Efficiency Analysis: A Primer on Recent Advances

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Efficiency Analysis: A Primer on Recent Advances[1]

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[1]This monograph is an extension of our lecture notes for several short courses presented at Aalto University, the University of Stavanger, and Wageningen University in 2013. The organizers of those workshops are warmly acknowledged. All errors are ours alone.

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Abstract

This monograph reviews the econometric literature on the estimation of stochastic frontiers and technical efficiency. Special attention is devoted to current research.

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Overview

At its core inefficiency is a nebulous concept. Førsund and Hjalmarsson [1974, p. 152] note that it is an easy term to use but much more difficult to precisely pin down its meaning. A precise definition is lacking mainly given that those who conform to the strict boundaries of price theory believe that output shortfall and rapid growth are related to pricing information and profit maximization; concepts defined as inefficiency can be construed as managerial goals which encapsulate maximizing behavior. In an outstanding review of the development of (or argument over) X-inefficiency, Perelman [2011] notes that both Leibenstein [1966] and Stigler [1976] fail to provide convincing evidence that the other is wrong. That is, while Leibenstein [1966] only provides anecdotal evidence on the existence of firm inefficiency and Stigler [1976] provides cursory discussion demonstrating an alternative view, neither can resoundingly reject the other's views.

And yet, the study of firm inefficiency persists to this day primarily because even though a formal, robust theory which details how inefficiency operates does not exist, many are unsatisfied with the strict optimizing restrictions placed on firms. Further, myriad evidence of productivity differences exists across firms that *ex ante* are close

to homogenous and standard views on productivity differences are not applicable. For example, Syverson [2011] finds that within United States manufacturing industries at the 4 digit SIC the 90th percentile plant within the productivity distribution produces nearly double the output of the 10th percentile plant with the same inputs. Moving offshore, Hsieh and Klenow [2009] find productivity differences at a ratio of 5 to 1 in both India and China.

Lest concerns over geographical differences, workforce characteristics and the like drive these differences, consider the study of Chew et al. [1990] of a large commercial food operation in the U.S. Chew et al.'s [1990] example is instructive since these plants should be able to transfer knowledge extensively and share best practices easily. Yet, this network was characterized by the almost complete void of knowledge transfer and large differences in productivity. In fact, within this division of the firm, there are over 40 operating units each of which produce a near identical set of outputs with almost all work done manually and free of international influences.

The stark reality of this division is that even with all the advantages of operating multiple units and sharing best practice, the most productive unit produces almost three times as much output for the same amount of inputs as the least productive unit. Chew et al. [1990] recognize that underlying differences could be driving these differences and control for geographic location, the size of the local market that is served, unemployment, unionization, equipment, quality, and local monopoly power. Even after accounting for these differences in what are considered relatively homogenous firms, productivity differences on the order of 2:1 still are pervasive; a clear signal that firm inefficiency is at play.

Our objective here is not to develop a formal theory or definition of inefficiency. Rather, we seek to detail the important econometric area of efficiency estimation; both past approaches as well as new methodology. Beginning with the seminal work of Farrell [1957], myriad approaches to discerning output shortfall have been developed. Amongst the proposed approaches, two main camps have emerged. Those that estimate maximal output and attribute all departures from this as inefficiency, known

as Data Envelopment Analysis (DEA) and those that allow for both unobserved variation in output do to shocks and measurement error as well as inefficiency, known as Stochastic Frontier Analysis (SFA).

Our review here will focus exclusively on SFA. For an exceptionally authoritative review of DEA methods and their statistical underpinnings see Simar and Wilson [2013].[1] The econometric study of efficiency analysis typically begins by constructing a convoluted error term that is composed on noise, shocks, measurement error and a one-sided shock called inefficiency. Early in the development of these methods attention focused on the proposal of distributional assumptions which yielded a likelihood function whereby the parameters of the distributional components of the convoluted error could be recovered. The field evolved to the study of individual specific efficiency scores and the extension of these methods to panel data. Recently, attention has focused on relaxing the stringent distributional assumptions that are commonly imposed, relaxing the functional form assumptions commonly placed on the underlying technology, or some combination of both. All told, exciting and seminal breakthroughs have occurred in this literature on regular bases and reviews of these methods are needed to effectively detail the state of the art.

To explain the generality of SFA we go back to neoclassical production theory. The textbook definition of a production function is: given the input vector $\boldsymbol{x}_i$ for a producer i, the production function $m(\boldsymbol{x}_i;\boldsymbol{\beta})$ is defined by the maximum possible output that can be produced. That is, $m(\boldsymbol{x}_i;\boldsymbol{\beta})$ is the technical maximum (potential). To emphasize on the word maximum we call $m(\boldsymbol{x}_i;\boldsymbol{\beta})$ the frontier production function. Not every producer can produce the maximum possible output, even if $\boldsymbol{x}$ were exactly the same for all of them. Thus, $y_i \leq m(\boldsymbol{x}_i;\boldsymbol{\beta})$ and the ratio $y/m(\boldsymbol{x}_i;\boldsymbol{\beta}) \leq 1$ is defined as technical efficiency ($0 \leq TE \leq 1$), when y is the actual output produced. Quite often we define technical inefficiency ($TI = 1 - TE$) as percentage shortfall of output from its maximum, given the inputs. Thus, $TI = (m(\boldsymbol{x}_i;\boldsymbol{\beta})) - y)/m(\boldsymbol{x}_i;\boldsymbol{\beta}) \geq 0$. This is important when the inequality $y \leq m(\boldsymbol{x}_i;\boldsymbol{\beta})$ is expressed

[1] For comprehensive book length treatments on SFA we suggest one consult Kumbhakar and Lovell [2000] or Kumbhakar et al. [2014b].

as $\ln y_i = \ln m(\boldsymbol{x}_i;\boldsymbol{\beta}) - u_i$ and $u_i \geq 0$ is interpreted as technical inefficiency.[2]

The above definition of inefficiency fits into the theory in which the role of unforeseen/uncontrollable factors is ignored. However, in reality, randomness, for obvious reasons, is a part and parcel of econometric models. And there are innumerable uncontrollable factors that affect output, given the controllable inputs $\boldsymbol{x}_i$. To accommodate this randomness (v_i), we specify the production frontier as a stochastic relationship and write it as $\ln y_i = \ln m(\boldsymbol{x}_i;\boldsymbol{\beta}) - u_i + v_i$.

The generality of SFA is such that the study of efficiency has gone beyond simple application of frontier methods to study firms and appears across a diverse set of applied milieus. Thus, we also hope that this review will be of appeal to those outside of the efficiency literature seeking to learn about new methods which might assist them in uncovering phenomena in their applied area of interest.

[2]Strictly speaking $-u_i \leq 0 \approx \ln TE$ is technical inefficiency.

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