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# *USA Total Energy Demand and Energy Efficiency: A Stochastic Demand Frontier Approach*

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## Overview

This paper estimates a 'frontier' total aggregate energy demand function using panel data for 47 US states over the period 1995 to 2007 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 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 47 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 an approach to model energy demand and efficiency based on previous work by Filippini and Hunt (2011) 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:

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

where $E_{it}$ is aggregate total energy consumption measured in trillion BTUs, $Y_{it}$ is GDP in \$, $P_{Eit}$ is the real energy price in \$ per million BTUs, $POP_{it}$ is population in thousand, $HDD_{it}$ is the heating degree days variable, $CDD_{it}$ is the cooling degree days variable, $AREA_{it}$ is the area size of a state, $SHIND_{it}$ is the share of the industrial sector to GDP, $SHSERV_{it}$ is the share of the service sector to GDP; all for state $i$ in year $t$. $D_t$ 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.

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[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).

Moreover, since energy consumption and the regressors are in logarithms the coefficients are directly interpretable as demand elasticities.

## Results

**Table 2: Energy inefficiency scores**

| | Pooled Mundlak | TRE Mundlak |
|---|---|---|
| min | 0.01 | 0.00 |
| max | 0.26 | 0.13 |
| mean | 0.10 | 0.03 |
| median | 0.09 | 0.03 |
| st.dev. | 0.05 | 0.01 |

Table 2 provides descriptive statistics for the overall underlying energy efficiency estimates of the countries obtained from the econometric estimation using the Pooled and the TRE models with Mundlak (1978)'s formulation, showing that the mean average inefficiency is estimated to be about 10% (Pooled model) and 3% (TRE model). Of course, these are preliminary results.

Generally, the level of energy efficiency in the USA states is relatively homogeneous; nonetheless, there are some states with a high level of energy inefficiency. The most efficient state appears to be Utah, while the less efficient state is Texas. Finally, the correlation of the estimated underlying energy efficiency with energy intensity is relatively low.

## Conclusions

This research is an 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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