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Scale Efficiency in Organic and Conventional Dairy Farming

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Paper prepared for presentation at the 1st AIEAA Conference
'Towards a Sustainable Bio-economy: Economic Issues and Policy Challenges'

4-5 June, 2012
Trento, Italy

Summary

Recently, several studies compared the performance of conventional and organic farms. Most studies concentrated on technical efficiency. In this paper we add to this literature by also comparing the scale efficiency of conventional and organic milk farms in Austria during the period 1997-2002. To do so we utilize a bilateral production frontier that includes both production technologies and Green's (1995a,b) true fixed effects model to account for firm specific time-invariant heterogeneity and technical inefficiency. We find both groups of farms to be on average equally technical efficient (when compared to their production frontier), but conventional farms being on average considerably more scale efficient. However, while scale efficiency remained constant over time for conventional farms it increased for organic farms which seem to catch up.

Keywords: scale efficiency, conventional vs. organic farming, milk production, Austria

JEL Classification codes: Q12, D20

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1. INTRODUCTION

Recently a number of studies (i.e., Tzouvelekas, Pantzios and Fotopoulos, 2001a, 2001b, 2002; Oude Lansink, Pietola and Bäckman, 2002, Diamara et al., 2005; Madau, 1995; Sipiläinen, 2005) compared the performance of conventional and organic farms. These contributions focused on technical and allocative efficiency. In this paper we add to this literature by comparing the technical efficiency and scale efficiency of conventional and organic milk farms in Austria during the period 1997 - 2002. According to EC (2010) Austria is with about 15.5% (as compared to 4.3% in EU-27) unambiguously the EU country with the largest share of organic area in the utilized agricultural area (UAA).

Our point of departure is a bilateral production frontier function where a dummy variable is incorporated to allow for technology differences between the two farming practices. We apply Green's (2005a,b) 'true' fixed effects model to account for unobserved time-invariant heterogeneity between farms and Ray's (1998) method of estimating output-oriented scale efficiency.

The rest of the paper is organized as follows. The next chapter discusses our modelling approach. Chapter 3 describes utilized data before we present our results in chapter 4. We finish with a discussion in chapter 5.

2. MODELLING APPROACH

Our point of departure is a bilateral production frontier which allows for technical inefficiency and hence, $Y \leq f(\boldsymbol{X}, D, t)$ with Y being a single output $\boldsymbol{X}$ a vector of inputs, D a dummy variable used to capture differences in production patterns between the two types of farm practices (i.e., conventional and organic) and t is a time trend that serves as a proxy for technical change.

To empirically estimate technical inefficiency we use a stochastic production frontier approach first developed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977) and first applied to panel data by Pitt and Lee (1981) and Schmidt and Sickles (1984). Here we utilize Green's (1995a, 1995b) true fixed effects model:

$$y_{it} = \alpha_i + \boldsymbol{x}_{it}\beta + \varepsilon_{it}\ , \qquad \varepsilon_{it} = v_{it} - u_{it}\ , \qquad u_{it} \geq 0 \tag{1}$$

where $i = 1,\ldots,N$ indexes firms and $t = 1,\ldots,T$ indexes time periods. The y is typically log output and $\boldsymbol{x}$ is a vector of logged inputs. α_i and β are coefficients to be estimated. The v_{it} are iid $N(0,\ \sigma_v^2)$ and u_{it} are iid $N^+(0,$

σ_u^2), i.e. half-normal. In addition, $\boldsymbol{x}_{it}$, v_{it} and u_{it} are mutually uncorrelated. This panel model is fundamentally different from Pitt and Lee (1981) and Schmidt and Sickles (1984) in differentiating between inefficiency (u_{it}) and firm specific heterogeneity (α_i). Hence, they control for time-invariant factors that affect firm's output, but are not regarded as inefficiency since they are not under control of the firm. In regard to agricultural production this seems important given heterogeneity of natural conditions including soil quality, climate, temperature and elevation.

Assuming a translog production technology the frontier in equation (1) can be estimated as

(2) $$y_{it} = \alpha_i + \sum_{j=1}^{J} \alpha_j x_{jit} + \frac{1}{2}\sum_{j=1}^{J}\sum_{k=1}^{J} \alpha_{jh} x_{jit}\, x_{kit} + \sum_{j=1}^{J} \alpha_{jt} x_{it}^{j} t + \alpha_t t + \frac{1}{2}\alpha_{tt} t^2 + \beta_0 D + \sum_{j=1}^{J} \beta_j x_{it}^{j} D + \alpha_t tD + \varepsilon_{it}$$

utilizing the maximum likelihood estimator proposed by Green (2005a, b) and implemented in NLogit4.

Technical efficiency is measured using the mean of the conditional distribution of and u_{it} given ($v_{it} - u_{it}$) as point estimator (Jondrow et al., 1982). Given the translog form of our production frontier we can apply Ray's (1998) method to derive output oriented scale efficiency for every farm in every year (SE_{it}^{O}):

(3) $$SE_{it}^{O} = exp\left[\frac{(1-E_{it})^2}{2\gamma}\right]$$

with $\gamma = \sum_{j=1}^{J}\sum_{k=1}^{J} \alpha_{jh}$, and $E_{it} = \sum_{j=1}^{J}\left(\alpha_j + \sum_{k=1}^{J} \alpha_{jk} x_{kit} + \alpha_{jt} t + \beta_j D\right)$

where E_{it} is the scale elasticity and $\gamma < 0$ guarantees that $0 < SE_{it}^{O} < 1$.

By taking the first difference of SE_{it}^{O} with respect to D, we can derive the effect of differences in technology on scale efficiency.

(4) $$\frac{\partial SE_{it}^{O}}{\partial D} = \frac{(E-1)}{\gamma}\frac{\partial E}{\partial D} SE_{it}^{O}$$

3. DATA

We use accountancy data of a panel of Austrian farms, specialized in milk production, between 1997 and 2002. On average over all years the milk revenues account for more than 2/3s of total revenues and of at least 50% in each particular year. The sample is unbalanced and includes 41 organic farms with 191 observations, and 138 conventional farms with 587 observations.

Output is measured in terms of total farm revenues and converted into a constant price quantity index using a milk price index. To account for differences in quality we use different indices for organic and conventional milk. Descriptive statistics are given in Table 1. Four inputs are included in the production function. Labor includes family as well as hired labor and is measured in working days per year. To adjust for differences in the quality of labor we multiply the working days per year by 0.8, 0.9 and 1, if the farm operator has a low (no specific education), a medium (vocational training) and a high (craftsman, secondary school with agricultural training) educational level, respectively. Land is measured in UAA. It is quality adjusted by multiplying the UAA by hectare rate (Hektar-Satz), a measure used for tax purposes which accounts for differences in natural and economic conditions. It gives a monetary measure of the potential gross margin a farmer can earn form a particular plot. Capital stock is measured by end of-year value of buildings, machinery, value of permanent crops and value of animal stock. It is converted into a constant price quantity index by using a price index for capital investments in agriculture. Intermediate inputs include expenses for animal production (feeding, veterinary, other expenses for animals), plant production (seeds, fertilizer, pesticides), insurance, energy and other exoenses. It is converted into a constant price quantity index by using a price index for intermediates in agriculture.

Table 1. Descriptive statistics

	No. Farms	Obs.		Output	Quality adjusted land	Quality adjusted labor	Capital	Intermed.
				Euro	Euro	Days/year	Euro	Euro
Conventional	142	595	min	4572	818	122	23590	2551
			max	433292	144217	1285	741877	197958
			mean	**47703**	**13560**	**520**	**194402**	**22956**
Organic	38	182	min	7508	2023	191	42287	3733
			max	146098	71432	1115	794496	97504
			mean	**47252**	**15003**	**488**	**245231**	**20683**

Source: own calculations based on Austrian farm accountancy data

Descriptive statistics in Table 1 reveal that organic farms produce on average a slightly lower output (1%) by utilizing on average more quality adjusted land (11%) and capital (26%) and less intermediates (-10%) and quality adjusted labor (6%).

4. RESULTS

Before we estimate the production frontier we apply some specification tests (Table 2). First of all, Cobb-Douglas production technology is clearly rejected. Second, non-neutral technical change as implemented in equation (2) is affirmed since formulations of neutral technical change and "no technical change" is rejected. Third, constant returns to scale are rejected. Fourth, differences in the production technology between conventional and organic are confirmed. Hence, the model to be estimated is exactly the one outlined in equation (2).

Table 2. Wald tests on model specification

Hypothesis	Test statistic	Critical value (a=0.05)
No second-order effects (Cobb Douglas)	240.79	$\chi^2_{(10)} = 18.31$
Neutral technical change	10.36	$\chi^2_{(4)} = 9.49$
No technical change	50.69	$\chi^2_{(6)} = 12.59$
Constant returns to scale	90.57	$\chi^2_{(4)} = 9.49$
No technology differences	295.65	$\chi^2_{(6)} = 12.59$

Source: own elaborations
LL for production function (fixed effects):187.45;

Estimation results are presented in Table 3. First order effects are all significant and positive. About half of the second order effects are significant. Organic production technology is significantly different from conventional in regard to labor, intermediates and technical change. High and significant sigma and lambda values confirm our frontier approach including technical inefficiency.

Table 3. Estimation results

Variable	Coeff.	Std.Er.		Variable	Coeff.	Std.Er.	
X_A	0.0991	0.0105	**	X_At	-0.0010	0.0044	
X_L	0.2334	0.0211	**	X_Lt	-0.0226	0.0088	**
X_C	0.1591	0.0158	**	X_Ct	0.0129	0.0059	**
X_I	0.6208	0.0205	**	X_It	-0.0001	0.0064	
X_A^2	-0.0456	0.0067	**	t	-0.0101	0.0068	
X_L^2	-0.1618	0.0299		t^2	-0.0081	0.0020	**
X_C^2	-0.0334	0.0138	**	DX_A	0.0285	0.0191	
X_I^2	0.0404	0.0141	**	DX_L	0.0688	0.0351	*
X_AX_L	0.0059	0.0224		DX_C	0.0232	0.0255	
X_AX_C	-0.0152	0.0148		DX_I	-0.0423	0.0236	*
X_AX_I	-0.0296	0.0161	*	D	-0.0120	0.0151	
X_LX_C	0.1017	0.0303	**	Dt	-0.0250	0.0071	**
X_LX_I	0.0393	0.0366		Sigma	0.3714	0.0086	**
X_CX_I	0.0488	0.0222	**	Lambda	2.1725	0.1666	**

Source: own elaborations
*,** indicate significance at the 5%, 1% level.

Technical efficiency scores are presented in Table 4. Interestingly, they are on average not very different between organic (78.3) and conventional (79.2) production units. However, while they are relatively stable for conventional farms, they are slightly decreasing for organic farms.

Table 4. Technical efficiency scores

		1997	1998	1999	2000	2001	2002	**all years**
conventional	mean	78.70	80.11	78.68	80.05	77.40	80.10	**79.18**
	st.dev.	7.32	5.56	5.17	4.98	5.55	5.63	**5.78**
organic	mean	78.29	80.83	78.76	79.37	77.03	75.62	**78.33**
	st.dev.	7.51	5.80	6.77	7.39	7.95	8.39	**7.42**

Source: own elaborations

Table 5 present the scale efficiency scores. Conventional farms are on average significantly more scale efficient (90.3%) as compared to organic farms (83.6%). This is mainly true to the fact that organic farms are much more heterogeneous in regard to scale efficiency with much more farms exhibiting relatively low scale efficiency. However, looking at patterns over time in Table 6 scale efficiency of conventional farms was quite stable while it increased for organic farms which are catching up.

Table 5. Distribution of scale efficiency scores

	all	conv	organic
Mean	88.7	90.3	83.6
Std. dev.	11.7	10.5	13.8
Min	32.3	48.8	32.3
Max	100.0	100.0	100.0
		% in group	% in group
50-60		1.5	6.6
60-70		3.4	9.3
70-80		11.6	20.3
80-90		20.3	23.1

Source: own elaborations

Table 6. Scale efficiency scores

		1997	1998	1999	2000	2001	2002
conventional	mean	89.04	90.67	90.31	90.56	90.64	90.58
	st.dev.	12.33	10.28	10.13	10.15	9.90	10.46
organic	mean	80.59	79.26	81.65	85.97	87.22	86.19
	st.dev.	16.84	15.88	16.24	10.91	9.66	10.87

Source: own elaborations

5. Conclusions

Scale efficiency is an important issue in the development of the agricultural sector. Average farm size is still very low in most EU countries and in particular in Austria. However, on average organic farms in the EU are considerably larger than the average conventional farm. This is not true for Austria where the average size of a conventional and an organic farms are about the same. Beside adopting a new production technology organic farmers also have to adjust to an optimal farm size which is not necessarily the same as for an conventional farm.

Before this background we investigate the technical and the scale efficiency of milk farms in Austria, the country with the largest density of organic farms in the EU. Our results reveal that organic farmers are comparably technical efficient as conventional, when compared to their own production technology. Hence, on average they were able to adapt to the new production technology and cope with it as good as their conventional counterparts. However, they are significantly less efficient in choosing the right size of the farm. The average scale efficiency is 4.5 percentage points lower. However, this considerably changed over time. There is a clear trend to catch up in regard to scale efficiency.

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