Technical Inefficiency in Organic and Conventional Agriculture - A Meta Regression

Justice G. Djokoto, Agribusiness Management Dept., Central University, Accra, Ghana;
jdjokoto@central.edu.gh; dgameli2002@gmail.com

1. Introduction

Conventional and organic agriculture have not been spared the sprawling technical efficiency studies in the productivity literature, ignited by the seminal work of Farrell (1957). Specifically, Tzouvelekas *et al.* (2001), reporting the first conventional and organic agricultural contrast study on cotton in Greece noted, that, conventional agriculture was relatively more inefficient than organic agriculture. This was later confirmed by Arandia and Aldanondo-Ochoa (2008), Oude Lansink *et al.* (2002) and Poudel *et al.* (2011). On the contrary, Charyulu and Biswas (2010), Karagiannias *et al.* (2006), Madau (2007) and Tiedemann and Latacz-Lohmann (2012) concluded that, organic agriculture is more technical inefficient than conventional agriculture. However, Mayen *et al.* (2010) intimated that, measured against the appropriate technology, organic and conventional agriculture (dairy) did not show any significant difference in technical inefficiency. The question that arises is, combining evidence, which is more technically inefficient than the other, organic agriculture or conventional agriculture? This article employs meta-analysis to compare technical inefficiency of organic and conventional agriculture using data from contrasting studies only, with the view of establishing which more technically inefficient.

Past meta-regressions of technical efficiency in agriculture have focused on conventional agriculture (Thiam et al., 2001; Bravo-Ureta et al., 2007; Moreira Lopez and Bravo-Ureta, 2009; Ogundari and Brummer, 2011; Iliyasu *et al*., 2014; Ogundari, 2014; Djokoto and Gidiglo, 2016), whilst Djokoto (2015) analysed organic agriculture. Lakner and Breustedt (2015) engaged in a qualitative review of organic and conventional agriculture. In this article, a quantitative review of 31 papers is accomplished. In recognition of the unit interval property of mean technical inefficiency (MTI) and heterogeneity arising from several observations from the same study, restricted maximum likelihood regression (REML) modelling was applied.

2. Data and Methods

Journals on organic and related disciplines were identified and searched: *Agricultural Systems*, *International Journal of Organic Agriculture Research and Development, Journal of Organic Agriculture*, *Journal of Organic Systems*, *Journal of Sustainable Agriculture* and *Organic Farming.* Diverse publishers' websites; such as Emerald, Oxford University Press, Sage, Taylor and Francis, and Wiley, among others and databases such as AgEcon search, Agora, Cab Abstract, DOAJ, EBSCOHost and Google scholar were searched. Further, the reference list of studies found were searched to identify additional literature that was not captured in the first two stages. The search for the first two stages ended on 30th April, 2016.

The data extracted was restricted to only comparative studies for three reasons. Firstly, primary studies have already compared technical efficiency of organic and conventional production. Secondly, the problem of the study relates to the inconsistency in the conclusions regarding technically efficiency. Thus, it is appropriate to combine only these to answer the research question. Thirdly, technical inefficiency measures are relativities which present some challenges in comparison. Thus, there is the need for a common basis of comparison such as metafrontier or meta-distance relation. These were found in studies that compared organic and conventional agriculture and not individual organic or conventional studies. In all, 30 organic and conventional contrasting studies were obtained yielding 148 observations, equally divided between organic and conventional production.

The model for the meta-regression is specified as:

$$MTI = f(ORG, ORGMETA, CONMETA, DATASIZE, TERMS, DATAYEAR, SFA, CD, TL, CS, CRS, VRS, CAOS, OFC, FAV, NEH, PC, MC, DAIRY, LIVESTOCK, NAMERICA, CAMERICA, ASIA, EUROPEM, SCAND) \quad 1$$

MTI = technical inefficiency. ORG= 1 for organic studies and zero otherwise. ORGMETA captures MTI of organic studies computed from organic-conventional metafrontier (and meta-distance) whilst CONMETA=1 for conventional MTIs computed relative to organic-conventional metafrontier (and meta-distance). Number of observations in primary studies was designated DATASIZE. TERMS represents the number of terms in the technical efficiency estimation relation. In the case of DATAYEAR, the last year of data was used for panel data and or data that crossed a year. As a result, if data covered 2003/2004 production year, the DATAYEAR was designated as 2004. Where technical efficiency was stated based on a specific year in a panel environment, the data year related to the specific technical efficiency year specified in the studies was used. For type of model estimation, SFA models were given the value 1 and 0 otherwise. Functional forms such as Cobb-Douglas (CD), translog (TL), and non-functional relations (reference) were identified. Data type relates to cross-sectional data (CS=1) and 0 otherwise. For returns to scale, constant returns to scale (CRS=1) and 0 otherwise; variable return to scale (VRS=1) and 0 otherwise with the reference category as those for distance functions and SFA. Products studied varied. These included cereals, oil seeds and protein seeds (CAOS); other field crops (OFC); fruits and vegetables (FAV); horticultural crops (NEH); permanent crops (PC); multiple crops (MC); dairy (DAIRY); livestock (non-dairy) (LIVESTOCK). The reference product is mixed products (livestock and crops). The categorisations in the study of Latruffe and Nauges (2014) influenced that of this article. Regarding location, dummy variables were also used. For location, North America (NAMERICA) was identified. Europe was split into mainland Europe (EUROPEM) and the Scandinavian countries (SCAND). Asia was also identified. Each of these was designated 1 and zero otherwise.

3. Results and discussion

The simple AMTI for organic and conventional agriculture differ slightly because the former posted 0.016 whilst the latter posted 0.297. The resulting simple AMTI from the metadata is 0.292. A test of difference between the means revealed that there is no statistically significant difference between the two. It is worthy of note, that, whilst the simple AMTI for organic agriculture is lower than that of the weighted AMTI; in the case of conventional agriculture, the simple AMTI exceeds the weighted AMTI. This is because of the statistically significant difference between the mean data size for organic and conventional agriculture. Therefore, some work is required to increase output between 24 and 29% without additional input use in the countries and for the products studied. Increased skills training that would be useful in appropriate combination of resources and response to climate change are required. The latter is particularly important as organic agriculture depends largely on the regenerative capacity of nature.

The statistical insignificance of the magnitude of the parameter of ORG imply MTI of organic agriculture is neither higher nor lower than MTI of conventional agriculture (Table 1). This multivariate result confirms the univariate results stated earlier. Both certified and uncertified organic agriculture is relatively recent compared to conventional agriculture for which reason conventional agriculture should be expected to outperform organic agriculture in technical efficiency. However, this is not the case. Also, whilst conventional agriculture may have more advanced technology, the relatively recent emergence of organic agriculture deprives it of the same time span for technology development.

Table 1. Results of Mixed-effects REML regression

MTI	Coefficients	Standard Errors
ORG	-0.0051	0.0282
ORGMETA	0.0365	0.0792
CONMETA	0.0440	0.0791
DATASIZE	-4.25e-05	1.24e-05
SFA	-0.1600	0.1331
CS	0.0132	0.0563
CAOS	-0.0496	0.0610
OFC	0.0863	0.0856
FAV	0.2758***	0.0584
NEH	0.0242	0.1249
PC	0.1626***	0.0591
MC	- 0.0403	0.0488
DAIRY	-0.1380***	0.0674
LIVESTOCK	-0.1241	0.1038
TERMS	0.0130***	0.0040
CRS	-0.0005	0.0601
VRS	-0.1120**	0.0569
DATAYEAR	-0.0041	0.0053
NAMERICA	0.0358	0.1289
ASIA	-0.0548	0.1064
EUROPEM	-0.0383	0.1094
SCAND	0.0241	0.1384
CD	0.0187	0.1284
TL	-0.0887	0.1306
Constant	8.4917	10.75832
Model properties		
N	148	
Wald	138.42***	
Random-effects Parameters sd(Residual)	0.1504	0.0087

Further, whilst organic production has tremendous inputs and quantity of usage restrictions, which have implications for yield (Mayen et al., 2010); conventional production has no such restrictions. Thus, although Tzouvelekas *et al.* (2001a), Arandia and Aldanondo-Ochoa (2008), Oude Lansink *et al.* (2002) and Poudel *et al.* (2011) reported that conventional agriculture was relatively more inefficient than organic agriculture whilst the contrary for Charyulu and Biswas (2010), Karagiannias *et al.* (2006), Madau (2007) and Tiedemann and Latacz-Lohmann (2012), the finding of this study conforms to the of the Mayen *et al.* (2010) primary study conclusion. Given the 148 data set used, a similar study with larger sample size will be interesting.

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