Input Specific Efficiency Measures using Bayesian Stochastic Frontier Analysis

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Introduction

Stochastic frontier model, introduced by Aigner, Lovell, Schmidt; Meeusen, van den Broeck; and Battesse and Cora in 1977 decomposes the error term into random error and inefficiency. Stochastic frontier analysis has become a popular tool to model the production relationship between input and output quantities and has been primarily used to estimate the technical efficiency of firm.

In 1982, Jondrow, Materov, Lovell, and Schmidt suggested a method to estimate firm specific inefficiency measures. Since it was introduced in 1977, the stochastic frontier analysis has been evolving theoretically with surge in empirical application. Furthermore, progress has been made on extending to fixed effects, random effects and random parameters panel models, time invariant and time variant models, correcting for heteroskedasticity and heterogeneity and alternative distributions of technical efficiency term.

Objectives

Traditionally SFA only estimates or recovers the overall efficiency or inefficiency of the firm. There have been attempts to estimate input-specific efficiency or inefficiency measures using the primal production or dual cost function along with the first order conditions which were hindered by identification problems. Here, we extend the literature by estimating input specific inefficiency measures using Bayesian random coefficients model with appropriate restrictions on parameter space that will provide model identification. This would allow us to tease out the input specific estimates from the overall inefficiency measures.

Model and Methodology

Following Tsionas (2002) we define the random coefficient production stochastic frontier model as follows

$$y_{it} = b_0 + \boldsymbol{x}_{it}\boldsymbol{\beta}_i + \epsilon_{it} - u_{it} \quad i = 1, \ldots, N, \quad t = 1, \ldots, T \quad (1)$$

where $\boldsymbol{x}_{kit}$ is the vector of input values, y_{it} is the output value, $\epsilon_{it} \sim N(0, \sigma^2)$ is the measurement error and u_i is non-negative disturbance observed for the ith state at year t. For this study we assume that the vector of random coefficients β_i is distributed as negative multivariate truncated normal distribution such that $\beta_i \sim TN^{-}(\boldsymbol{b}, \boldsymbol{\Omega})$. Similarly, it is assumed that traditional state specific terms u_i are iid distributed and follow half-normal distribution with variance σ_u^2 which completes the specification for random intercept $\beta_0 \sim TN(b_0, \sigma_u^2)$. Relatively noninformative priors are placed on hyperparameters assuming $\boldsymbol{\Omega} = diag\{\sigma_1^2, \sigma_2, \ldots, \sigma_k^2\}$. More specifically, we set $\boldsymbol{b} \sim N(0, 10^{-6}\boldsymbol{I}_k)$, $\sigma_u^2 \sim IG(0.01, 0.01)$ and $\sigma_j^2 \sim IG(2.01, 0.01)$ for $j = 1, \ldots, k$. In order to identify the model, $\beta_{11}, \beta_{22}, \ldots, \beta_{kk}$ are set to 0. This parametrization implies that states $j = 1, \ldots, k$ are assumed to be efficient in a corresponding input while the input inefficiency of the rest of the country is measured relatively to selected benchmark states performance. Clearly, the parametrization is not unique and the subjective choice of the benchmark states should be based on the available prior information.

The model is fit using Gibbs sampler by applying the standard Bayesian estimation protocol for hierarchical linear models.

Data

The U.S. Department of Agriculture's Economic Research Service (ERS) constructs and publishes the state and aggregate production accounts for the farm sector (the data are available at the USDA/ERS website http://www.ers.usda.gov/data/agproductivity/).

The features of the state and national production accounts are consistent with gross output model of production and are well documented in Ball et al. (1999). Output is defined as gross production leaving the farm, as opposed to real value added. Price of land is based on hedonic regressions. Specifically the price of land in a state is regressed against land characteristics and location (state dummy). Prices of capital inputs are obtained on investment goods prices, taking into account the flow of capital services per unit of capital stock in each state (Ball et al, 2001). In the primal production function, physical input and output quantities are used in the estimation.

Results

The point estimates (medians) of inefficiency measures are reported in Figures $1 - 6$. Estimated values demonstrate significant heterogeneity of inefficiency levels both by states and inputs, indicating potential advantage of incorporating the input specific one-sided random disturbances into traditional stochastic frontier model for more accurate and complete inefficiency measurement.

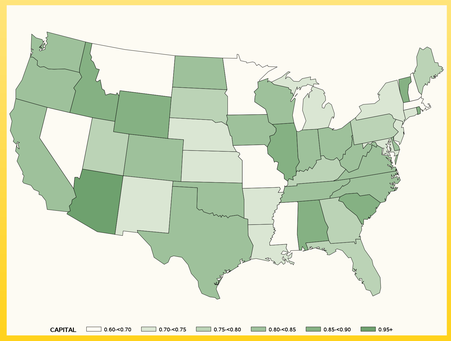

FIGURE 1: Estimates of inefficiency in capital use.

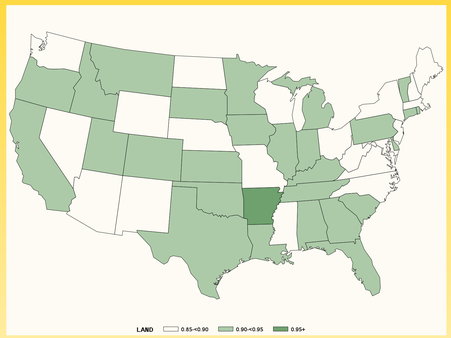

FIGURE 2: Estimates of inefficiency in land use.

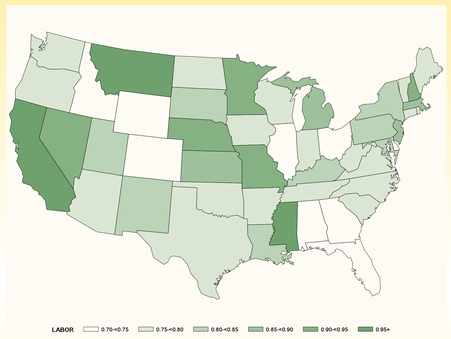

FIGURE 3: Estimates of inefficiency in labor use.

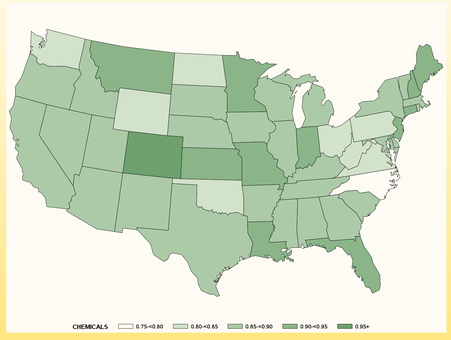

FIGURE 4: Estimates of inefficiency in chemicals use.

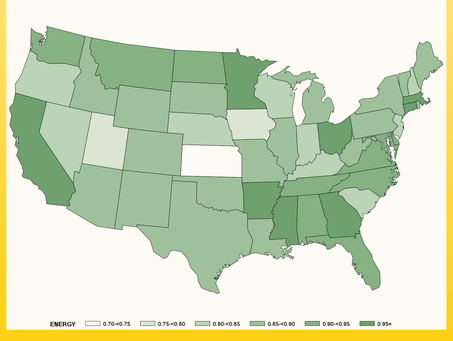

FIGURE 5: Estimates of inefficiency in energy use.

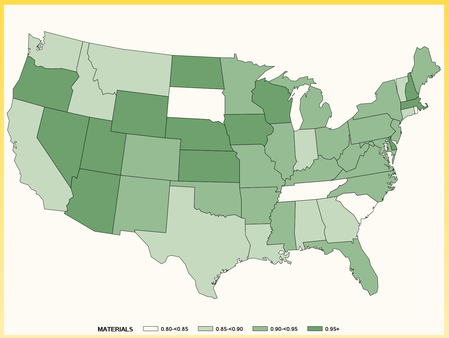

FIGURE 6: Estimates of inefficiency in materials use.

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