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A META ANALYSIS OF FARM EFFICIENCY: EVIDENCE FROM THE PRODUCTION FRONTIER LITERATURE

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ABSTRACT

This study updates previous meta-analysis of farm-level frontier function studies in order to provide a detailed systematic and comprehensive analysis of the effects that different study-specific attributes have on mean technical efficiency (MTE) scores. Before presenting the technical efficiency (TE) analysis, we provide an overview of the evolution of key methodological approaches that have been developed and applied to measure and examine TE.

A detailed descriptive analysis is then performed for a meta-dataset that includes 408 farm level TE studies, published between 1981 and mid-2014. Some studies report several MTEs, resulting in 900 observations or cases. A key result from the descriptive analysis is that the Average of the Mean Technical Efficiencies (AMTE) reported for all studies is 74.2%. The AMTE across methodological attributes tend to be quite similar but several significant differences are observed when comparisons are made across geographical regions, income levels, and types of product.

The paper goes on to report the results of meta-regressions estimated using the fractional regression procedure, which is well suited for dependent variables that are defined on the unit interval or as a fraction (between 0 and 1), as is the case with TE. In the concluding section, we provide some thoughts concerning recent work that uses stochastic production frontier methodologies to evaluate the impact of developments projects while addressing biases from observable and unobservable variables.

Keywords: Agriculture; Technical Efficiency; Fractional Regression, Meta-Analysis

JEL Classification: Q25, Q12, D24

A META ANALYSIS OF FARM EFFICIENCY: EVIDENCE FROM THE PRODUCTION FRONTIER LITERATURE

1. INTRODUCTION

An important strand in the economics literature is the analysis of productivity and efficiency using frontier function methodologies. These methodologies provide measures of efficiency as a potential input reduction or potential output expansion, relative to a reference "best practice" frontier, constructed from observed inputs and output(s) (Coelli *et al.* 2005).

The frontier function model was introduced by Farrell (1957) in a seminal article that laid out a framework to define and measure various types of efficiency: technical efficiency (TE) measures the ability of the firm to obtain the maximum output from given inputs; allocative efficiency (AE) measures the ability of the firm to use inputs in optimal proportions given their prices; and overall economic efficiency (EE) is the product of TE and AE. The estimation of the best practice frontier to derive these efficiency measures can be done with different methods. Over the past few decades, such frontier function methods have been developed extensively and have been widely used to study the TE component of productivity in a number of sectors (Fried, Lovell and Schmidt 2008).

In agricultural economics, frontier function methods have become the basis for a prolific research area. Surveys of this literature are provided in Battese and Coelli (1992), Battese (1992), Bravo-Ureta and Pinheiro (1993), Gorton and Davidova (2004), and Darku, Malla and Tran (2013). Meta-analyses of different parts of this literature have been undertaken by Thiam, Bravo-Ureta and Rivas (2001), Bravo-Ureta *et al*. (2007), Moreira and Bravo-Ureta (2009), Ogundari (2014), and Minviel and Latruffe (2017). This study draws from a recent meta-analysis of farm-level frontier function studies (Bravo-Ureta *et al*. 2016), which updates Bravo-Ureta *et al*. (2007), in order to provide a detailed systematic and comprehensive analysis of the effects that different methodologies and study-specific attributes have on mean TE scores. A comprehensive literature search was conducted which yielded a total of 408 farm-level studies with 900 data points given that some studies report multiple average TE results.

The remainder of this report is structured as follows. Section 2 contains an overview discussion of the alternative methodologies used in frontier analysis. Section 3 briefly discusses how the dataset was generated and then presents a descriptive analysis of the data. Section 4 goes on to explain the meta-regression framework used, the specification of the empirical equations estimated along with a definition of all variables included in the models, and presents the results from the meta-regressions. Section 5 provides a summary, conclusions and suggestions for further work.

2. OVERVIEW OF FRONTIER METHODOLOGIES

Although preceded a few years by Debreu (1951) and Koopmans (1951), the 1957 seminal article by Farrell is widely credited as the intellectual impetus that has propelled frontier function research to the present day (Fried, Lovell and Schmidt 2008; Greene 2008). Farrell relied on the efficient unit isoquant to define and measure TE, AE, and EE, which is equal to the product of TE and AE. The focus of this study is farm level TE, so this methodological summary favors this particular efficiency concept as opposed to a number of other related notions. It should be noted that the idea is not to present an exhaustive methodological review but rather to point out some of the key features that will appear in the models used in the studies included in the meta-analysis.

For clarity, it is important at the outset to differentiate between Technological Change (TC) and TE. TC measures upward (typically) shifts of the production frontier stemming from the fruit of innovation (Färe, Grosskopf and Margaritis 2008). By contrast, TE refers to the distance a firm operates relative to the frontier and such distance can be measured with an input or an output orientation. In the simple single input production frontier case, the output oriented approach, which is most commonly used in applied work, TE is given by the ratio between the observed and the maximum (frontier) level of output that can be produced given a quantity of input and the technology. By contrast, the input orientated approach is given by the ratio of the quantity of input needed to produce a given level of output if the farm operates on the frontier relative to the input actually used. Therefore, TE, whether input or output oriented, is an index that ranges between 0% and 100% and can be interpreted as a proxy measure for managerial effort or performance (Martin and Page 1983; Triebs and Kumbhakar 2013). Analogous measures can be defined for multiple input-multiple output technologies (Coelli *et al*. 2005).

Frontier function methods have become widely used in applied production economics given their consistency with the neo-classical notion of maximization or minimization imbedded in the definitions of production, revenue, profit or cost functions. The popularity of frontier methods is substantiated by the abundance of methodological and empirical frontier studies over the last three decades.

Methodological reviews of the wide array of models that have been developed can be found in Forsund, Lovell and Schmidt (1980), Schmidt (1985-86), Bauer (1990), Seiford and Thrall (1990), Kumbhakar and Lovell (2000), Fried, Lovell and Schmidt (2008), Greene (2008), Thanassoulis, Portela and Despić (2008), and Lachaud, Bravo-Ureta and Ludena (2017), among others. The popularity of applied frontier studies in agriculture is documented in several reviews and meta-analyses including Battese (1992), Bravo-Ureta and Pinheiro (1993), Thiam, Bravo-Ureta and Rivas (2001), Gorton and Davidova (2004), Bravo-Ureta *et al*. (2007), Moreira and Bravo-Ureta (2009), Darku, Malla and Tran (2013), Ogundari (2014), and Minviel and Latruffe (2017).

The frontier methodology is commonly divided into parametric and non-parametric methods. Parametric methods require the specification of a functional form for the technology (e.g., Cobb-Douglas, Translog) whereas non-parametric models do not have such requirement and this constitutes a major advantage of the latter. Parametric models can be subdivided into deterministic and stochastic frontier analysis (SFA) where the former assumes that any deviations from the frontier stem from inefficiency while the stochastic approach incorporates statistical noise (Coelli *et al*. 2005). Hence, a key limitation of deterministic frontiers is that measurement errors, as well as other sources of random variation are captured as inefficiency and this means that outliers have a distorting effect on TE scores (Fried, Lovell and Schmidt 2008).

The stochastic frontier model, developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), copes with outliers through a composed error structure with a two-sided symmetric term and a one-sided component. The two-sided error captures random shocks outside the control of the firm whereas the one-sided component takes care of inefficiency.

Non-parametric frontiers trace their origin directly to Farrell (1957); however, it took almost 20 years for non-parametric frontiers to get a firm footing in the literature and such recognition is in great part due to Seitz (1970; 1971), and Charnes, Cooper and Rhodes (1978). As already noted, the main feature of non-parametric frontiers is that they do not require the specification of a functional form while a major drawback is that these methods are deterministic and thus sensitive to extreme observations. In addition, the TE scores generated by non-parametric methods can be sensitive to the number of observations in the data and to the dimensionality of the frontier. However, Daraio and Simar (2007) have developed robust non-parametric tests to address the issue of extreme observations. Non-parametric measures of efficiency are obtained using mathematical programming techniques widely known as Data Envelopment Analysis or DEA (Thanassoulis, Portela and Despić 2008). This area of the frontier literature gained major popularity early on in management science and operations research but now is also firmly established in economics including agricultural economics (Fried, Lovell and Schmidt 2008).

Frontier studies can also be separated into primal and dual approaches, depending on the underlying behavioral assumptions that are made. The primal approach has been more common in frontier estimation since it does not require price data, often difficult to get at the firm/farm level, nor does it rely on maintained hypothesis regarding behavioral assumptions such as cost minimization or profit maximization (Coelli *et al*. 2005). It should be noted that the validity of dual models has been questioned, particularly when profit maximization is the maintained hypothesis in the context of developing country agriculture (e.g., Junankar 1980).

An important advantage that non-parametric models enjoyed for a number of years is their ability to easily accommodate multi-input multi-output technologies within a primal specification. By contrast, to accommodate such technologies, parametric models had to appeal initially to dual cost or profit frontiers, which presented data challenges as well as the need to make stringent behavioral assumptions (e.g., Ali and Flinn 1987; Bailey *et al*. 1989). More recently, developments in the parametric stochastic literature have enabled the estimation of multi-input multi-output models by means of input and output distance functions. The main advantage of using a distance function is that price information is not needed and these models can be estimated without assuming input-output separability (Coelli*et al*. 2005). A further extension is the directional distance function, which is a generalization of the input and output distance functions. The directional distance specification simultaneously allows for the expansion of outputs and the reduction of inputs toward all points that are on the frontier that dominate the observation being assessed (Färe, Grosskopf and Margaritis 2008). Directional distance functions have also been used to incorporate bad outputs and examine the tradeoff between good and bad outputs (e.g., Njuki and Bravo-Ureta 2015, Njuki, Bravo-Ureta and

Mukherjee 2016, and studies cited therein).

Frontier function analyses can also be characterized in terms of the type of data used, as cross-section or panel data. The estimation of frontiers with panel data has made considerable progress in both the non-parametric and the parametric worlds and this is an appealing feature because it can significantly enhance the analysis particularly in decomposing total factor productivity change in terms of TC, TE change (TEC) and scale efficiency change (SEC) (Kumbhakar and Lovell 2000; Fried, Lovell and Schmidt 2008). In the stochastic approach, the recent work by Greene (2005a; 2005b) has opened up useful options to account for time invariant firm heterogeneity in addition to time variant TE and the standard two-sided model.

Very recently, several authors have presented and applied models that decompose (overall) efficiency into a persistent (long-run) and a transient (short run) component while also capturing unobserved time invariant heterogeneity (Colombi *et al*. 2014; Filippini and Greene 2014; Kumbhakar, Lien and Hardaker 2014; Tsionas and Kumbhakar 2014; Lachaud, Bravo-Ureta and Ludena 2015). Panel data methodologies clearly offer an interesting path forward but the challenge is to develop the necessary data sets to take full advantage of the emerging methods.

Another strand on the frontier literature has to do with efforts geared at explaining the variability of TE in terms of exogenous factors that typically include socioeconomic and environmental variables. The original approach is the so-called two-step model where TE is estimated in the first step, using any of the models we have discussed, without accounting for exogenous and environmental factors and then in the second-step TE is regressed on such factors (Bravo-Ureta and Pinheiro 1993; Greene 2008). Several researchers have examined the validity of the two-step procedure and the evidence clearly indicates that this approach leads to biased or invalid results in both parametric and non-parametric models (Wang and Schmidt 2002; Simar and Wilson 2007). Taking a forceful position on this matter, Fried, Lovell and Schmidt (2008) state: “We hope to see no more two-stage SFA models” (p. 39).

Objections to the validity of two-step models have motivated the development of one-step procedures in the stochastic frontier literature, where the most widely applied model has been the one introduced by Battese and Coelli (1995) and work along these lines continues (e.g., Latruffe *et al*. 2017). Progress has also been made in the explanation of TE in the non-parametric literature using bootstrapping techniques. Simar and Wilson (2007; 2008) argue that many studies that have estimated second-step regressions to explain the variation in TE scores, derived from DEA models, have produced invalid results. The first problem they pinpoint is that a large volume of these studies does not describe the associated data generating process (DGP) "that would make a second-stage regression sensible" (Simar and Wilson 2008, p 501). A second and "more serious problem in all of the two stage studies… arises from the fact [that] DEA efficiency estimates are serially correlated" (Simar and Wilson (2007 p. 33). The latter invalidates any inferences regarding the parameters of the second-step regression. These authors then present a DGP that affords the foundation for the second-step regression of TE scores from DEA models. The authors also present a truncated regression model along with a double bootstrap approach and argue that this framework makes it possible to obtain unbiased TE scores (first bootstrap) and valid estimates of confidence intervals for the coefficients of the second-step regression (second bootstrap) while increasing statistical efficiency in the estimation. Examples of applications of this procedure in agriculture include Latruffe, Davidova and Balcombe (2008), Balcombe *et al*. (2008), and Keramidou and Mimis (2011).

An additional and emerging strand of the literature that should be mentioned here concerns recent efforts in stochastic frontier models to correct for selectivity bias (Kumbhakar, Tsionas and Sipiläinen 2009; Lai, Polachek and Wang 2009; Greene 2010). Bravo-Ureta, Greene and Solís (2012) have combined the Greene (2010) model with Propensity Score Matching (PSM) to account for biases from observable and unobservable variables in order to decompose the impact of development projects into output growth (i.e., upwards shifts in the production frontier due to TC) and management improvements (i.e., narrowing the gap from the frontier) when only cross-sectional data are available (Bravo-Ureta 2014). The model is applied to data generated from the MARENA Project in Honduras. Additional applications of the Bravo-Ureta, Greene and Solís (2012) model include the work by González-Flores *et al*. (2014) for a sample of small-scale potato farmers from Ecuador and by Villano *et al*. (2015) who investigate the impact of adopting certified seed varieties on the productivity of rice farmers in the Philippines.

Another area that is receiving attention in the recent literature concerns the possible endogeneity of inputs in stochastic frontiers. Zellner, Kmenta and Drèze (1966) provided what has become the classical justification for valid econometric estimates of production functions. These authors assumed that firms maximize the mathematical expectation of profits rather than observed profits. More recently, several authors such as Tran and Tsionas (2013), and Shee and Stefanou (2014) have proposed alternative approaches to tackle endogeneity in stochastic frontier models building on previous work by Olley and Pakes (1996), Levinsohn and Petrin (2003), and Kutlu (2010), among others.

It is useful to underscore that major methodological advances have been made in both parametric (econometric) and non-parametric (programming) frontiers. Paraphrasing from Fried, Lovell and Schmidt (2008), SFA and DEA have important similarities as well as differences. Both approaches are rigorous analytical tools to measure efficiency relative to a frontier. "At the risk of oversimplification, the differences between the two approaches boil down to two essential features: [1] The econometric approach is stochastic. This enables it to attempt to distinguish the effects of noise from those of inefficiency, thereby providing the basis for statistical inference; [2] The programming approach is nonparametric. This enables it "to avoid confounding the effects of misspecification of the functional form (of both technology and inefficiency) with those of inefficiency" (p. 32-33).

Despite the 'conciliatory' remarks in the preceding paragraph, in a recent paper O'Donnell (2014) argues that the core assumptions on which the DEA machinery stands "… are rarely, if ever true (e.g., output, input and environmental variables are almost always measured with error, if not unobserved). It follows that most, if not all, DEA estimators are inconsistent" (p. 22). O'Donnell goes on to quote Simar and Wilson (2000) who wrote: "Consistency is an essential property of any estimator [p. 56] … If the data contains noise, DEA … estimators will be inconsistent, and there seems little choice but to rely on SFA [p. 76]." One is left with the distinct impression that the SFA-DEA controversy will go on for a few more rounds.

This section provided an overview of the evolution of key methodological approaches that have been developed and applied to examine farm/firm level TE. The purpose was not to present an exhaustive methodological review but rather to highlight some of the important methods and concepts that are found in this literature, many of which will appear as we proceed with our study.

3. DATASET AND DESCRIPTIVE ANALYSIS

3.1 Dataset Generation

A key aspect in a meta-analysis is to conduct a thorough and systematic review of the literature to develop the list of studies to be included in the investigation. The point of departure for the work undertaken in this study is the database developed by Bravo-Ureta *et al*. (2007). In that study, the search included the following databases: Agricola; Agris International; Ingenta; Science Direct; Social Science Citation Index; and the World Agricultural Economics and Rural Sociology Abstracts. A complementary search was implemented in the following Journals: Agricultural and Resource Economics Review; American Journal of Agricultural Economics; Australian Journal of Agricultural Economics; Canadian Journal of Agricultural Economics; European Journal of Operations Research; European Review of Agricultural Economics; Journal of Agricultural and Applied Economics; Journal of Agricultural Economics; Journal of Comparative Economics; Journal of Econometrics; and Journal of Productivity Analysis. This search was done for studies published between January 1979 and June 2005. The search produced a total 167 papers that contained the information required for the analysis undertaken at that time. Moreover, the 167 papers yielded 569 observations given that many papers reported various measures on TE obtained from the application of different methods.

For this study, we decided to undertake a new comprehensive search which was conducted using the following databases: EBSCOhost, Econlit, Academic Search Premier, Agricola, Scopus and ISI Web of Knowledge which includes Agris International, Science Direct and Social Science Citation Index. An additional search was done for specific journals that overtime have published a good number of applied TE studies and/or are major outlets of agricultural economics work. The journals included are the American Journal of Agricultural Economics, the Journal of Agricultural Economics, Agricultural Economics, the European Review of Agricultural Economics, the Australian Review of Agricultural and Resources Economics, the Canadian Journal of Agricultural Economics, the Journal of Productivity Analysis, Empirical Economics, the European Journal of Operations Research and Applied Economics.

Here we define a case as a specific MTE value reported by a given study from a particular model specification. If the study reports several MTEs from a given specification, e.g., TE per year for a panel data model, then we only report the arithmetic average of all years as one MTE or case. In other words, we only report one MTE per model from each study. On the other hand, if a study reports several TEs based on different model specifications (e.g., DEA and SPF), we consider each TE as a different case.[1]

3.2 Descriptive Analysis

Appendix A presents a list of all 408 studies along with some key attributes of each. The key variable in our analyses is the mean technical efficiency (MTE) reported in each paper. Some papers present more than one MTE due to the use of alternative methods; so, the total number of MTEs, or cases, from the 408 farm level studies is 900.

Table 1 shows that of the 900 total cases, 622 come from parametric and 278 from non-parametric models; in addition, 551 observations come from stochastic and 349 from deterministic frontiers. The AMTE for all papers is 74.2%, which is slightly lower than the 76.6% reported by Bravo-Ureta *et al*. (2007).

Figure 1 provides a visual summary of the number of cases by year of publication and separately for parametric and non-parametric models. The figure shows that the number of cases has increased steadily since the early 1980s but a noticeable dip is observed after a peak in 2012. This dip could be due to more stringent acceptance criteria for frontier studies where articles now need to go beyond the estimation of a frontier model and a relatively simple analysis of TE. In addition, Figure 1 indicates that parametric analyses have dominated throughout the period especially towards the end. Figure 2 displays the distribution of cases of DEA and SFA models and here we observe the dominance of the latter particularly in the last few years.

Comparing the results in Table 1 with those of Bravo-Ureta *et al*. (2007) for the key methodological attributes, we see that their AMTE for the parametric observations is 76.3% and ours here is 74.6%, while they report an AMTE of 78.3% for Non-parametric we obtain 73.5%. Thus, the ordering of these values is not consistent across the two studies. We find an AMTE higher for parametric cases while the opposite is reported in Bravo-Ureta *et al*. (2007). Moreover, our values for parametric and non-parametric cases are quite close to each other while the 2007 study reported a much wider spread.

The numbers reported by Bravo-Ureta *et al*. (2007) for deterministic observations is 70.2% compared to 73.2% obtained here, and they find a value of 77.3% for stochastic cases while we got 74.9%. Thus, these results are consistent in the ordering; that is, stochastic AMTE

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[1] Bravo-Ureta *et al*. (2007) defined a case in the same manner, but all TE reported in a given paper were included separately in their study, in some cases representing a sub-group of the whole sample. In the current study, we avoid this procedure because the frontier represents the whole sample and any sub-group is a partial representation of the results.

is higher in both cases, but again the spread in our study between stochastic and deterministic AMTEs is much closer than in Bravo-Ureta *et al*. (2007).

Table 1 also reports statistical tests for the null hypothesis that AMTE for each category is the same. Overall, we observe only a few differences. We note a significant difference (underlined) between the stochastic and deterministic approaches,74.9% vs. 73.2%, respectively. Another significant difference is for the data structure category where the AMTE for panel data (77.2%) is higher than its cross-sectional counterpart (73.5%). The last difference is regarding functional form where the translog AMTE is higher than the Cobb-Douglas, 77.3% vs. 72.5%, respectively. Looking at the highest AMTE, the translog and the panel data exhibit the highest AMTE, at 77.3% and 77.2%, respectively.

Table 2 contains a summary of AMTE for various groupings according to geographical region, income category and product types. The following six geographical regions are included: Africa, Asia, Latin America, North America, Eastern Europe, and Western Europe and Oceania (Australia, New Zealand and one study from Papua New Guinea). Since there are only a few cases for Oceania, we combine it with Western Europe based on the notion that both of these regions contain high-income countries, except for the one observation from Papua New Guinea. In terms of country income, we use the following four categories based on the World Bank classification (World Bank 2014): LICs (Lower Income Countries); LMICs (Lower Middle Income Countries); UMICs (Upper Middle Income Countries); and HICs (Higher Income Countries). The product groups are as follows: Rice; Maize; Wheat; Mixed Grains; Crops and Livestock; Dairy; Other Animals; and Whole Farm. As is the case with Table 1, we note only a few significant AMTE differences. The data shows that AMTE is 74.1% for LIC, 77.5% for HIC, and the lowest is for UMIC,67.4%.

Taking a broader look at the data in Table 2, the lowest AMTE values are for Latin America at 61.7% and Africa at 68.3%. By contrast, North America (78.9%) and W. Europe and Oceania (76.8%) display the highest AMTE. By comparison, Bravo-Ureta *et al*. (2007) find that the lowest AMTE for all cases analyzed is for Eastern Europe (70.0%) followed by Africa (73.7%) while the highest is for W. Europe and Oceania (82.0%) followed by Latin America (77.9%). Aggregating the countries by income level leads to a fairly irregular pattern although the HICs have the highest AMTE at 77.5% and the UMICs the lowest at 67.4%. This latter pattern is consistent with Bravo-Ureta *et al*. who report an AMTE of 78.8% for HICs (their highest) and 68.3% for UMICs (their lowest).

Turning to the Product grouping, we see that the lowest AMTE in Table 2 is for Crops and Livestock at 69.5%. By contrast, the highest AMTE is for Dairy papers at 80.9%. It is interesting to note that this is very close to the results of Bravo-Ureta *et al*. (2007) who reported an AMTE for Dairy and Cattle of 80.6% which is the second highest average in their paper followed by Other Animals at 84.5% but the latter has only six observations.

In sum, this section presented a descriptive analysis of 408 farm level studies, which yielded an AMTE of 74.2%. The AMTE across methodological attributes tend to be quite similar but several significant differences are observed when comparisons are made across geographical regions, income levels, and type of product. Some comparisons are made with the previous comprehensive meta-analysis by Bravo-Ureta *et al*. (2007). We now move to Section 4 where we present the meta-regression models and estimation results.

4. META-REGRESSION ANALYSIS

In this section, we first present a brief overview of the methodology used to undertake the Meta-Regression Analysis (MRA). We then present the empirical models and proceed to report the results obtained from the meta-regressions.

4.1 Methodology

The estimation of meta-regressions to explain the variation in TE as a function of the key attributes of the studies requires dealing with the fact that the dependent variable, TE scores, range between 0 and 1. A common approach has been to apply OLS. However, Judge *et al*. (1988), among others, show that when a model contains a ratio as the dependent variable, OLS can suffer from heteroskedasticity and lead to imprecise estimates.

Another common approach, perhaps the most common particularly in DEA studies, is to explain TE using a one-limit (1LT) or two-limit Tobit (2LT) model (Simar and Wilson 2007; Greene 2002). However, the Tobit procedure assumes that there is a latent variable of interest, which is not fully observed. Instead of observing y*, we observe y, which is defined as follows (Ramalho, Ramalho and Henriques 2010):

$$y = 0 \; if \; y^* \leq 0, \;\; y = y^* \; if \; 0 < y^* < 1, and \; y = 1 \; if \; y^* \geq 1 \qquad (1)$$

The commonly used approaches, OLS and Tobit, require arbitrary adjustments for the boundary values of $TE \in [0,1]$, and without such adjustments it is not possible to recover an estimate of $E(TE|x)$where x represents a vector of the explanatory variables or the main attributes of the studies (Wooldridge 2002). A meta-regression model of TE uses results from both SPF and DEA studies. The former rarely yields limit values (0 or 1) while the latter regularly gives values equal to 1 (100% TE) and values close to or equal to 0 are rare. If we use a 2LT model, the absence of observations for TE=0 makes the first term of the log-likelihood function disappear. Thus, estimation is based on a one-limit Tobit model for $TE \in [-\infty, 1]$. Ramalho, Ramalho and Henriques (2010) show that the consequences of this procedure are not usually significant, but the data-generating process (DGP) that supports the Tobit estimation is not the model that governs the variable of interest.

Simar and Wilson (2007) and McDonald (2009) also criticize the Tobit approach on the ground that the TE scores are known once estimated, and are not the result of a censoring mechanism but instead are fractional data. Moreover, McDonald (2009) argues that Tobit estimation in this situation is inappropriate and that the best that can be said is that such estimates are often similar to OLS estimates. These authors also conclude that the Fractional Regression Model (FRM) has some advantages, as noted below, despite its complexity.

Ramalho, Ramalho and Murteira (2011) argue that the Papke and Wooldridge (1996) FRM methodology is a suitable framework to deal with dependent variables defined on the unit interval, irrespective of whether boundary values are observed or not. More recently, Ogundari (2014) applied this approach to examine TE in African countries. Here we follow these authors lead and rely on FRM for our Meta Regression Analyses.

The FRM is estimated using a Quasi Maximum Likelihood Estimator (QMLE), which consists of maximizing a pseudo-function that is related to the log-likelihood function. QMLE is consistent and asymptotically normally distributed (Davidson and Mackinnon, 2004).[2] Based on Papke and Wooldridge (1996) and following Ogundari (2014), we use the following Bernoulli quasi log-likelihood function:

$$L(\alpha, \gamma, \beta) \equiv TE_i \log\big(G(x_i)\big) + (1 - TE_i) \log\big(1 - G(x_i)\big) \qquad (2)$$

where $\alpha, \gamma, and\ \beta$ are the parameters for the TE equation to be estimated and x_i is a vector of explanatory variables. As inPapke and Wooldridge (1996), a logistic functional form such as

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[2] The pseudo function is in general a simplified expression of the Log likelihood one function.

$G(x_i) = \frac{\exp(x_i)}{1+\exp(x_i)}$ is adopted and the STATA software Version 12 is used to carry out the estimation. Estimates of the parameters are obtained by maximizing equation (2).

Ramalho, Ramalho and Henriques (2010) analyze several alternative specifications of the FRM, which are consistent with the Papke and Wooldridge (1996) cumulative distribution function for the Logit and Probit models. Ramalho, Ramalho and Henriques (2010) also report two alternative specifications, the loglog and the complimentary loglog (cloglog) functional forms and perform several tests in order to compare the various specifications. Ogundary (2014) keeps the original specification of Papke and Wooldridge (1996), which relies on the logistic functional form.

4.2 Empirical Models and Results

The aforementioned FRM approach is now applied to estimate meta-regressions to examine the effect of key attributes of the 408 farm studies included in the meta-data set. As shown in Section 3, a total of 900 observations, which contain all the variables needed for the estimation, are obtained from the 408 studies. Many studies include different model specifications and report several TE estimates; thus, the number of studies is smaller than the number of cases.

The empirical regression model to be estimated below can be written as:

$$TE_i = \alpha_0 + x_i'\beta + \varepsilon_i\,, \quad i = 1, \dots \dots N;\ \varepsilon_i \sim N(0, \sigma_\varepsilon) \tag{3}$$

where TE represents the MTE for each observation obtained from the meta-dataset and x_i is a vector of attributes of the studies. The Greek letters are vectors of unknown parameters to be estimated; ε_{it} is the error term that captures noise in the data and is assumed to follow a normal distribution with mean zero and variance σ_ε.

The specific explanatory variables in the meta-regression model for the meta-database including are:

SPF:	1 if the model is a stochastic production frontier and 0 otherwise, the omitted category is deterministic frontier;
PAR:	1 if it is a parametric model and 0 otherwise, the omitted category is non-parametric;
CS:	1 for cross sectional data and 0 otherwise, the omitted category is panel data;
NVAR:	Is the total number of explanatory variables, including first order, interactions, dummies, etc., used in the estimation of the production frontier;

NOBS: Is the number of observations included in the study divided by 1,000 to avoid very small coefficients. For a panel data we add all observations per year;

YPUB: Is the year of publication of each study;

TI: 1 if the model includes explanatory variables to explain TE and 0 otherwise;

FSTEP: 1 if the model uses variables to explain TE in one step and 0 otherwise;

RICE: 1 if rice is the product analyzed and 0 otherwise;

WHEAT: 1 if wheat is the product analyzed and 0 otherwise;

DAIRY: 1 if dairy is the enterprise analyzed and 0 otherwise;

SIO: 1 if a single output is used and 0 otherwise, the omitted category is farm with two or more outputs;

AFRICA: 1 if the region of the study is Africa and 0 otherwise;

ASIA: 1 if the region of the study is Asia and 0 otherwise;

E. EUROPE: 1 if the region of the study is Eastern Europe and 0 otherwise;

LAC: 1 if the region of the study is Latin America and the Caribbean and 0 otherwise;

NAMERICA: 1 if the region of the study is North America and zero otherwise, the omitted geographical category is Western Europe and Oceania;

IRRIG: 1 if irrigation is considered in the study and 0 otherwise.

Table 3 reports the FRM results for MTEs for the three alternative models. In all cases 842 observations are included from the total of 900 because some cases do not contain all the variables listed above. Model 1 ignores the possible presence of a geographical effect and omits a dummy variable that captures the potential effect of irrigation-related papers. Model 2 introduces a set of five dummy variables to capture geographical effects, while Model 3 also includes a dummy variable that accounts for those studies that introduce irrigation.

Regarding a priori expectations of the sign of the parameters, Ogundary (2014) includes the variable “data-year” in order to analyze the evolution of TE overtime. He argues that for Africa, his focal area, a negative trend for TE would be an indication that efficiency would have contributed negatively to Total Factor Productivity (TFP) growth in African agriculture. He also includes other regressors as control variables such as methodology used, data, functional form, product type, sample size, and geographical location without articulating a priori expectations on the sign of the respective parameters. In addition, Bravo-Ureta *et al*. (2007) suggest that non-parametric deterministic studies (DEA) typically yield several TE indexes equal to 100% and such high measures tend to increase the MTEs.

In this study, we formulate a few working hypotheses regarding the effects we expect for some of the regressors included in the meta-regressions. One such hypothesis is that the income level of a country is positively correlated with MTE based on earlier empirical results (Bravo-Ureta *et al*. 2007). Moreover, we expect higher incomes to be positively associated with better educational and information networks, which should reduce the number of highly inefficient producers. In addition, farms that produce one output are likely to exhibit higher TE with respect to farms that produce several products because in the former case the producer can have specialized and deeper knowledge of farm practices; thus, again we expect a tighter distribution of TE with relatively few highly inefficient farmers. Also, and according to Greene (2008), models relying on panel data should yield more accurate and higher efficiency estimates relative to models estimated from cross-sectional data.

We first compare Model 1 versus Model 2 (Restricted versus Unrestricted, respectively) and we reject the null hypothesis of the restricted model (coefficients of the regional variables are jointly null); i.e., the hypothesis that the coefficients of regional dummies are jointly zero is rejected. To compare Model 2 versus Model 3, we use the Deviance criterion, which is a quality of fit statistic applicable when QMLE is used. The model with lower Deviance outperforms the other ones (Greene, 2008). Consequently, the discussion below is based on the results obtained from Model 3.

The econometric results of Model 3 show that 9 out of 18 parameters are significant at least at the 10%. The variables SPF and PAR capture the effect of the methodology used to estimate the frontier on MTE estimates where the excluded category for SPF is deterministic frontiers and for PAR is the non-parametric approach. The positive sign and statistical significance of the parameter for SPF indicates that parametric stochastic models consistently yield higher MTEs than deterministic frontiers. The parameter for the variable PAR is significant and negative which means that the parametric approach yields lower MTEs than non-parametric ones.

In comparison, Bravo-Ureta *et al*. (2007) use three variables to capture the effect of the methodology: parametric stochastic frontier, parametric deterministic frontiers and the omitted category is the non-parametric studies. The results show that the latter category exhibits a significantly higher MTE than the deterministic parametric approach. In contrast with our results, Ogundary (2014) reports higher levels of MTE for parametric studies in Africa for the

1984-2013 period. This same author divided the data in two periods (1984-2003 and 2004-2013) and reports negative but non-significant values of MTEs for the first period and significant and positive values for the latter. However, the author uses not only articles published in indexed journals but also in the grey literature including working papers, conference proceedings and theses.

The variable CS groups those studies with cross sectional data and the parameter is negative but non-significant in Model 3. This result is not in line with Bravo-Ureta *et al*. (2007) and Ogundary (2014) and does not support the notion that frontier models using cross-sectional data yield lower MTE estimates. The parameters for NVAR show significant and positive effects on MTEs but the values are very low. Bravo-Ureta *et al*. (2007) include in their meta-analysis the ratio between the number of explanatory variables and the number of observations and this ratio does have a significant effect on the MTEs. The number of observations in each study (NOBS) shows a negative association with MTEs. Models that use a one-step approach to explain inefficiency exhibit a positive and significant coefficient for the FSTEP variable. On the other hand, SIO and TI show inconclusive results.

Our Meta-regression model also includes a continuous variable (YPUB) that indicates the year of publication of each study. The results show a negative but non-significant trend for model 3. Ogundary (2014) includes in his analysis the year of the data used in each study and also reports a negative trend. Based on his results, he argues that average efficiency levels of African agriculture and food production have declined over the years.

Regarding the type of output, we include in the models dummy variables for cereals (RICE and WHEAT) and DAIRY since these products have received considerable attention in the TE literature. The omitted category is the rest of agricultural products (see Table 2). Our results indicate that DAIRY farm studies report higher levels of MTE than the rest of the agricultural products (RICE, WHEAT and others) and this finding is in line with Bravo-Ureta *et al*. (2007). Ogundary (2014) shows that studies focusing on grain crops report significantly lower efficiency estimates compared to non-grain.

The coefficients for all the regional dummies are negative except for NAMERICA and ASIA but they are not all significant. The excluded category for this group of dummy variables is countries located in Western Europe and Oceania. The results suggest that, compared to other regions, the MTE for AFRICA and LAC is significantly (1%) lower while the same is found for E. EUROPE but with a weaker statistical significance (10%).

5. SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

5.1 Summary

The general objective of this study was to undertake a meta-analysis of the production frontier literature focusing on farm level studies. The point of departure was the previous meta-analysis for agriculture by Bravo-Ureta *et al*. (2007) as updated by Bravo-Ureta et al. (2016). The specific objectives of the study were: 1) to generate a comprehensive data set of TE studies published in English in refereed journals; 2) to perform a meta-regression analysis for farm level studies; and 3) to discuss how frontier models could be used in impact evaluation. This latter issue is addressed briefly later in this Section. This study provides an up to date comprehensive analysis of the effects that different methodologies and study-specific attributes have on Mean Technical Efficiency (MTE).

A wide-ranging literature search was conducted using a variety of search engines. The search yielded a total of 408 studies suitable for our analysis. These 408 studies yield 900 observations or cases given that some studies use alternative frontier models and report more than one MTE. The descriptive analysis showed that of the 900 total cases, 622 come from parametric and 278 from non-parametric models, 551 observations come from stochastic and 349 from deterministic frontiers. The Average MTE (AMTE) is 74.2%. We also conducted statistical tests of AMTE within groupings according to geographical region, income category and product type and again found only a few statistically significant mean differences.

Fractional Regression Models (FRM) were then used to estimate MTE as a function of a number of methodological attributes of the papers. FRM was chosen because it is an approach well suited for cases where the dependent variable consists of fractional data, i.e., data that falls in the unit interval. Alternative specifications were tested and the preferred alternative includes regional effects (unrestricted model). The methodological approaches (stochastic production frontier or SPF versus other; parametric versus non-parametric) and type of data (cross-sectional versus panel data) significantly affect AMTE in the same direction. Parametric models and cross-sectional data yielded, on average, lower levels of MTEs while SPF approaches showed higher ones.

5.2 Concluding Comments

Many agricultural projects are designed to increase output growth by promoting the adoption of improved technologies while also providing technical assistance and training designed to enhance managerial performance (e.g., Cavatassi *et al*., 2011; Bravo-Ureta, Greene and Solís, 2012; Maffioli *et al*., 2011). Expressed differently, a common objective is to promote upward shifts in the production frontier while at the same time make the best use possible of the relevant technology.

Conceptually, Stochastic Production Frontiers (SPF) are well suited to evaluate the impact of projects that are designed to promote improved technologies to increase output while also attempting to enhance productivity by developing or boosting human capital and managerial performance (Bravo-Ureta, 2014). Nevertheless, very few studies have used SPF models in impact evaluation work. An early exception is the evaluation of the PROMEDATA agricultural credit program in Brazil on technical and allocative efficiency (Taylor and Shonkwiler, 1986; Taylor, Drummond and Gomes, 1986). More recently, Dinar, Karagiannis and Tzouvelekas (2007) used a SPF model to evaluate the impact of agricultural extension on the performance of farmers in Crete. These three papers, however, did not consider selectivity bias, a critical challenge in impact evaluation work. Moreover, it is possible that the dearth of studies that make use of SPF models in impact evaluation work is due to the realization that selectivity bias is problematic in such models.

One avenue to incorporate SPF models that address selectivity bias in impact evaluation applications is based on Greene (2010) as extended by Bravo-Ureta, Greene and Solís (2012). The latter authors combined Propensity Score Matching (PSM) with Greene's (2010) model to deal with biases from observables and unobservables, respectively, when only cross-sectional data is available. They apply their model to a cross-sectional data set from the MARENA Program implemented in Honduras and funded by the Inter-American Development Bank (Bravo-Ureta *et al*., 2012). González-Flores *et al*. (2014) applied the Bravo-Ureta, Greene and Solís (2012) model for a sample of small-scale potato farmers from Ecuador to explore the impact of Plataformas de Concertación on productivity. Villano *et al*. (2015) also applied the model to examine the impact of adopting certified seed varieties for a sample of rice farmers in the Philippines and to measure the technology gap, understood as the distance between the production frontiers between adopters and non-adopters, and the managerial gap given by the average TE for each group.

In sum, if only end line cross-sectional data is available, which is not a rare occurrence at the time of evaluating a project, it is possible to measure the impact of a project on the technology and managerial effects of the intervention. Clearly, having both baseline and end line data for controls and beneficiaries is a much more desirable alternative but the estimation methodology of such models within a SPF framework needs development.

Table 1. Average Mean Technical Efficiency (AMTE) by Methodological Characteristics

Category	**No. of Cases**	**AMTE***
Approach		
Parametric	622	**74.6**
Non-Parametric	278	**73.5**
Stochastic	551	**74.9**
Deterministic	349	**73.2**
Data		
Panel	301	**77.2**
Cross Sectional	530	**73.5**
Functional Form**		
Cobb-Douglas	347	**72.5**
Translog	252	**77.3**
Others	24	**73.7**
Primal/Dual		
Primal	852	**74.2**
Dual	32	**73.8**
AMTE	***74.2%***	
Number of Cases	***900***	
Number of Studies	***408***	

* Numbers underlined denote statistical differences for each category.

** Valid for Parametric approach studies.

Table 2. Average Mean Technical Efficiency (AMTE) by Selected Study Attributes

	All Studies	
Category	**No.**	**AMTE %**
Geographical Region		
Africa	103	**68.3**
Asia	255	**74.9**
L. America	72	**61.7**
N. America**	138	**78.9**
E. Europe	30	**72.7**
W. Europe & Oceania	302	**76.8**
Country Income		
LIC***	97	**74.1**
LMIC	202	**72.4**
UMIC	154	**67.4**
HIC	447	**77.5**
Product		
Rice	120	**74.7**
Maize	29	**76.2**
Wheat	37	**74.4**
Mixed Grains	38	**73.7**
Crops and Livestock	372	**69.5**
Dairy	211	**80.9**
Other Animals	73	**78.3**
Whole Farm	20	**72.5**
AMTE		***74.20%***
Number of Cases		***900***
Number of Studies		***408***

* Numbers underlined denote statistical differences for each category.

** North America includes the United States and Canada.

*** LICs: Lower Income Countries, LMICs: Lower Middle Income Countries, UMICs: Upper Middle Income Countries, and HICs: Higher Income Countries (World Bank 2014).

Table 3. Fractional Meta-regressions of Mean Technical Efficiency (MTE)

N=842	**Model 1**			**Model 2**			**Model 3**			**Marginal Effects-Model 3**		
Variables	**Coeff.**		**Robust S.E.**	**Coeff.**		**Robust S.E.**	**Coeff.**		**Robust S.E.**	**Coeff.**		**Delta** S.E.**
Constant	1.260	***	0.132	1.172	***	0.132	1.178	***	0.133			
SPF	0.200	*	0.105	0.298	***	0.091	0.305	***	0.092	0.059	***	0.018
PAR	-0.360	***	0.108	-0.297	***	0.104	-0.313	***	0.105	-0.058	***	0.019
CS	-0.156	***	0.054	-0.087	*	0.053	-0.082		0.053	-0.015		0.010
NVAR	0.002	***	0.001	0.001	*	0.001	0.001	*	0.001	0.0002	*	0.0001
NOBS	-0.001	***	0.0002	-0.001	***	0.0002	-0.001	***	0.0002	-0.0002	***	0.00003
YPUB	-0.010	**	0.004	-0.006		0.004	-0.006		0.004	-0.001		0.001
TI	0.012		0.078	0.030		0.078	0.019		0.079	0.004		0.015
FSTEP	0.334	***	0.088	0.260	***	0.086	0.272	***	0.088	0.050	***	0.016
RICE	0.082		0.076	-0.031		0.090	-0.017		0.094	-0.003		0.018
WHEAT	0.111		0.124	-0.006		0.127	0.016		0.132	0.003		0.025
DAIRY	0.500	***	0.079	0.359	***	0.082	0.364	***	0.082	0.065	***	0.014
SIO	0.059		0.065	0.042		0.064	0.037		0.064	0.007		0.012
AFRICA				-0.324	***	0.095	-0.307	***	0.094	-0.061	***	0.020
ASIA				-0.005		0.086	0.013		0.085	0.003		0.016
E.EUROPE				-0.244	*	0.139	-0.240	*	0.139	-0.048	*	0.029
LAC				-0.674	***	0.110	-0.675	***	0.109	-0.144	***	0.026
NAMERICA				0.111		0.081	0.111		0.081	0.021		0.015
IRRIG							-0.057		0.072	-0.011		0.014
QMLE	-337.3			-334.1			-334.1					
Deviance	89.43			83.18			83.12					

* 10%, ** 5% and *** 1% level of significance.

** The Delta method is used to calculate the standard errors.

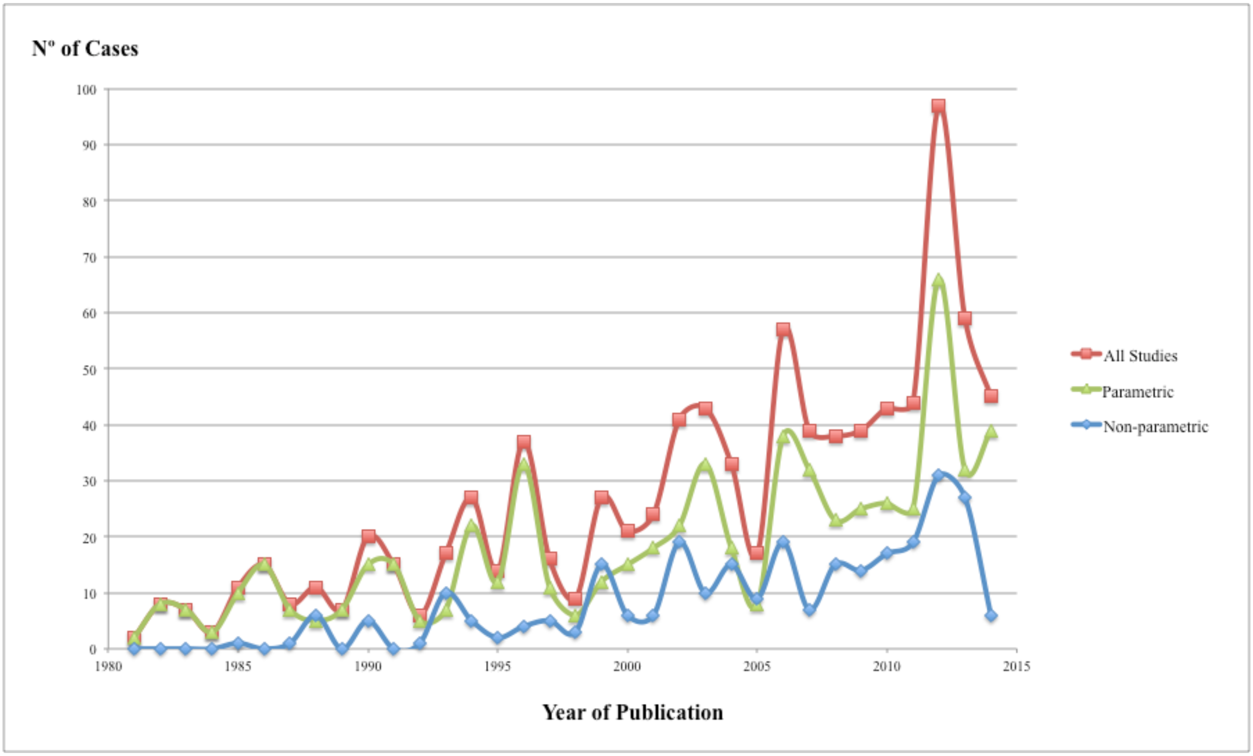

Figure 1. Number of TE Cases by Year of Publication: Parametric and Non-parametric Models

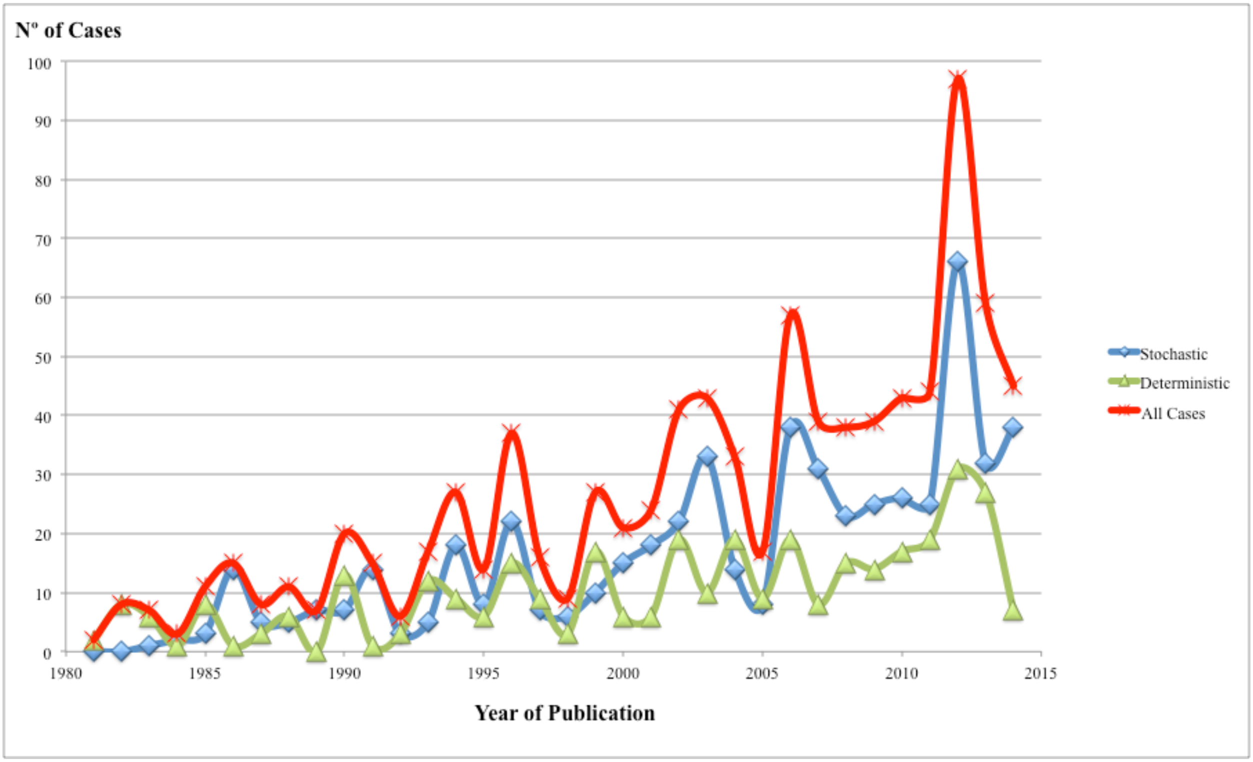

Figure 2. Number of TE Cases by Year of Publication: Stochastic and Deterministic Models

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APPENDIX A

Major Characteristics of the 408 Studies in the Meta Dataset

First Author	Year	Country	Product(s)	No. Obs.	Mean TE
I. NON-PARAMETRIC					
Abay	2004	Turkey	Crops & Livestock	120	57.4
Abrar	2006	Ethiopia	Crops & Livestock	514	54.0
Adhikari	2012	Nepal	Crops & Livestock	2,585	47.5
Ali	1990	Pakistan	Crops & Livestock	61	84.7
Ali	1990	Pakistan	Rice	32	79.6
Anriquez	2010	Ghana	Whole Farm	2,289	18.0
Asmild	2003	Denmark	Dairy	1,714	82.0
Asmild	2006	Denmark	Other Animals	290	73.8
Aye	2011	Nigeria	Maize	240	82.8
Aye	2013	Nigeria	Maize	240	85.5
Balcombe	2006	Australia	Dairy	241	65.0
Balcombe	2008	Bangladesh	Rice	295	61.5
Barnes	2011	UK	Dairy	160	93.0
Begum	2010	Bangladesh	Other Animals	100	88.5
Begum	2012	Bangladesh	Other Animals	75	92.5
Beltran-Esteve	2014	Spain	Crops & Livestock	106	92.0
Bojnec	2009	Slovenia	Whole Farm	130	59.0
Bojnec	2013	Slovenia	Crops & Livestock	1,784	44.0
Brümmer	2001	Slovenia	Crops & Livestock	185	44.0
Byrnes	1987	USA	Mixed Grains	107	99.4
Candemir	2006	Turkey	Dairy	80	94.4
Chakravorty	2002	USA	Crops & Livestock	39	82.0
Chang	2010	USA	Dairy	1,593	58.0
Chavas	1993	USA	Crops & Livestock	545	96.4
Chemak	2012	Tunisia	Crops & Livestock	141	76.5
Cloutier	1993	Canada	Dairy	374	89.8
Cobanoglu	2013	Turkey	Crops and Livestock	198	51.0
Coelli	2002	Bangladesh	Rice	406	67.8
Davidova	2007	Czech Republic	Crops & Livestock	753	53.0
Davidova	2007	Czech Republic	Other Animals	753	67.3
Dawson	1985	UK	Crops & Livestock	56	96.0
Dhungana	2004	Nepal	Rice	76	82.0
Elhendy	2013	Saudi Arabia	Crops & Livestock	225	43.5
Featherstoen	1997	USA	Other Animals	195	78.0
Fernandez-Cornejo	1994	USA	Crops & Livestock	87	52.1
Fernández-Navarro	2011	Spain	Whole Farm	1,617	76.0
Fletschner	2002	Paraguay	Crops & Livestock	283	84.0
Fraser	1999	Australia	Dairy	50	88.5
Fraser	2001	Australia	Other Animals	26	81.0
Frija	2009	Tunisia	Crops & Livestock	47	71.5
Galanopoulos	2006	Greece	Other Animals	80	83.0
Galanopoulos	2011	Greece	Other Animals	106	47.0
Garcia	2011	Vietnam	Crops & Livestock	207	74.0
Gaspar	2009	Spain	Other Animals	69	70.0
Gelan	2012	Kenya,Rwanda,Uganda	Dairy	371	55.0
Gillespie	1997	USA	Other Animals	57	82.0
Günden	2010	Turkey	Dairy	87	72.5
Haese	2009	France	Dairy	34	93.9
Haji	2006	Ethiopia	Crops & Livestock	150	91.0
Hansson	2007	Sweden	Crops & Livestock	507	86.9
Hansson	2008	Sweden	Crops & Livestock	507	87.7
Heidari	2011	Iran	Other Animals	44	91.5
Hoang	2013	Sri Lanka	Rice	40	91.2
Idris	2013	Malaysia	Crops & Livestock	124	71.0
Iraizoz	2003	Spain	Crops & Livestock	46	84.5

Isin	2013	Turkey	Crops & Livestock	204	79.2
Jaforullah	1999	New Zealand	Dairy	264	89.0
Jordaan	2013	South Africa	Crops & Livestock	40	54.0
Kalaitzandonakes	1992	USA	Mixed Grains	50	94.0
Kalaitzandonakes	1995	Guatemala	Maize	82	93.0
Kane	2012	Cameroon	Mixed Grains	62	56.2
Kelly	2012	Ireland	Dairy	190	80.9
Keramidou	2011	Greece	Other Animals	328	95.0
Khoshnevisan	2013	Iran	Crops & Livestock	26	83.5
Khoshnevisan	2013	Iran	Wheat	26	90.5
Kiatpathomchai	2008	Thailand	Rice	120	89.6
Kilic	2009	Turkey	Crops & Livestock	151	85.0
Koeijer	2002	The Netherlands	Crops & Livestock	467	63.0
Koeijer	2003	The Netherlands	Crops & Livestock	57	57.0
Kumar	2005	India	Rice	50	83.5
Kwon	2004	Korea	Rice	5,130	72.0
Latruffe	2004	Poland	Crops & Livestock	222	57.0
Latruffe	2004	Poland	Other Animals	250	71.0
Latruffe	2005	Poland	Crops & Livestock	219	68.5
Latruffe	2005	Poland	Other Animals	179	81.0
Latruffe	2008	Czech Republic	Crops & Livestock	128	72.8
Latruffe	2008	Czech Republic	Other Animals	44	73.4
Latruffe	2012	France	Crops & Livestock	NA	43.3
Latruffe	2012	France	Dairy	NA	63.7
Latruffe	2012	Hungary	Crops & Livestock	NA	47.7
Latruffe	2012	Hungary	Dairy	NA	65.9
Lemba	2012	Kenya	Crops & Livestock	107	30.2
Lissitsa	2005	Ukraine	Crops & Livestock	920	83.5
Llewelyn	1996	Indonesia	Crops & Livestock	61	98.5
Lous	2010	India	Crops & Livestock	180	78.6
Mahadevan	2009	Fiji	Crops & Livestock	677	70.4
Mahdhi	2011	Tunisia	Crops & Livestock	NA	72.2
Manevska-Tasevska	2011	Macedonia	Crops & Livestock	900	62.0
Marioni	2013	Australia	Wheat	188	78.0
Mathijs	2001	Bulgaria	Crops & Livestock	93	44.0
Mathijs	2001	Hungary	Crops & Livestock	93	58.0
Mathijs	2001	Hungary	Dairy	93	50.0
Mbaga	2003	Canada	Dairy	1,143	93.6
Mehdian	1988	USA	Mixed Grains	77	59.7
Morrison	2004	USA	Crops & Livestock	780	89.5
MousaviAvval	2011	Iran	Crops & Livestock	95	87.0
Nastis	2012	Greece	Crops & Livestock	65	66.4
Nehring	2005	USA	Crops & Livestock	650	72.9
Nguyen	2012	South Korea	Rice	480	77.2
Njiraini	2013	Kenya	Crops & Livestock	201	63.0
Nyemeck	2003	Côte d'Ivoire	Crops & Livestock	81	41.5
Ogada	2014	Kenya	Crops & Livestock	2,334	60.5
Olson	2009	USA	Crops & Livestock	216	77.0
Oren	2006	Turkey	Crops & Livestock	149	50.5
Osborne	2006	Russia	Crops & Livestock	70	73.0
Oude Lansink	2002	Finland	Crops & Livestock	434	81.5
Oude Lansink	2002	Finland	Other Animals	1,580	78.5
Oude Lansink	2004	The Netherlands	Other Animals	96	89.5
Oxouzi	2012	Greece	Crops & Livestock	78	64.9
Oxouzi	2013	Greece	Crops & Livestock	78	64.9
Oxouzi	2013	Greece	Other Animals	49	83.3
Padilla-Fernández	2012	Philippines	Crops & Livestock	127	77.0
Pahlavan	2012	Iran	Crops & Livestock	29	68.0

Pahlavan	2012	Iran	Crops & Livestock	44	74.0
Pandit	2009	India	Crops & Livestock	142	54.0
Pascual	2005	Mexico	Maize	74	78.0
Picazo-Tadeo	2006	Spain	Crops & Livestock	23	79.2
Piesse	1996	Croacia	Dairy	272	92.7
Radam	1995	Malaysia	Rice	317	49.8
Rebelo	2000	Portugal	Crops & Livestock	30	84.1
Reinhard	2000	The Netherlands	Dairy	1,535	79.7
Rios	2006	Vietnam	Crops & Livestock	209	78.0
Rouse	2010	New Zealand	Dairy	120	85.8
Rowland	1998	USA	Other Animals	129	89.0
Salazar-Ordoñez	2013	Spain	Crops & Livestock	295	55.9
Sarker	2004	India	Crops & Livestock	80	98.0
Sarker	2004	India	Rice	80	99.0
Serra	2014	Spain	Crops & Livestock	190	86.0
Shafiq	2000	Pakistan	Crops & Livestock	120	58.8
Sharma	1997	USA	Other Animals	60	68.5
Sharma	1999	USA	Other Animals	52	71.1
Sherlund	2002	Côte d'Ivoire	Rice	464	91.0
Shortall	2013	UK	Dairy	200	67.5
Singbo	2010	Benin	Crops & Livestock	33	81.6
Singbo	2010	Benin	Rice	28	65.1
Skevas	2012	Denmark	Crops & Livestock	703	79.8
Smith	2011	India	Rice	113	64.3
Speelman	2008	South Africa	Crops & Livestock	60	67.5
Speelman	2011	South Africa	Crops & Livestock	59	67.5
Steeneveld	2012	The Netherlands	Dairy	408	77.0
Tauer	1993	USA	Dairy	395	78.3
Tauer	1998	USA	Dairy	630	89.0
Theodoridis	2012	Greece	Other Animals	58	76.0
Thiele	1999	Germany	Crops and Livestock	300	92.0
Thomas	1994	USA	Dairy	125	89.2
Wadud	2000	Bangladesh	Rice	150	82.4
Wang	2010	China	Wheat	432	61.5
Weersink	1990	Canada	Dairy	105	94.9
Wouterse	2010	Burkina Faso	Mixed Grains	103	70.0
Wu	2003	USA	Crops and Livestock	147	88.0
Xiaoyan	2014	China	Maize	171	59.3
Yang	2009	China	Other Animals	31	66.0
Zaibet	1999	Oman	Crops and Livestock	35	66.3
Zaibet	2004	Oman	Other Animals	43	62.0
Zhengfei	2003	The Netherlands	Crops and Livestock	1,072	75.5
Mean Non-Parametric					***73.5***
II. PARAMETRIC					
Deterministic Frontiers					
Aguilar	1993	Kenya	Crops & Livestock	347	76.5
Ahmad	1996	USA	Dairy	1072	76.5
Alvarez	1999	Spain	Dairy	410	72.0
Alvarez	2004	Spain	Dairy	1176	70.0
Aly	1987	USA	Mixed Grains	88	58.0
Amara	1999	Canada	Crops & Livestock	81	80.3
Bagi	1982	USA	Crops & Livestock	48	80.5
Bagi	1983	USA	Crops & Livestock	97	69.6
Belbase	1985	Nepal	Maize	0	67.0
Belbase	1985	Nepal	Mixed Grains	537	78.0

Belbase	1985	Nepal	Rice	0	84.0
Bhattacharyya	1996	India	Crops & Livestock	105	84.1
Bravo-Ureta	1986	USA	Dairy	213	82.2
Bravo-Ureta	1990	USA	Dairy	404	68.4
Chandra	1981	India	Crops & Livestock	62	77.3
Croppenstedt	1997	Ethiopia	Mixed Grains	344	41.0
Dawson	1985	UK	Crops & Livestock	56	66.7
Hallam	1996	Portugal	Dairy	340	68.0
Huang	1997	China	Maize	1061	68.4
Huang	1997	China	Rice	770	77.5
Huang	1997	China	Wheat	314	73.0
Kalaitzandonakes	1992	USA	Crops & Livestock	50	57.0
Kalaitzandonakes	1995	Guatemala	Maize	82	52.0
Kontos	1983	Greece	Crops & Livestock	83	57.0
Krishna	2014	India	Wheat	180	89.0
Neff	1991	USA	Mixed Grains	1020	71.0
Orea	2004	Spain	Dairy	445	65.9
Pérez	2007	Spain	Other Animals	49	66.0
Piesse	1996	Croacia	Dairy	272	56.7
Poe	1992	USA	Dairy	675	73.0
Russell	1983	UK	Crops & Livestock	56	72.5
Shah	1994	Pakistan	Crops & Livestock	380	67.3
Shah	1994	Pakistan	Maize	378	59.6
Shah	1994	Pakistan	Wheat	382	72.2
Shapiro	1983	Tanzania	Crops & Livestock	37	66.3
Tauer	1987	USA	Dairy	432	69.3
Turk	1995	Slovenia	Dairy	11	77.7
Wicks	1984	Sri Lanka	Rice	110	75.0
Mean Deterministic Frontiers					***73.2***
III. STOCHASTIC FRONTIERS					
Abdulai	2000	Ghana	Rice	256	73.0
Abdulai	2001	Nicaragua	Crops & Livestock	120	74.2
Abdulai	2001	Nicaragua	Maize	120	69.8
Abdulai	2007	Germany	Dairy	1,341	85.9
Abedullah	2007	Pakistan	Rice	200	91.0
Adeoti	2006	Nigeria	Crops & Livestock	117	75.5
Adewumi	2013	Nigeria	Maize	150	65.0
Adhikari	2012	Nepal	Crops & Livestock	2,585	73.0
Admassie	1999	Ethiopia	Crops & Livestock	64	90.9
Agbonlahor	2007	Nigeria	Crops &d Livestock	242	74.4
Ahmad	1995	USA	Dairy	1,072	77.0
Ahmad	1996	USA	Dairy	1,072	81.0
Ahmad	2003	Pakistan	Crops & Livestock	1,566	57.0
Ajibefun	1999	Nigeria	Crops & Livestock	98	67.0
Ajibefun	2002	Nigeria	Crops & Livestock	67	82.0
Alam	2012	Pakistan	Crops & Livestock	77	84.9
Alam	2012	Pakistan	Wheat	77	76.6
Alene	2003	Ethiopia	Maize	60	76.0
Ali	1994	Pakistan	Crops & Livestock	436	75.6
Alsururi	2014	Yemen	Wheat	308	73.8
Amaza	2002	Nigeria	Crops & Livestock	123	69.0
Areal	2012	UK	Dairy	215	85.0
Asadullah	2009	Bangladesh	Rice	2,357	72.3

Athipanyakul	2014	Thailand	Rice	181	70.0
Athukorala	2012	Sri Lanka	Crops & Livestock	413	55.4
Audibert	1997	Mali	Rice	662	66.8
Ayanwale	2007	Nigeria	Crops & Livestock	120	75.0
Aye	2011	Nigeria	Maize	240	86.7
Aye	2013	Nigeria	Maize	240	86.7
Bailey	1989	Ecuador	Dairy	68	78.1
Bakhshoodeh	2001	Iran	Wheat	164	92.0
Bakucs	2010	Hungary	Whole Farm	3,210	73.0
Balcombe	2006	Australia	Dairy	241	81.8
Balcombe	2007	Bangladesh	Rice	164	94.0
Bardhan	2013	India	Dairy	60	90.0
Bardhan	2012	India	Dairy	150	94.9
Barnes	2008	UK	Dairy	NA	72.0
Barnes	2008	UK	Mixed Grains	NA	71.0
Barnes	2008	UK	Other Animals	NA	79.5
Bashir	1995	Ethiopia	Wheat	150	77.0
Battese	1988	Australia	Dairy	56	70.7
Battese	1989	India	Crops & Livestock	289	83.7
Battese	1992	India	Rice	129	86.7
Battese	1993	India	Crops & Livestock	NA	83.9
Battese	1993	Pakistan	Wheat	292	79.5
Battese	1996	Pakistan	Wheat	314	68.0
Belloumi	2006	Tunisia	Crops & Livestock	272	72.4
Bhende	2007	India	Crops & Livestock	450	83.0
Binam	2004	Cameroon	Crops & Livestock	150	71.0
Binam	2004	Cameroon	Maize	150	75.0
Binam	2004	Cameroon	Mixed Grains	150	73.0
Bogale	2005	Ethiopia	Crops & Livestock	80	87.0
Bojnec	2009	Slovenia	Whole Farm	130	54.0
Bokusheva	2006	Russia	Crops & Livestock	443	90.3
Boshrabadi	2008	Iran	Wheat	225	67.0
Bozoglu	2007	Turkey	Crops & Livestock	75	82.0
Bravo-Ureta	1991	USA	Dairy	511	83.0
Bravo-Ureta	1994	Paraguay	Crops & Livestock	94	58.5
Bravo-Ureta	1997	Dominican Republic	Crops & Livestock	60	70.0
Bravo-Ureta	2008	Argent., Chile, Uruguay	Dairy	107	84.3
Bravo-Ureta	2012	Honduras	Crops & Livestock	177	58.7
Brümmer	2000	Germany	Dairy	5,093	96.0
Brümmer	2001	Slovenia	Crops & Livestock	185	74.4
Brümmer	2002	Germany	Crops & Livestock	128	95.5
Brümmer	2002	Poland	Crops & Livestock	200	75.7
Brümmer	2002	The Netherlands	Crops & Livestock	564	89.6
Brümmer	2006	China	Whole Farm	154	58.0
Butso	2010	Thailand	Rice	590	69.4
Byma	2010	USA	Dairy	2,855	91.5
Cabrera	2010	USA	Dairy	273	88.0
Chakravorty	2002	USA	Crops & Livestock	39	75.5
Chang	2011	China	Rice	1,326	81.8
Cobanoglu	2013	Turkey	Crops & Livestock	198	91.0
Coelli	1996	India	Crops & Livestock	340	73.2
Coelli	2004	Papua New Guinea	Crops & Livestock	36	78.0
Coelli	2013	Australia	Crops & Livestock	214	79.0
Cuesta	2000	Spain	Dairy	410	82.7
Cukur	2013	Turkey	Crops & Livestock	66	63.1
Dawson	1987	UK	Dairy	434	85.3
Dawson	1988	UK	Dairy	406	81.0
Dawson	1990	UK	Dairy	306	86.3

Dawson	1991	Philippines	Rice	103	73.0
Dawson	1991	UK	Dairy	NA	86.0
del Corral	2011	Spain	Dairy	1,130	91.4
Dey	2010	Malawi	Whole Farm	315	77.0
Dhehibi	2007	Tunisia	Crops & Livestock	432	67.7
Diagne	2012	Senegal	Rice	485	57.2
Ekanayake	1987	Sri Lanka	Rice	62	57.0
Elias	2014	Ethiopia	Crops & Livestock	300	72.0
Feng	2008	China	Rice	215	82.0
Ferenji	2007	Ethiopia	Maize	175	82.0
Fraser	2003	Australia	Other Animals	26	72.0
Fuwa	2007	India	Rice	919	74.9
Gebregziabher	2012	Ethiopia	Crops & Livestock	494	63.5
Gerada	2012	Sri Lanka	Rice	460	72.0
Ghosh	1994	USA	Dairy	145	91.9
Giannakas	2000	Greece	Crops & Livestock	125	69.7
Giannakas	2001	Canada	Wheat	100	76.9
Giannakas	2003	Greece	Crops & Livestock	125	76.6
Gonzalez	2007	Colombia	Whole Farm	822	87.0
González-Flores	2014	Ecuador	Crops & Livestock	236	54.6
Goyal	2006	India	Rice	231	76.6
Hadley	2006	UK	Crops & Livestock	6,948	76.5
Hadley	2006	UK	Dairy	10,597	89.7
Hadley	2006	UK	Mixed Grains	4,772	75.4
Hadley	2006	UK	Other Animals	2,412	84.6
Hadri	2003	UK	Mixed Grains	385	85.8
Haghiri	2004	Canada	Dairy	751	64.0
Haghiri	2004	USA	Dairy	6,085	67.5
Hasnah	2004	Indonesia	Crops & Livestock	NA	66.0
Heshmati	1994	Sweden	Dairy	559	82.2
Heshmati	1995	Sweden	Other Animals	1,506	90.8
Heshmati	1996	Uganda	Crops & Livestock	288	65.0
Heshmati	1997	Sweden	Crops & Livestock	929	76.0
Heshmati	1998	Sweden	Other Animals	1,425	94.5
Hoang	2013	Sri Lanka	Rice	40	82.6
Huang	1984	India	Crops & Livestock	151	89.0
Huang	2012	India	Crops & Livestock	289	72.9
Hung	1993	Vietnam	Crops & Livestock	165	59.0
Hussain	2012	Pakistan	Wheat	210	61.9
Iraizoz	2003	Spain	Crops & Livestock	46	84.5
Islam	2012	Bangladesh	Rice	243	90.3
Ivaldi	1994	France	Mixed Grains	405	61.2
Jabbar	2006	Vietnam	Other Animals	1,118	73.1
Jabbar	2008	Vietnam	Other Animals	1,962	75.5
Jaime	2012	Chile	Wheat	5,580	61.0
Johnson	1994	Ukraine	Crops & Livestock	16,508	69.2
Johnson	1994	Ukraine	Maize	12,615	74.6
Johnson	1994	Ukraine	Mixed Grains	27,993	78.7
Kalaitzandonakes	1992	USA	Crops & Livestock	50	85.0
Kalaitzandonakes	1992	Guatemala	Maize	82	74.0
Kalirajan	1983	Philippines	Rice	79	50.0
Kalirajan	1984	Philippines	Rice	81	63.0
Kalirajan	1986	Malaysia	Rice	191	67.0
Kalirajan	1986	Philippines	Rice	73	64.7
Kalirajan	1989	India	Rice	34	70.2
Kalirajan	1990	Philippines	Rice	103	78.9
Kalirajan	1991	India	Rice	180	69.3
Kalirajan	2001	India	Rice	500	67.4

Karagiannis	2001	Greece	Crops & Livestock	770	78.6
Karagiannis	2002	UK	Dairy	2,147	70.4
Karagiannis	2003	Greece	Crops & Livestock	50	70.2
Karagiannis	2005	Greece	Crops & Livestock	1,481	69.0
Karagiannis	2005	Greece	Other Animals	178	67.9
Karagiannis	2009	Greece	Crops & Livestock	190	88.6
Karagiannis	2012	Greece	Crops & Livestock	300	74.8
Khan	2010	Bangladesh	Rice	150	93.1
Khan	2013	Pakistan	Crops & Livestock	300	66.0
Kompas	2006	Australia	Dairy	415	87.4
Krasnozhon	2011	Ukraine	Crops & Livestock	535	72.0
Külekci	2010	Turkey	Crops & Livestock	170	64.0
Kumbhakar	1989	USA	Dairy	116	75.2
Kumbhakar	1994	India	Rice	227	75.4
Kumbhakar	1995	Sweden	Dairy	4,890	87.6
Kumbhakar	2009	Finland	Dairy	1,921	82.2
Kumbhakar	2009	Russia	Whole Farm	73	87.0
Kumbhakar	2014	Norway	Mixed Grains	687	76.5
Kurkalova	2003	Ukraine	Mixed Grains	164	94.2
Kwon	2004	Korea	Rice	5,130	75.0
Lachaal	2005	Tunisia	Crops & Livestock	178	82.0
Lambarraa	2009	Spain	Whole Farm	9,852	81.0
Larochelle	2013	Bolivia	Crops & Livestock	124	56.0
Larson	2006	Ecuador	Crops & Livestock	107,269	43.3
Latruffe	2004	Poland	Crops & Livestock	222	73.0
Latruffe	2004	Poland	Other Animals	250	88.0
Lawson	2004	Denmark	Dairy	574	94.6
Lee	2006	Indonesia	Rice	171	42.3
Li	2011	China	Rice	126	80.0
Li	2013	China	Crops & Livestock	8,955	73.8
Li	2013	China	Crops & Livestock	2,155	78.6
Lindara	2006	Sri Lanka	Crops & Livestock	127	84.3
Liu	2000	China	Crops & Livestock	3,964	86.8
Lohr	2006	USA	Crops & Livestock	774	73.7
Lohr	2007	USA	Crops & Livestock	774	78.8
Ma	2007	China	Dairy	230	66.0
Ma	2012	China	Dairy	331	85.0
Ma	2014	China	Rice	320	84.2
Madau	2011	Italy	Crops & Livestock	321	71.0
Mahadevan	2009	Fiji	Crops & Livestock	677	74.7
Mahadevan	2013	Fiji	Crops & Livestock	244	61.3
Maietta	2000	Italy	Dairy	533	55.0
Mamardashvili	2013	Switzerland	Dairy	3,000	94.0
Mamardashvili	2014	Switzerland	Dairy	927	95.0
Manevska-Tasevska	2013	Macedonia	Crops & Livestock	900	69.0
Marchand	2012	Brazil	Crops & Livestock	14,724	61.0
Mar	2013	Myanmar	Crops & Livestock	151	71.0
Mariano	2010	Philippines	Rice	5,539	75.7
Mariano	2011	Philippines	Rice	2,769	74.6
Marioni	2013	Australia	Wheat	188	63.0
Mayen	2010	USA	Dairy	1,482	82.7
Mbaga	2003	Canada	Dairy	1,143	95.2
McGuckin	1992	USA	Maize	172	81.0
Melfou	2009	Greece	Other Animals	432	76.8
Mochebelele	2000	South Africa	Mixed Grains	150	70.0
Moreira	2006	Chile	Dairy	92	72.2
Moreira	2010	Argent.,Chile,Uruguay	Dairy	161	83.9
Moreira	2011	Chile	Crops & Livestock	263	77.8

Morrison	2000	New Zealand	Other Animals	704	98.4
Morrison	2004	USA	Crops & Livestock	780	93.5
Mukherjee	2012	USA	Dairy	419	82.6
Nauges	2011	Finland	Crops & Livestock	1,020	58.7
Ndlovu	2014	Zimbabwe	Maize	NA	68.0
Nehring	2005	USA	Crops & Livestock	650	95.1
Nehring	2006	USA	Crops & Livestock	1,128,397	60.8
Nehring	2009	USA	Dairy	150,000	78.9
Newman	2006	Ireland	Dairy	8,103	74.4
Ofori-Bah	2011	Ghana	Crops & Livestock	340	86.0
Ogundari	2010	Nigeria	Rice	96	66.9
Ogundari	2011	Nigeria	Crops & Livestock	846	72.1
Ogundari	2013	Nigeria	Crops & Livestock	846	80.7
Ogunniyi	2013	Nigeria	Crops & Livestock	253	64.3
Oren	2006	Turkey	Crops & Livestock	149	54.0
Osborne	2006	Russia	Crops & Livestock	70	76.0
Oude Lansink	2000	The Netherlands	Crops & Livestock	985	66.9
Parikh	1995	Pakistan	Crops & Livestock	436	88.5
Pascual	2005	Mexico	Maize	74	75.0
Phillips	1986	Guatemala	Maize	1,384	75.6
Pierani	2003	Italy	Dairy	533	66.2
Rahman	2008	Bangladesh	Rice	298	91.6
Rahman	2008	Bangladesh	Wheat	293	88.1
Rahman	2009	Bangladesh	Rice	406	84.0
Rahman	2009	Thailand	Rice	141	64.5
Rahman	2011	Bangladesh	Rice	622	80.5
Rao	2012	Kenya	Crops & Livestock	302	50.5
Rawlins	1985	Jamaica	Crops & Livestock	101	71.2
Reddy	2004	India	Rice	270	25.5
Reinhard	1999	The Netherlands	Dairy	1,545	89.4
Reinhard	2000	The Netherlands	Dairy	1,886	87.5
Rezitis	2002	Greece	Crops & Livestock	3,643	71.0
Rezitis	2003	Greece	Crops & Livestock	482	71.8
Samarajeeva	2012	Canada	Other Animals	333	83.0
Sauer	2008	Romania	Maize	64	91.3
Sauer	2009	Denmark	Dairy	168	93.0
Schmid	2014	Switzerland	Dairy	927	95.0
Serra	2008	USA	Crops & Livestock	540	70.0
Serra	2010	The Netherlands	Dairy	2,624	89.6
Seyoum	1998	Ethiopia	Maize	20	86.6
Shah	1994	Pakistan	Crops & Livestock	380	76.8
Shah	1994	Pakistan	Maize	378	76.1
Shah	1994	Pakistan	Wheat	382	87.1
Sharma	1997	USA	Other Animals	60	74.9
Sharma	1999	USA	Other Animals	52	78.8
Sharma	2001	Nepal	Rice	282	77.8
Sherlund	2002	Côte d'Ivoire	Rice	464	77.0
Solís	2007	El Salvador, Honduras	Whole Farm	639	78.0
Solís	2009	El Salvador, Honduras	Whole Farm	639	78.0
Squires	1991	Indonesia	Crops & Livestock	136	60.5
Squires	1991	Indonesia	Rice	406	70.1
Tadesse	1997	India	Rice	60	83.3
Tamini	2012	Canada	Whole Farm	210	43.7
Taylor	1986	Brazil	Crops & Livestock	217	29.5
Theriault	2014	Benin, B. Faso, Mali	Crops & Livestock	263	80.3
Tiedemann	2013	Germany	Whole Farm	37	92.8
Tijani	2006	Nigeria	Rice	NA	86.6
Toro-Mujica	2011	Spain	Other Animals	31	66.0

Trewin	1995	Indonesia	Rice	1,026	90.4
Tzouvelekas	2001	Greece	Crops & Livestock	67	67.9
Udoh	2007	Nigeria	Crops & Livestock	160	65.0
van der Voort	2014	Belgium	Dairy	410	84.5
Villano	2006	Philippines	Rice	368	79.0
Wadud	2000	Bangladesh	Rice	150	79.0
Wang	1996	China	Crops & Livestock	1,838	61.6
Wang	2013	USA	Other Animals	76	95.1
Wilson	1998	UK	Crops & Livestock	140	89.5
Wilson	2001	UK	Wheat	362	87.0
Xu	1998	China	Rice	95	85.0
Yélou	2010	Canada	Dairy	3,322	96.7
Yigezu	2013	Syria	Wheat	385	78.2
Yu	2012	China	Dairy	550	73.0
Zaibet	1999	Oman	Crops & Livestock	35	42.2
Zhang	2011	China	Whole Farm	8,743	91.2
Zhu	2010	Germany	Crops & Livestock	7,730	64.0
Zhu	2010	Sweden	Crops & Livestock	7,730	71.0
Zhu	2010	The Netherlands	Crops & Livestock	7,730	76.0
Zhu	2011	Greece	Crops & Livestock	2492	69.0
Zhu	2012	Germany	Dairy	NA	61.4
Zhu	2012	Sweden	Dairy	NA	78.8
Zhu	2012	The Netherlands	Dairy	NA	55.3
Mean Stochastic Frontiers					***74.9***
OVERALL MEAN					***74.2***