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USA RESIDENTIAL ENERGY DEMAND AND ENERGY EFFICIENCY: A STOCHASTIC DEMAND FRONTIER APPROACH

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OVERVIEW

This paper estimates a ‘frontier’ residential aggregate energy demand function using panel data for 41 US states over the period 1995 to 2006 using stochastic frontier analysis (SFA). Utilising an econometric energy demand model, the (in)efficiency of each state is modelled and it is argued that this represents a measure of the inefficient use of residential energy in each state (i.e. ‘waste energy’). This underlying efficiency is therefore observed for each state over time as well as the relative efficiency across the 41 USA states. Moreover, the analysis suggests that energy intensity is not necessarily a good indicator of energy efficiency,[1] whereas by controlling for a range of economic and other factors, the measure of energy efficiency obtained via this approach is. This is a novel approach to model energy demand and efficiency and it is arguably particularly relevant given current USA energy policy discussions related to energy efficiency.

METHODS

The stochastic frontier approach[2] is utilised to estimate the following log-log ‘frontier’ energy demand function:

$$\ln E_{it} = \square_P + \square_{PE} \ln P_{Eit} + \square_Y \ln Y_{it} + \square_{HS} \ln HS_{it} + \square_{HDD} \ln HDD_{it} + \square_{CDD} \ln CDD_{it} + \square_{SH} SH_{it} + \square_{R1} DR_1 + \square_{R2} DR_2 + \square_{R1} DR_3 + \square_t D_t + v_{it} + u_{it} \qquad (1)$$

[1] Other more precise economy-wide energy efficiency indicators have been proposed, such as the composite energy efficiency index. However, such approaches still suffer from problems, for instance, the choice of the decomposition and aggregation technique can have an impact on the level of the efficiency index. See Ang (2006) for a discussion and application of this approach.

[2] Introduced by Aigner et al. (1977) and Greene (2005).

where E_{it} is aggregate residential energy consumption per capita measured in trillion of BTU, Y_{it} is income per capita in \$, P_{Eit} is the real energy price in \$ per million of BTU, HS_{it} is household size, HDD_{it} are the heating degree days, CDD_{it} are the cooling degree days, SH_{it} is the share of the detached houses for state *i* in year *t*. DR_1, DR_2, and DR_3 are three dummy variables to distinguish the three distinct most important regions in the USA (West, Midwest, Northeast and South). *Dt* is a series of time dummy variables. Furthermore, the error term in Equation (1) is composed of two independent parts. The first part, v_{it}, is a symmetric disturbance capturing the effect of noise and as usual is assumed to be normally distributed. The second part, u_{it}, is interpreted as an indicator of the inefficient use of energy, e.g. the 'waste energy'. It is a one-sided non-negative random disturbance term that can vary over time, assumed to follow a half-normal distribution.[3] Moreover, since energy consumption and the regressors are in logarithms the coefficients are directly interpretable as demand elasticities.

The study is based on a balanced panel data set for a sample of 41 USA states ($i = 1, \ldots, 41$) over the period 1995 to 2006 ($t = 1995\text{-}2006$). This data set is based on information taken from the U.S. Energy Information Administration database "States Energy Data system" and from the US Department of Commerce.

From the econometric point of view, equation (1) is estimated using the stochastic frontier model proposed by Aigner, et al., (1977), but in order to assess the robustness of equation (1) it is also estimated using the model for panel data proposed by Greene (2005a and 2005b) as a comparison.

RESULTS

The estimated coefficients all have the expected signs and are statistically significant in both models. The estimated income elasticity is about 0.22, consistent with previous estimates. The estimated own price elasticity is about -0.35, again not out of line with previous estimates. The climate variables, HDD and CDD, appear to have an important influence on a state energy demand. The time dummies, as a group, are significant and, as expected, overall the trend in their coefficients is general negative. Furthermore, there is a fair degree of variation around the estimated underlying energy inefficiency estimates for all states.

Table 1. Energy efficiency scores

min	0.84
max	0.99
mean	0.95
median	0.95
st.dev.	0.027

Table 1 provides descriptive statistics for the overall underlying energy efficiency estimates of the countries obtained from the econometric estimation, showing that the mean average efficiency is estimated to be about 95% (median 95%). Generally, the level of energy efficiency in the USA states is relatively homogeneous; nonetheless, there are some states with a low level of energy efficiency. The most efficient state appears to be California, while the less efficient state is Illinois. Finally, the correlation of the estimated underlying energy efficiency with energy intensity is relatively low (0.27).

[3] It could be argued that this is a strong assumption, but it does allow the 'identification' of the efficiency for each country separately.

CONCLUSIONS

This research is a fresh attempt to isolate core energy efficiency for the US states, opposed to relying on the simple energy to GDP ratio – or energy intensity. By combining the approaches taken in energy demand modelling and frontier analysis, a measure of the 'underlying energy efficiency' for each state is estimated. The estimates for the core energy efficiency using this approach show that although for a number of states the change in energy intensity might give a reasonable indication of efficiency improvements; this is not always the case both over time and across states. Therefore, unless the analysis advocated here is undertaken, it is not possible to know whether the energy intensity of a country is a good proxy for energy efficiency or not. Hence, it is argued that this analysis should be undertaken in order to give policy makers an additional indicator other than the rather naïve measure of energy intensity in order to try to avoid potentially misleading policy conclusions.

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