Brantley Liddle[1]

ANALYZING ENERGY CONSUMPTION, ECONOMIC GROWTH, & URBANIZATION

[1]Victoria University, Australia, btliddle@alum.mit.edu

OVERVIEW

The causality between energy consumption and economic growth has been studied extensively. Indeed, a recent survey by Payne [1] listed 101 such papers, the first of which was published in 1978; over half the papers listed were published since 2005, and 35 were published in 2007 and 2008 alone. To improve the power of unit root and cointegration tests that can be impaired by the short data spans typically available for single countries, many in the literature now use panel data; in addition, to avoid the missing variable problem, a few authors have adopted a production-function approach, where output is a function of energy consumption, physical capital, and labor (e.g. [2]). This paper adds urbanization as a shift factor to that production function model to analyze panels of rich, middle, and poor countries (roughly separated by the World Bank income category definitions). (McCoskey and Kao [3] similarly considered urbanization, but their production function did not contain energy consumption—it only had capital and labor.) Urbanization may be related to economic growth [4] as well as to energy consumption [5]; yet only one energy-GDP causality study has considered urbanization [6], and that study did not use a production function approach and had the rather narrow focus of a panel of nine Pacific Island countries.

MODEL, DATA, AND METHODS

We begin with a Cobb-Douglas production function:

$$y_{i,t} = \left(U_{i,t}\right)^{\lambda}\left(K_{i,t}^{\beta}E_{i,t}^{\alpha}L_{i,t}^{1-\beta+\alpha}\right) \qquad (1)$$

where $y_{i,t}$ is GDP for country i in time period t, $U_{i,t}$ is the percent of the population living in urban areas, $K_{i,t}$ is capital stock, $E_{i,t}$ is energy consumption, and $L_{i,t}$ is the labor force. Normalizing by population/labor force and taking natural logs forms the following model:

$$\ln y_{i,t}^{*} = a_i + b_t + \beta \ln K_{i,t}^{*} + \alpha \ln E_{i,t}^{*} + \lambda \ln U_{i,t} + \varepsilon_{i,t} \qquad (2)$$

where super script * denotes per capita variables, the constants a and b are the country and time fixed effects, respectively, and ε is the error term.

GDP per capita is real 2000 US$ converted at PPP per person and total final energy consumption per capita is in thousand tons oil equivalent per person; both measures are from the International Energy Agency. Both gross fixed capital formation per capita (in real 2000 US$ per person) and urbanization are from the World Bank Development Indicators. The data spans 1971-2007; and there are 22 rich countries, 21 middle countries, and 26 poor countries in the panels.

First it must be determined if the variables contain a panel unit root. A number of panel unit root test have been developed, I employ four. If all the variables are integrated of the same order, the next step is to test for cointegration, i.e., whether there is a long-run relationship among the variables. The Pedroni [7 and 8] heterogeneous panel cointegration test is an extension to panel data of the Engle-Granger framework. If the variables are shown to be cointegrated, then Pedroni's FMOLS estimator produces asymptotically unbiased estimates of the long-run elasticities and efficient, normally distributed standard errors. Lastly, if a set variables are determined to be cointegrated, then the relationship among them can be modeled using Vector Error Correction Modeling (VECM), and statistical tests on the individual equations in the VECM can be used to reveal the direction of Granger-causality between variables.

RESULTS

The panel unit root test determined that all of the variables are panel I(1), as was expected given the previous findings in the literature (e.g., [2] and [6]). In addition, the panel cointegration tests found that the production function variables with urbanization as a shift factor are cointegrated for all three panels (rich, middle, and poor countries). Thus, having satisfied that the variables are both I(1) and panel cointegrated for the three panels, we estimate the long run elasticities via FMOLS. Those results are displayed in Table 1 below.

Table 1. Long run elasticities from FMOLS

Panel	**K**	**Energy**	**Urban**
Rich	0.262*	0.174*	0.812*
Middle	0.217*	0.396*	-0.0013
Poor	0.145*	0.482*	-0.152*

Statistical significance is indicated by: * $p < 0.001$.

The direction of causality among the variables also differed across the three panels. For the rich countries, GDP and energy consumption had a bi-causal relationship, and energy consumption (but not GDP) also was caused by urbanization. For both the middle and poor countries energy consumption was one-way caused by GDP.

CONCLUSIONS

The long run elasticities vary across panels in a more-or-less linear way with income. Urbanization is positive for rich countries, insignificant for middle countries, and negative for poor countries. Physical capital's elasticity also increases with development, but is positive and significant for all three panels. On the other hand, energy consumption's elasticity declines with development (but is significant for all three panels); it is more than twice as large for middle countries than for rich countries and is larger still for poor countries.

REFERENCES

1. Payne, J. (2010). Survey of the international evidence on the causal relationship between energy consumption and growth. *Journal of Economic Studies*, Vol. 37, 53-95.
2. Lee, C. (2005.) Energy consumption and GDP in developing countries: a cointegrated panel analysis. *Energy Economics*, Vol. 27, 415-427.
3. McCoskey S. and Kao, C. (1999). Testing the stability of a production function with urbanization as a shift factor. *Oxford Bulletin of Economics and Statistics*, 671-690.
4. Moomaw, R. and Shatter, A. (1993). Urbanization as a factor in economic growth. *Journal of Economics*, Vol. 19, 1-6.
5. Liddle, B. and Lung, S. (Forthcoming). Age Structure, Urbanization, and Climate Change in Developed Countries: Revisiting STIRPAT for Disaggregated Population and Consumption-Related Environmental Impacts. *Population and Environment*.
6. Mishra, V., Smyth, R., and Sharma, S. (2009). The energy-GDP nexus: Evidence from a panel of Pacific Island countries. *Resource and Energy Economics*.
7. Pedroni, P. (1999). Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors. *Oxford Bulletin of Economics and Statistics*, Vol. 61, 653–70.
8. Pedroni, P. (2004). Panel Cointegration; Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis. *Econometric Theory*, Vol. 20, 597–625.