Yamamoto	1949 - 2006	USA	EC≠ GDP

Ozturk and Acaravci (2010)	ARDL bounds testing cointegration	1968-2005	Turkey	EC≠ GDP
Belke et al., (2011)	Dynamic panel causality	1981 - 2007	25 OECD	EC ↔ GDP
Kahsai et al., (2011)	Panel co-integration approach	1980–2007	40 Sub-Saharan African countries	GDP↔ EC
Disaggregate Energy Consumption				
Murray and Nan (1996)	Causality test	1970–1990	15 countries	Mixed
Yang (2000)	Engle–Granger	1954–1997	Taiwan	CC↔GDP
Shiu and Lam (2004)	ECM	1971–2000	China	ELC → GDP
Lee and Chang (2005)	Gregory and Hansen co-integration	1954–2003	Taiwan	NGC→GDP
Yoo (2005)	ECM	1970–2002	Korea	ELC ↔ GDP
Halicioglu (2007)	Causality test	1968–2005	Turkey	GDP→ELC
Zamani (2007)	ECM	1967–2003	Iran	NGC↔GDP
Jinke et al., (2008)	Causality tests	1980–2005	OECD countries and non-OECD countries	Mixed
Narayan and Smyth (2009)	Panel co-integration	1974–2002	6 MENA countries	ELC ↔ GDP
Abosedra et al., (2009)	Causality test	1995–2005	Lebanon	ELC→GDP
Odhiambo (2009)	Causality test	1971–2006	South Africa	ELC ↔ GDP
Akinlo (2009)	Johansen–Juselius co-integration	1980–2006	Nigeria	ELC→GDP
Apergis and Payne (2010a)	Panel causality test	1980–2006	15 emerging countries	CC↔GDP
Apergis and Payne (2010b)	ECM	1992–2005	67 countries	NGC↔GDP
Lee and Chiu (2011)	Granger causality test and variance decomposition	1965–2008	6 highly industrialized countries	Mixed
Kum et al., (2012)	Bootstrap-corrected causality tests	1970–2008	France, Germany and US Italy	NGC↔GDP NGC→GDP

			United Kingdom	NGC→GDP

Note: EC→GDP means that the causality runs from energy consumption to growth.
GDP→EC means that the causality runs from growth to energy consumption.
EC↔GDP means that bi-directional causality exists between energy consumption and growth.
EC ≠GDP means that no causality exists between energy consumption and growth.
ELC→GDP means that the causality runs from electricity consumption to growth.
GDP→ELC means that the causality runs from growth to electricity consumption.
ELC↔GDP means that bi-directional causality exists between electricity consumption and growth.
ELC ≠GDP means that no causality exists between electricity consumption and growth.
CC↔GDP means that bi-directional causality exists between coal consumption and growth.
NGC↔GDP means that bi-directional causality exists between natural gas consumption and growth.
NGC→GDP means that the causality runs from natural gas consumption to growth.
NGC→GDP means that the causality runs from natural gas energy consumption to growth.

Abbreviations are defined as follows: EC=energy consumption, ECM=error correction model, ELC= electricity consumption, CC= coal consumption, NGC= natural gas consumption, GDP=real gross domestic product and GMM=generalized method of moments.

The objective of this paper is to investigate the relationship and causality between energy consumption and economic growth in 47 USA states for the period 1997-2009 by using panel co-integration and panel causality method. Unlike previous studies which have relied upon US aggregate data, states data are used in order to avoid problems such as potential aggregation and endogeneity bias.

The rest of the paper is organized as follows: The next section describes the data, methodology and the results from empirical analysis. Section 3 presents conclusion and policy implications of the paper.

DATA AND METHODOLOGY

We use annual energy consumption, EC hereafter and reel GDP data in this study. The data are sourced from U.S. Department of Commerce Bureau of Economic Analysis and U.S. Energy Information Administration's (EIA). 47 states are considered in this study are selected according to data availability for the 1997-2009 period. All variables are employed with their natural logarithms form to reduce heteroscedasticity.

Table 2. Total Energy Consumption and GDP, Ranked by State, 2009

Rank	Total Energy Consumption		Gross Domestic Product (GDP)	
	State	**Trillion Btu**	**State**	**Billion Chained (2005) Dollars**
1	Texas	11,297.4	California	1,736.9
2	California	8,005.5	Texas	1,066.4
3	Florida	4,295.2	New York	976.6

4	New York	3,818.5	Florida	660.9
5	Illinois	3,815.1	Illinois	560.0
6	Pennsylvania	3,654.1	Pennsylvania	492.0
7	Ohio	3,633.7	New Jersey	434.0
8	Louisiana	3,366.3	Ohio	420.4
9	Georgia	2,949.3	Virginia	367.4
10	Michigan	2,696.6	North Carolina	360.6
11	Indiana	2,622.6	Georgia	356.3
12	North Carolin a	2,545.4	Massachusetts	329.8
13	New Jersey	2,393.6	Michigan	327.4
14	Virginia	2,385.8	Washington	305.8
15	Tennessee	2,136.0	Maryland	256.0
16	Washington	2,032.9	Minnesota	234.9
17	Alabama	1,906.8	Indiana	232.3
18	Kentucky	1,876.6	Colorado	232.1
19	Missouri	1,817.8	Arizona	230.9
20	Minnesota	1,809.5	Tennessee	219.3

Source: US Energy Information Administration.
All data are available at http://www.eia.gov/state/seds/seds-data-complete.cfm

Table 2 displays some statistics related to the total energy consumption along with GDP for 20 US states in 2009. In terms of total energy consumption, Texas ranks the highest while Minnesota ranks the lowest. In the case of GDP value, California ranks the highest while Tennessee is the lowest.

The highest 6 states are Texas, California, Florida, New York, Illinois and Pennsylvania for both total energy consumption and GDP value. In fact, there is a great deal of variation in energy consumption statistics especially between Texas even California that is second. Since Texas consumes more electricity than any other state, accounting for more than one-tenth of total U.S. energy use. Texas' energy use is tied to its large population, hot climate and extensive industrial sector. Compared to the U.S., Texas has a high concentration of energy-intensive industries, including aluminum, chemicals, forest products, glass, and petroleum refining.

It is well known that the traditional unit root tests or co-integration tests method (e.g., ADF or residual-based co-integration tests) involves the low power problem for non-stationary data. The primary motivation for panel data unit root tests as proposed to traditional unit root tests is to take advantage of the additional information provided by pooled cross-section time series to increase test power. Thus, one of the most widely used unit root test, which is called Im, Pesaran and Shin (IPS, 2003) test, is used in this study. It can be inferred from the Table 3 that the unit root hypothesis cannot be rejected when the variables are taken in levels. On the other hand, when the first differences are used, the hypothesis of unit root non-stationary is rejected at the 1 percent level of significance.

Table 3. IPS panel unit root test results

Variables	Without trend	With trend	Without trend	With trend
	Level		**First Difference**	

GDP	-1.442	-2.225	-4.2641	-3.6009*
EC	-1.398	-1,447	-18.2618*	-22.4673*

Note: (*) 99% confidence level. Optimal lag determination is based on Schwarz Bayesian Information Criterion (SBIC).

A relationship between energy consumption (EC) and economic growth (GDP) is searched by employing co-integration framework introduced by Pedroni (1999) in the second step of estimation. Table 4 reports both the within and between dimension panel co-integration test statistics. With the exception of the panel v-test, the other six test statistics reject the null hypothesis of no co-integration at the 1% significance level.

Table 4. The results of panel co-integration tests

	Without trend	**With trend**
	Within dimension Test statistics	
Panel v-statistic	4.4665*	-2.7446
Panel p-statistic	-56.4410*	-54.9635*
Panel PP-statistic	-54.1147*	-68.7139*
Panel ADF statistic	-42.1778*	
	Between dimension Test statistics	
Panel p-statistic	-34.1403*	-24.1236*
Group PP-statistic	-53.7769*	-52.6814*
Group ADF statistic	-40.1445*	-38.4573*

Note: * indicates statistical significance at the 1% level

Having established co-integration in Table 4, we examine the direction of causality between GDP and EC in a panel context which is based on the following regressions:

$$\Delta \ln GDP_{it} = \varphi_{1i} + \sum_{p} \varphi_{11ip} \Delta \ln GDP_{it-p} + \sum_{p} \varphi_{12ip} \Delta \ln EC_{it-p} + \Psi_{1i} ECT_{t-1} \quad (1)$$

$$\Delta \ln EC_{it} = \varphi_{2i} + \sum_{p} \varphi_{21ip} \Delta \ln EC_{it-p} + \sum_{p} \varphi_{22ip} \Delta \ln GDP_{it-p} + \Psi_{2i} ECT_{t-1} \quad (2)$$

Equations (1) and (2) are estimated using the pooled mean group estimator (PMGE) proposed by Pesaran et al. (1999). Causality is tested based on $H_0 = \varphi_{12ip} = 0$ and $H_0 = \varphi_{22ip} = 0$ for all i and k[1]. The panel Granger causality test results are reported in Table 5.

[1] The optimal lag structure is set to one and the significance of the causality tests is determined by theWald F-test.

According to the causality test results, there is a unidirectional causality from energy consumption to economic growth. In other words, feedback hypothesis (bidirectional relationship between energy and economic growth in which causation runs in both directions) is confirmed in these states. Therefore, any negative shock on energy supply will have negative effects on economic growth and vice versa.

Table 5. Panel Granger causality test results

	Sources of causation		
	ΔGDP	**ΔEC**	**ECT**
ΔGDP	**-**	0.186 [0.288]	.00275 [0.038]*
ΔEC	0.177* [0.038]	**-**	.03786 [0.027]*

Note: Probability values are in brackets and * denotes statistical significance at the 5% level.

CONCLUSION AND POLICY IMPLICATIONS

Although the economies of countries like China and India are growing at an incredible rate, the US remains the nation with the highest GDP in the world – and by far: US GDP is projected to be $14,7 trillion in 2010. The creator of this information has had the interesting idea to break down that enormous US GDP into the GDPs of individual states, and compare those to other countries' GDP. For example, California would be the world's sixth- or seventh-largest economy if it was a separate country. Actually, that would be the *eighth* as France (with a GDP of $2,2 trillion). In addition, Texas would be nearly tenth largest economy ($1,3 trillion) as Canada.

Although the causal relationship between energy consumption and economic growth has been widely studied for especially countries, the direction of causality is also highly relevant for policymakers in states. Therefore, this study has attempted to examine the contribution of energy consumption to economic growth in 47 states using annual data from 1999 to 2008. The aim of this study is to investigate if there is relationship between energy consumption and real GDP, examine the causality between these variables. A relationship between energy consumption and economic growth is examined by utilizing Pedroni (1999) panel co-integration method. In addition, panel causality test results reveal that feedback hypothesis (bidirectional relationship between energy and economic growth in which causation runs in both directions) is confirmed in these states. The empirical results of this study provide policymakers a better understanding of energy consumption-economic growth nexus to formulate energy policies in these states. As a policy implication, since there is no evidence indicating that energy consumption leads economic growth in any of states considered in this study, the policymakers should take into consideration the degree of economic growth in each state when energy consumption policy is formulated. The findings of this study have important policy implications and it shows that this issue still deserves further attention in future research. As a policy implication for future research on states energy-growth relationship and causality, the authors may use multivariate models including new variables (such as: real gross fixed capital formation, labor force, carbon dioxide emissions and etc.) and taking breaks into account.

REFERENCES

Abosedra, S., Dah, A., Ghosh, S., 2008. Electricity consumption and economic growth: the case of Lebanon. Applied Energy 86, 429-432.

Akinlo, A.E., 2009. Electricity Consumption and Economic Growth in Nigeria: Evidence from Cointegration and Co-Feature Analysis. Journal of Policy Modeling 31, 681-693.

Apergis, N., Payne, J.E., 2009. CO2 emissions, energy usage, and output in Central America. Energy Policy 37, 3282–3286.

Apergis, N., Payne, J.E., 2010a. The causal dynamics between coal consumption and growth: Evidence from emerging market economies. Applied Energy 87, 1972–1977.

Apergis, N., Payne, J.E., 2010b. Natural gas consumption and economic growth: A panel investigation of 67 countries. Applied Energy 87, 2759–2763.

Belke, A., Dobnik F., Dreger C., 2011. Energy consumption and economic growth: New insights into the cointegration relationship. Energy Economics 33, 782–789.

Energy Information Administration (EIA). State energy data system. 2011 database.

Fatai, K., Oxley, L., Scrimgeour, F.G., 2004. Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, the Philippines, and Thailand. Mathematics and Computers in Simulation 64, 431-445.

Halicioglu, F., 2007. Residential Electricity Demand Dynamics in Turkey. Energy Economics 29, 199-210.

Huang, B.N., Hwang, M.J.,Yang, C.W., 2008. Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach. Ecological Economics 67, 41-54.

Im S., Pesaran M.H., Shin Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53–74.

Jinke, L., Hualing, S., Dianming, G., 2008. Causality relationship between coal consumption and GDP: difference of major OECD and on-OECD countries. Applied Energy 85, 421-429.

Kahsaia M.S., Nondob C., Schaefferc P.V., Tesfa G.G,. 2011. Income level and the energy consumption–GDP nexus: Evidence from Sub-Saharan Africa. Energy Economics, doi:10.1016/j.eneco.2011.06.006.

Kum, H., Ocal, O., Aslan A., 2012. The relationship among natural gas energy consumption, capital and economic growth: Bootstrap-corrected causality tests from G-7 countries, Renewable and Sustainable Energy Reviews 16, 2361– 2365

Lee C.C, Chang C.P., 2005. Structural breaks, energy consumption and economic growth revisited: evidence from Taiwan. Energy Economics 27, 857–872.

Lee, C.C., Chang, C.P., Chen, P.F., 2008. Energy-income causality in OECD countries revisited: the key role of capital stock. Energy Economics 30, 2359-2373.

Lee, C.C., Chang, C.P., 2008. Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. Resource and Energy Economics 30, 50-65.

Lee C.C., Chiua Y.B., 2011. Nuclear energy consumption, oil prices, and economic growth: Evidence from highly industrialized countries. Energy Economics 33, 236-248.

Murray, D.A., Nan, G.D., 1996. A definition of the gross domestic product-electrification interrelationship. Journal of Energy and Development 19, 275-283.

Odhiambo, N. M., 2009. Electricity consumption and economic growth in South Africa: A trivariate causality test. Energy Economics 31, 635-640.

Ozturk, I. 2010. A literature survey on energy–growth nexus, Energy Policy, 38: 340-349.

Ozturk, I. and Acaravci, A. 2010. CO2 Emissions, Energy Consumption and Economic Growth in Turkey. Renewable and Sustainable Energy Reviews 14, 3220-3225.

Payne, J.E., 2009. On the dynamics of energy consumption and output in the US. Applied Energy 86, 575–577.

Soytas, U. and Sari, R., 2003. Energy consumption and GDP: causality relationship in G-7 and emerging markets. Energy Economics 25, 33-37.

Shiu, A., Lam, P.L., 2004. Electricity consumption and economic growth in China. Energy Policy 32, 47-54.

Pedroni P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics 61, 653–678.

Pesaran M.H., Shin Y.,Smith R., 1999. Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association 94, 621–634.

Yalta A.T., 2011. Analyzing energy consumption and GDP nexus using maximum entropy bootstrap: The case of Turkey. Energy Economics 33, 453–460.

Yang, H.Y., 2000. A note on the causal relationship between energy and GDP in Taiwan. Energy Economics 22, 309–317.

Yoo, S.H., 2005. Electricity consumption and economic growth: evidence from Korea. Energy Policy 33, 1627-1632.

Zamani M., 2007. Energy consumption and economic activities in Iran. Energy Economics 29, 1135–1140.