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On the Dynamics of Energy Consumption and Employment in Illinois

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Abstract. This short empirical study utilizes U.S. annual data from 1976 to 2006 to examine the causal relationship between energy consumption and employment in Illinois within a multivariate framework. The Toda-Yamamoto long-run causality tests reveal unidirectional causality from energy consumption to employment supportive of the growth hypothesis. However, the importance of energy consumption in economic activity should not overshadow the environmental consequences of heavy reliance on fossil fuel consumption as well as the relevance of alternative renewable energy sources and improved energy efficiency for future economic growth.

1. Introduction

The heightened interest in the impact of energy consumption on economic activity by both academics and policymakers can be attributed to the recent experience of rising energy costs, growing dependency on foreign energy sources, and increasing concerns about greenhouse gas emissions. Though the dynamic causal relationship between energy consumption and economic activity has been explored for a number of countries including the U.S., an examination of such a relationship at the state level has not been undertaken in the published literature (Payne, forthcoming). The task of this short empirical study is to fill this void in the literature by examining the causal relationship between energy consumption and employment in Illinois The state of Illinois ranks fifth in both population and output produced among U.S. states and is one of the top energy-consuming states. In addition to the size of the state's population and output produced, the state's energy intensive industrial sector contributes significantly to the demand for energy (Energy Information Administration).

Illinois exhibits variation with respect to energy sources and usage across fossil fuels and renewable energy. While Illinois is ranked third in the U.S. in terms of recoverable coal reserves, it is not ranked among the top coal producers in the U.S. due in large part to the high sulfur content of the coal produced. In terms of petroleum and natural gas, Illinois has the largest crude oil refining capacity in the Midwest and serves as a vital transportation hub for crude within North America. Almost eighty percent of Illinois households use natural gas for heating their homes though Illinois has limited indigenous natural gas production. With respect to clean energy, Illinois is ranked first in the U.S. with respect to nuclear power generation with eleven operating nuclear reactors at six nuclear power plants. Nuclear power generates almost half of the state's electricity, and Illinois is a net exporter of electricity to other states. On the renewable energy front, Illinois is a major exporter of ethanol to other U.S. markets and exhibits a great deal of potential in this area given its corn production. Ethanol refining capacity ranks second in the U.S. to Iowa.

Before proceeding to an empirical investigation of the causal relationship between energy consumption and employment in Illinois, the four hypotheses associated with this relationship along with a summary of the empirical literature on the U.S. are summarized in Section 2. Section 3 presents the data, methodology, and results while Section 4 provides concluding remarks.

2. Energy consumption-growth hypotheses and empirical evidence for the U.S.

The direction of causality between energy consumption and economic growth, measured by either employment or real output, can be summarized in four testable hypotheses: growth, conservation, feedback, and neutrality. First, the growth hypothesis suggests that energy consumption contributes directly to economic growth within the production process. If such is the case, the policy implications are that energy conservation policies which reduce energy consumption may possibly reduce real output. The growth hypothesis is supported if there is unidirectional Granger-causality from energy consumption to real output. For the U.S., Akraca and Long (1979), Stern (1993, 2000), and Soytas and Sari (2006) provide empirical support for the growth hypothesis. Second, the conservation hypothesis implies that energy conservation policies designed to reduce energy consumption and waste may not reduce real output. Unidirectional Granger-causality from real output to energy consumption would lend support for the conservation hypothesis. Studies by Kraft and Kraft (1978), Erol and Yu (1989), Abosedra and Baghestani (1991), Murry and Nan (1992), Thoma (2004), and Sari et al. (2008) support the conservation hypothesis in the case of the U.S.

Third, the feedback hypothesis asserts that energy consumption and real output are interdependent and act as complements to each other. The existence of bidirectional Granger-causality between energy consumption and real output substantiates the feedback hypothesis. Research by Glasure and Lee (1995, 1996), Zarnikau (1997), Lee (2006), and Mahadevan and Asafu-Adjaye (2007) lend support to the feedback hypothesis for the U.S. Finally, the neutrality hypothesis views energy consumption as a relatively minor factor in the production of real output in which case energy conservation policies may not adversely impact real output. The absence of Granger-causality between energy consumption and real output is supportive of the neutrality hypothesis. Studies by Akraca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Erol and Yu (1987), Yu et al. (1988), Yu and Jin (1992), Cheng (1996), Murry and Nan (1996), Soytas and Sari (2003), Chontanawat et al. (2006, 2008), Soytas et al. (2007), Chiou-wei et al. (2008), Narayan and Prasad (2008), Payne (2009), and Payne and Taylor (forthcoming) are supportive of the neutrality hypothesis in the U.S.[1]

[1] While not explicitly testing for causality, Ewing et al. (2007) employ only forecast variance decompositions to infer the impact of various energy consumption measures on economic growth for the U.S. Zachariadis (2007) and Bowden and Payne (2009) find that the causal relationship between energy consumption by sector and real output are not uniform across sectors. Bowden and Payne (forthcoming) differentiate between renewable and non-renewable energy consumption by sector finding support for the growth hypothesis for residential renewable energy consumption and industrial non-renewable energy consumption; the feedback hypothesis for commercial and residential non-renewable energy consumption; and the neutrality hypothesis for commercial and industrial renewable energy consumption. Payne (forthcoming) also finds mixed results across disaggregated measures of fossil fuel consumption and real GDP.

3. Data, methodology, and results

Annual data for the period 1976-2006 for Illinois total energy consumption measured in trillions of Btu was obtained from the *Energy Information Administration*. Illinois total nonfarm employment was obtained from the *Bureau of Labor Statistics* and U.S. total nonfarm employment from the *Economic Report of the President*. All variables are in natural logarithms. U.S. total nonfarm employment is included as a control variable for the aggregate economy and to minimize any potential problem with omitted variable bias.

The causal relationship between energy consumption and employment in Illinois is examined using the Toda-Yamamoto (1995) test for long-run causality. The Toda-Yamamoto procedure avoids the difficulties encountered in testing for Granger-causality in regards to the power and size properties of conventional unit root and cointegration tests (Zapata and Rambaldi, 1997). To minimize the risks associated with incorrectly identifying the order of integration of the respective time series and the cointegration properties among the variables, the Toda-Yamamoto approach requires the estimation of a VAR model in levels. The long-run causality test is undertaken by augmenting the correct order of the VAR, k, by the maximum order of integration, d_{max}, with the test statistics for Granger-causality portraying the standard asymptotic distribution.

To infer the maximum order of integration among the variables Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) unit root tests are undertaken as displayed in Table 1. Energy consumption (EC) is integrated of order one based on the unit root tests with an intercept as well as intercept and trend. Illinois employment (E^{IL}) is integrated of order one based on the unit root tests without a trend term and the Phillips-Perron unit root test with intercept and trend, but not for the augmented Dickey-Fuller unit root test with intercept and trend term. U.S. employment (E^{US}) is integrated of order one based on the augmented Dickey-Fuller unit root test without a trend term and the Phillips-Perron unit root test with an intercept and

trend term only. In summary, the unit root tests suggest that the maximum order of integration is one.

Table 1. Unit root tests

Variable	ADF(C)	ADF(C+T)	PP(C)	PP(C+T)
E^{IL}	-1.434	-3.302[c]	-1.031	-2.053
ΔE^{IL}	-3.783[a]	-------	-3.563[b]	-3.387[c]
EC	-1.590	-1.933	-1.590	-1.837
ΔEC	-3.784[a]	-4.257[b]	-4.208[a]	-4.291[b]
E^{US}	-2.147	-3.307[c]	-3.526[c]	-2.103
ΔE^{US}	-3.580[b]	-------	-------	-3.421[b]

Notes: C denotes intercept and C+T with intercept and trend in the respective unit root tests. Significance levels denoted as follows: a(1%), b(5%), and c(10%). Lag lengths for the ADF unit root tests determined by Schwarz information criterion while PP unit root tests determined by Newey-West with Bartlett kernel for bandwidth.

Next, the lag length for the respective VAR models in levels was initially set at $k = 4$. Several lag length criteria were examined. The Schwarz and Hannan-Quinn information criterion yielded a lag length of one whereas the final prediction error and Akaike information criterion yielded a lag length of two. The $(k+d_{max})^{th}$ order VAR models associated with the two different lag lengths were estimated with the lagged d_{max} vector ignored in testing for long-run causality via a modified Wald test. The equations for the energy consumption and employment in Illinois are shown as follows with the equation for U.S. employment suppressed to conserve space:[2]

Employment:

$$E_t^{IL} = \eta_0 + \sum_{i=1}^{k}\theta_{1i}E_{t-i}^{IL} + \sum_{j=k+1}^{d_{\max}}\theta_{2j}E_{t-j}^{IL} + \sum_{i=1}^{k}\psi_{1i}EC_{t-i} + \sum_{j=k+1}^{d_{\max}}\psi_{2j}EC_{t-j} + \sum_{i=1}^{k}\omega_{1i}E_{t-i}^{US} + \sum_{j=k+1}^{d_{\max}}\omega_{2j}E_{t-j}^{US} + \varepsilon_{1t} \quad (1)$$

Energy Consumption:

$$EC_t = \tilde{\eta}_0 + \sum_{i=1}^{k}\tilde{\theta}_{1i}E_{t-i}^{IL} + \sum_{j=k+1}^{d_{\max}}\tilde{\theta}_{2j}E_{t-j}^{IL} + \sum_{i=1}^{k}\tilde{\psi}_{1i}EC_{t-i} + \sum_{j=k+1}^{d_{\max}}\tilde{\psi}_{2j}EC_{t-j} + \sum_{i=1}^{k}\tilde{\omega}_{1i}E_{t-i}^{US} + \sum_{j=k+1}^{d_{\max}}\tilde{\omega}_{2j}E_{t-j}^{US} + \varepsilon_{2t} \quad (2)$$

where E^{IL} is Illinois total nonfarm employment; *EC* is Illinois energy consumption; and E^{US} is U.S. total nonfarm employment. The growth hypothesis is supported if there is unidirectional Granger-causality from energy consumption to employment ($\psi_{1i} \neq 0 \forall_i$) in Equation (1). The presence of unidirectional Granger-causality from employment to energy consumption ($\tilde{\theta}_{1i} \neq 0 \forall_i$) in Equation (2) provides support for the conservation hypothesis. Bidirectional Granger-causality between energy consumption and employment ($\psi_{1i} \neq 0 \forall_i$ and $\tilde{\theta}_{1i} \neq 0 \forall_i$) in Equations (1) and (2) confirms the feedback hypothesis while the absence of Granger-causality between energy consumption and employment ($\psi_{1i} = 0 \forall_i$ and $\tilde{\theta}_{1i} = 0 \forall_i$) in Equations (1) and (2) denotes the neutrality hypothesis.

Table 2 presents the results of the Toda-Yamamoto long-run causality tests between the energy consumption and employment in Illinois.[3] In Panel A, the null hypothesis that energy consumption does not Granger-cause employment is rejected at the 1 percent significance level. However, one is unable to reject the null hypothesis that employment does not Granger-cause energy consumption. The results in Panel B are comparable to those reported in Panel A. These results favor the growth hypothesis whereby an increase in energy consumption has a positive and statistically significant impact employment in Illinois.

4. Concluding remarks

Unlike previous studies on energy consumption and real output for the U.S. economy as a whole, this short empirical study examines the relationship between energy consumption and employment for a specific state, Illinois. The Toda-Yamamoto long-run causality tests reveal a positive and statistically significant unidirectional causality from energy consumption to employment in Illinois over the period 1976 to 2006 which supports the growth hypothesis. On the surface the policy implications associated with the growth hypothesis are that energy conservation policies which reduce energy consumption may possibly reduce employment. However, the importance of energy consumption in economic activity should not overshadow the environmental consequences of heavy reliance on fossil fuel consumption. Moreover, one cannot overlook the relevance of alternative renewable energy sources and improved efficiency in energy production and consumption patterns on the prospects for future economic growth.

[2] Using either lag length U.S. employment was insignificant in explaining Illinois energy consumption or employment. However, Illinois energy consumption had small, but statistically significant positive impact on U.S. employment.

[3] The Ljung-Box Q-statistics at 12 lags reveal the residuals are free of serial correlation and the ARCH statistics indicate the residuals do not exhibit autoregressive conditional heteroskedasticity of the first order.

Future research into the various disaggregated energy sources within each sector by state may shed additional insight on the relative impact of energy consumption patterns on economic activity. Such efforts would also provide valuable information in the development of a more prudent and effective energy and environmental policies for the U.S.

Table 2. Toda-Yamamoto causality tests of Illinois energy consumption and employment

Panel A: Schwarz and Hannan-Quinn Information Criterion, k = 1		
Null Hypotheses	Modified Wald Statistics	Sum of Lagged Coefficients
Energy Consumption does not Granger-cause Employment	12.774 [0.000][a]	0.3479
Employment does not Granger-cause Energy Consumption	0.203 [0.653]	0.3224
Panel B: Final Prediction Error and Akaike Information Criterion, k =2		
Null Hypotheses	Modified Wald Statistics	Sum of Lagged Coefficients
Energy Consumption does not Granger-cause Employment	8.253 [0.016][b]	0.0168
Employment does not Granger-cause Energy Consumption	0.218 [0.897]	0.1719

Notes: Modified Wald chi-square statistics to test whether the *k* lags are equal to zero are displayed with probability values in brackets. The sum of the lagged coefficients represents the summation of the lags in the VARs excluding the lagged coefficient with the highest order. Significance levels are as follows: a(1%), b(5%), and c(10%).

References

Abosedra, S. and H. Baghestani. 1991. 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 T.V. Long. 1979. Energy and employment: A time series analysis of the causal relationship. *Resources and Energy* 2:151-162.

Akarca, A.T. and T.V. Long. 1980. On the relationship between energy and GNP: A reexamination. *Journal of Energy and Development* 5:326-331.

Bowden, N. and J.E. Payne. 2009. The causal relationship between U.S. energy consumption and real output: A disaggregated analysis. *Journal of Policy Modeling* 31:180-188.

Bowden, N. and J.E. Payne. (forthcoming). Sectoral analysis of the causal relationship between renewable and non-renewable energy consumption and real output in the U.S. *Energy Sources, Part B: Economics, Planning, and Policy*.

Cheng, B.S. 1996. An investigation of cointegration and causality between energy consumption and economic growth. *Journal of Energy and Development* 21:73-84.

Chiou-Wei, S.Z., C.F. Chen, and Z. Zhu. 2008. Economic growth and energy consumption: Evidence from linear and nonlinear Granger causality. *Energy Economics* 30:3063-3076.

Chontanawat, J., L.C. Hunt, and R. Pierse. 2006. Causality between energy consumption and GDP: Evidence from 30 OECD and 78 non-OECD countries. Surrey Energy Economics Discussion Paper Series 113.

Chontanawat, J., L.C. Hunt, and R. Pierse. 2008. Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. *Journal of Policy Modeling* 30:209-220.

Dickey, D. and W.A. Fuller. 1979. Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association* 74:427-431.

Energy Information Administration. State Energy Profiles. www.eia.doe.gov.

Erol, U. and E.S.H. Yu. 1987. Time series analysis of the causal relationships between US energy and employment. *Resources and Energy* 9:75-89.

Erol, U. and E.S.H. Yu. 1989. Spectral analysis of the relationship between energy consumption, employment and business cycles. *Resources and Energy* 11:395-412.

Ewing, B.T., R. Sari, and U. Soytas. 2007. Disaggregate energy consumption and industrial output in the United States. *Energy Policy* 35:1274-1281.

Glasure, Y.U. and A.R. Lee. 1995. Relationship between U.S. energy consumption and employment: Further evidence. *Energy Sources*. 17:509-516.

Glasure, Y.U. and A.R. Lee. 1996. The macroeconomic effects of relative prices, money, and federal spending on the relationship between U.S. energy consumption and employment. *Journal of Energy and Development* 22:81-91.

Kraft, J. and A. Kraft. 1978. On the relationship between energy and GNP. *Journal of Energy and Development* 3:401-403.

Lee, C. 2006. The causality relationship between energy consumption and GDP in G-11 countries revisited. *Energy Policy* 34:1086-1093.

Mahadevan, R. and J. Asafu-Adjaye. 2007. Energy consumption, economic growth and prices: A reassessment using panel VECM for developed and developing countries. *Energy Policy* 35: 2481-2490.

Murray, D.A. and G.D. Nan. 1992. The energy and employment relationship: A clarification. *Journal of Energy and Development* 16:121-131.

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

Narayan, P.K. and A. Prasad. 2008. Electricity consumption-real GDP causality nexus: Evidence from a bootstrapped causality test for 30 OECD countries. *Energy Policy* 36:910-918.

Payne, J.E. 2009. On the dynamics of energy consumption and output in the U.S. *Applied Energy* 86:575-577.

Payne, J.E. (forthcoming). Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies*.

Payne, J.E. (forthcoming). U.S. disaggregate fossil fuel consumption and real GDP: An empirical note. *Energy Sources, Part B: Economics, Planning, and Policy*.

Payne, J.E. and J.P. Taylor. (forthcoming). Nuclear energy consumption and economic growth in the U.S.: An empirical note. *Energy Sources, Part B: Economics, Planning, and Policy*.

Phillips, P.C.B. and P. Perron. 1988. Testing for a unit root in time series regression. *Biometrika* 75:335-346.

Sari, R., B.T. Ewing, and U. Soytas. 2008. The relationship between disaggregate energy consumption and industrial production in the United States: An ARDL approach. *Energy Economics* 30:2302-2313.

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

Soytas, U. and R. Sari. 2006. Energy consumption and income in G7 countries. *Journal of Policy Modeling* 28:739-750.

Soytas, U., R. Sari, and B.T. Ewing. 2007. Energy consumption, income, and carbon emissions in the United States. *Ecological Economics* 62:482-489.

Stern, D.I. 1993. Energy 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.

Thoma, M. 2004. Electrical energy usage over the business cycle. *Energy Economics* 26:363-385.

Toda, H.Y. and T. Yamamoto. 1995. Statistical inference in vector autoregressions with possibly integrated process. *Journal of Econometrics* 66:225-250.

Yu, E.S.H. and B. Hwang. 1984. The relationship between energy and GNP: Further results. *Energy Economics* 6:186-190.

Yu, E.S.H. and J.Y. Choi. 1985. The causal relationship between energy and GNP: An international comparison. *Journal of Energy and Development* 10:249-272.

Yu, E.S.H., P.C.Y. Chow, and J.Y. Choi. 1988. The relationship between energy and employment: A reexamination. *Energy Systems and Policy* 11:287-295.

Zachariadis, T. 2007. Exploring the relationship between energy use and economic growth with bivariate models: New evidence from G-7 countries. *Energy Economics* 29:1233-1253.

Zapata, H.O. and A.N. Rambaldi. 1997. Monte carlo evidence on cointegration and causation. *Oxford Bulletin of Economics and Statistics* 59:285-298.

Zarnikau, J. 1997. A reexamination of the causal relationship between energy consumption and gross national product. *Journal of Energy and Development* 21:229-239.