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Productivity and technical efficiency of organic farming – A literature survey

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The following article summarizes the findings of 30 studies on efficiency and productivity of organic farming systems. In a lot of studies organic farms shows a lower productivity than conventional farms, however, we cannot find evidence for a systematic lower efficiency. Environmental variables (if included) show a strong impact on efficiency and productivity of organic farms. We finally discuss conclusions from the productivity and efficiency literature.

Keywords: technical efficiency, productivity, organic farming, environmental efficiency

1 Introduction

The question of how productive and efficient are organic farms are widely discussed. However, during the last 15 years there has been an increasing number of studies, who explicitly model efficiency and productivity of organic farms. The following short paper summarizes the literature on efficiency and productivity and draws some short conclusions.

2 Material and Methods

In an economic context '**productivity**' is defined as the relation of outputs to multiple inputs, what in plant, animal or soil science is often referred to as efficiency. Furthermore, we understand '**technical efficiency**' as the relation of observed output (*input*) to the theoretical maximum output (input) in the output-(*input*)-oriented version. The theoretical maximum output or minimum input is modeled or determined by different model setups, however, all models are assuming homogenous technologies for the participating farms: One is the **Data Envelopment Analysis (DEA)**, where the so called frontier is determined by a linear optimization procedure, that determines some farms as fully efficient and relates the other farms to those efficient farms. So the best observed farms define the so-called '*best practice frontier*'. We can distinguish between output- and input-oriented models (Coelli et al., 2005). The virtues of the DEA-models are the straightforward interpretation. Besides this, modeling with a comparatively low number of observations is possible. In **Stochastic Frontier Analysis (SFA)** we use a parametric model to model the upper production frontier of observed farms, in order to compare the observed output in relation to the optimal output given by the production frontier (Coelli et al., 2005). The SFA-models are regression-based, therefore, statistical tests and model extensions like *fixed-effects*- or *selection*-models are possible, which is one of the strengths of this method. However, more observations are needed to perform this model-class.

As a basis of our analysis we will use 30 studies: 18 published indexed journal articles, 5 non-indexed journal articles, five selected peer-reviewed conference papers and two dissertations. Most of these studies have a regional focus in Western Europe (12), Southern Europe (8), Scandinavia (6) and the United States (4), but we also include one study from Turkey and from Egypt. (A list with all references can be provided on request.)

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3 Results

One important outcome of a Stochastic Frontier (SFA) efficiency model in organic farming are 'output-elasticities of inputs' which characterize the structure of production, which is a unit-free measure for the impact of one input on the output of a farm. The interpretation of an output-elasticity of 0.22 is as follows: If a farm increases one single input (such as e.g. labour, land or capital) by 1.0 %, the output would grow by 0.22 %.

The **output-elasticity** of the direct costs are highest in most studies. Therefore, increasing the direct costs might have the largest impact on outputs. The output elasticity of land is heterogeneous, deviating from 0.076 to 0.83, which might be explained by different land-markets and different shadow-prices for land depending on where the study was conducted. Labor plays a rather small role within most studies with values between 0.1 and 0.2. Capital and other costs usually play an even smaller role.

Returns to scale (RTS) describe the effect of an increase of all inputs at the same time (i.e. the sum of output-elasticities of all inputs). In most studies we rather find constant or increasing RTS: six of thirteen samples show constant RTS, six samples find increasing RTS, and one study finds decreasing RTS. If organic farms increase all their inputs at the same time, we can always expect the same or an even proportionately higher output increase. In a more general sense this might still indicate an incentive for structural change in the organic sector.

Comparative studies: A number of studies is comparing efficiency and productivity between organic and conventional farms: Most of those studies work with data sets which contain a large-group of conventional farms and a small subgroup of organic farms. In 11 of 20 studies, the share of organic farms is below 25 % of the total sample, in 4 studies the share is even below 10 %. In the case of such uneven distribution in the sample, the results might be biased due to stochastic effects or due to structural differences between organic and conventional farms. Besides distributional issues, the questions of selection bias and of how the sample was constructed are not always discussed in detail. If the group of organic and conventional farms cannot be compared with respect to farm structure, efficiency differences might stem from structural differences. One way of coping with this challenge is to apply a selectivity model (Kumbhakar et al. 2009), or to adjust for structural differences by applying e.g. a matching model (Mayen et al. 2010; Tiedemann u. Latacz-Lohmann 2011, 2012). Another way might be the application of a Metafrontier model for both groups.

Comparing the productivity of organic and conventional farms, in three of four studies organic farms show a lower productivity (Kumbhakar et al., 2009; Mayen et al., 2010; Oude Lansink et al., 2002; Tiedemann and Latacz-Lohmann, 2011). However, productivity differences are not as high as the differences in yields (De Ponti et al., 2012; Seufert et al., 2012). Under specific production systems, some studies also find a higher productivity per hectare (Serra et al., 2008; Tzouvelekas et al., 2001) or a higher total factor productivity (Tiedemann and Latacz-Lohmann, 2011). The models also document the advantage of modeled productivity against partial measures like the single crop yield. A direct comparison of efficiency is in most cases not possible due to methodological restrictions. Just very few studies apply models that allow for a direct comparison. From the few studies, who allow for a direct comparison, we cannot see clear evidence whether organic farms are more or less efficient than conventional farms.

In contrast to conventional farms, achieving **environmental services** is one of the main objectives of organic farms. Therefore, for a full comparison of efficiency and productivity, it might be interesting to include environmental variables into productivity and efficiency models. There are just a few studies using environmental variables: Dreesman (2006) analyzes data from fifty-eight organic milk farms in Luxembourg in 1999 and 2000 with respect to their environmental efficiency. The results suggest that energy is used more intensively in the production process on organic farms and has therefore a larger impact on productivity than the environmental indicators 'nitrogen' and 'phosphorus'. Kantelhardt et al.

(2009) investigate the technical and environmental efficiency of 102 farms using different agri-environmental programs (AEP) in southern Bavaria. The results show that the group of organic farms has the highest economic efficiency and according to the authors, the organic farms is also most successful combining environmental and economic efficiency. Sipiläinen and Huhtala (2012) investigate the impact of crop diversity on farm efficiency for both organic and conventional crop farms in Finland. The study applies a DEA-approach which introduces crop diversity (measured by a Shannon diversity index) as a secondary environmental output besides the output from agricultural production. The results confirm that by taking into account the ecological dimension of farming substantially changes the efficiency score of organic farming. In this two-output model, organic farms are performing on the same efficiency level as conventional farms.

4 Conclusions

Productivity and efficiency analysis can provide a complete overview on farm performance, going beyond the typical farm-success indicators (like profit) or partial productivity measures (like crop yield per hectare). Organic farms also show a lower productivity than conventional farms, however, not as low as found in the literature of yield comparisons. Just a few studies are comparing efficiency of organic and conventional farms and there is no clear evidence for a higher or lower efficiency of organic farms.

Many studies do not critically discuss the **selection of data**: This is especially true for the relation of technical efficiency and the question whether to convert to organic farming. If we are to compare efficiency of conventional and organic farms, but the conversion to organic farming is determined by e.g. a low farm efficiency, any analysis will suffer from a selectivity bias. The papers of Kumbhakar et al. (2009) and Latruffe and Nauges (2013) find a negative impact of efficiency on the decision to convert to organic farming. Therefore, we might conclude that rather decide the organic production if they are inefficient prior the conversion. We also know that the decision to convert is influenced by a number of different economic and also non-economic factors. Therefore, there is still more research needed.

The topic of **environmental efficiency** has been analyzed in a few studies. Furthermore, two of the three studies have the characteristics of case studies (Dreesman, 2006; Kantelhardt et al., 2009) and their results have to be interpreted with caution due to a low number of observations. Only the recent work of Sipiläinen and Huhtala (2012) show through a broader data set that environmental performance – if explicitly taken into account in the model – can lead to an increased farm efficiency for organic farms. From society's point of view, environmental efficiency is crucial in order to identify adequate policy measures since this efficiency measure takes the environmental dimension of farming into account. However, there is a substantial lack of appropriate data – as the few studies above show.

The efficiency studies show that **subsidies** have an impact on technical efficiency (e.g. in Lakner et al., 2012), in most cases the impact is negative. An explanation for those results might be rent-seeking behaviour of farmers: Organic farmers (similar to their conventional colleagues) pursue optimization strategies either for their farms' competitiveness or for their farms' subsidy revenue. However, this explanation is only valid for countries, where the organic farming support can be combined with other support schemes, which is not the case in all EU-member-states (Sanders et al., 2011). Overall, the conclusions of many studies are that subsidies even when supporting the environmental objectives of organic farming distort markets and might be inefficient. Therefore, it is necessary to further study the impact of policy measures on organic farming in order to increase the efficiency and effectiveness of agricultural policies in this area.

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