



Modelling the effects of low-input dairy farming using bookkeeping data from Austria

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Abstract.

Despite the ongoing trend of higher intensities in dairy farming, some farmers select rather low-input systems. We identify such system in an agricultural bookkeeping dataset and assess economic effects of this system selection under volatile prices situations using cluster analysis and direct covariates matching. We find one low-input cluster with low levels of input use and three clusters with rather higher input levels. Those clusters differ in site conditions, farm size and milk production. After applying the matching methodology, the results indicate that choosing a low-input system does not affect farm income but reduces the work load and borrowed capital even under volatile markets.

Keywords: Dairy Farming, Farm Competitiveness, Low-input farming, Cluster Analysis, Matching Method

JEL codes: Q12, Q16



1. Introduction

Due to the high share of grassland and quite good natural site conditions dairy farming plays a major role in Austrian agriculture. Dairy farms are often small and plot structure is scattered, so profitability tends to be low. However, from the societal point of view dairy production goes beyond pure milk production, but contributes to maintain touristic and ecologically valuable areas as well as to increase welfare in rural areas. Consequently, maintaining dairy farms is an important goal of Austrian agrarian policy. But, as public payments will get reduced and milk quota will be abolished, market influence and farm competitiveness will gain in importance.

In order to be competitive dairy farms have to use inputs like labor, capital, land, fuel, fertilizer, pesticides, concentrate feed and purchased roughage as efficient as possible to produce their outputs (Reinhard *et al.*, 2000; Alvarez *et al.*, 2008). The optimal amounts and combinations of these inputs are based on in- and output prices. Especially with the background of increasing prices for land and labor as well as the abolishment of the milk quota the use of rather higher inputs in technology, fertilizer and concentrates seem to be more competitive (Alvarez *et al.*, 2008; Alvarez and del Corral, 2010; Bernués *et al.*, 2011; Kellermann and Salhofer, 2014).

These optima's also depend next to other farm characteristics on farmers' attitudes. Thus some farmers might pursue a system which purposely uses lower inputs farming. This is referred as low-input farming systems tries to achieve high profits by minimizing costs through low inputs in dairy farming, even if overall revenues are small (Alvarez *et al.*, 2008). This is done by optimizing the management and use of internal production inputs and minimizing the use of production external inputs (Pointereau *et al.*, 2008). It clearly shows positive effects regarding environmental efficiency (Bava *et al.*, 2014), especially on the local level (Müller-Lindenlauf *et al.*, 2010). Furthermore shows greater independence with regard to external markets (van der Ploeg, 2003), which show more and more volatility. These reasons might make this system more likely being (more) competitive with (than) high input dairy farming in the future. In order to know this, economic effects of adopting such system have to be calculated.

But there has been no study (at least to the knowledge of the authors) concerning the economic effects of adopting a low-input system in dairy farming. Although low-input farming is analyzed in several papers, the system is defined very differently. Some paper analyze the whole farm and describe low-input farms regarding the low use of labor and external inputs, the low costs for machinery and housing as well as extensive animal husbandry including the maximization of grazing (Beaufoy *et al.*, 1994; Poetsch, 2008), whereas others just focus on dairy production itself (Alvarez and del Corral, 2010; Müller-Lindenlauf *et al.*, 2010; Bava *et al.*, 2014; Kellermann and

Salhofer, 2014), and again others just look on the reduction in the level of external inputs on land (Strijker, 2005).

As dairy production is often (at least in Europe) based on self-produced fodder, the inputs used for land cultivation for producing fodder also have to be taken into account. So it is the aim of this paper to show the effects on microeconomic farm performances of choosing a low-input system (defined as farms with low external inputs in dairy feeding and land cultivation) in comparison to systems with rather higher inputs. In order to do so we firstly aim to identify such low-input systems in the Austrian dairy farming sector and distinguish them from other production strategies. Therefore we use bookkeeping data from specialized dairy farms and the cluster analysis to identify homogenous farm groups regarding use of inputs.

Secondly, we want to analyze the effect of farmer's choice for such a low input system on the economic performance of farms. In this context one has to recognize, that the decision might be endogenous and dairy farmers might select themselves in a low-input system. This is due to that individual optima's of input use also depend on farm individual characteristics like site conditions and other farm characteristics. In order to avoid potentially resulting bias, we control for other potentially influencing factors (such as farm size and site conditions) using the matching method. This procedure allows us to estimate the effects resulting from a selection a low-input system on selected outcome variables. Since volatile input and output prices might influence the competitiveness of farms, we conduct our analysis for a longer time period reaching from 2005 to 2010.

Our paper is structured as follows: Chapter 2 displays the applied methodology as well as the used data basis. In chapter 3 the results of the cluster analysis and the matching procedure is shown and in chapter 4 we draw some conclusions.

2. Data basis and applied methodology

Our analysis is based on the Austrian dataset of voluntary bookkeeping farms. We consider all specialized dairy farms having bookkeeping recordings in the period of 2005 to 2010. These restrictions result in a dataset of 509 dairy farms. As bookkeeping data is only reported on farm level, we also have to analyze production strategies on farm level and cannot exclusively focus on a specific production branches such as dairy farming.

We identify farm strategies by applying a cluster analysis. This technique creates homogeneous farm groups which differ by the predefined cluster variables. From the technical point of view we apply an agglomerative hierarchical clustering, which treats each unit as a single cluster in the beginning and merges units in an increasing hierarchy (Backhaus *et al.*, 2011). As measure of

dissimilarity we use Euclidian distance metric, as linkage criterion the ward's criterion. Our cluster analysis is based on three standardized input variables: Firstly we identify the expenses per livestock units for concentrate feed (expenses for concentrate feed). Secondly we consider depreciation and maintenance costs for machinery as well as for machinery leasing and hired machinery work per hectare utilized agricultural area (expenses for machinery). Thirdly we calculate the energy expenses per hectare, based on costs for electricity, fuel, fertilizer and roughage.

In order to assess the impact of the identified strategies on economic performance we apply Direct Covariate Matching (DCM). Matching basically controls for observable variables assuming that under a given vector of observable variables (Z), the outcome (Y) of one individual is independent of treatment (T):

$$\{Y_0, Y_1 \perp\!\!\!\perp T\} | Z \quad (1)$$

where $\perp\!\!\!\perp$ denotes independence (Sekhon, 2009). As matching is performed in a non/semi-parametric way, it has the considerable advantage of requiring fewer functional forms than regression-based analyses (Lechner, 2002b; Smith and Todd, 2005; Imbens and Wooldridge, 2009). Further advantages of matching are its allowance for arbitrary heterogeneity of the effects, its simplicity and its intuitive appeal (Lechner, 2002a, b) In this paper we consider a certain system selection as treatment. Our matching model is based on the nearest neighbor approach: for each farm of a certain cluster (treated farm) we determine the farm from another cluster (the so-called control unit) with the smallest distance with regard to predefined covariates. DCM identifies control units directly on the absolute value of the covariates. This approach seems to us – as the following description of the matching procedure will show – the most appropriate matching approach with regard to our purposes and data set. The most important argument as to why we favour direct-covariate matching to other approaches (such as propensity score), is that this approach does not require a parametric description of the interrelations between investment support and outcome variables. Accordingly, an exact balance of covariates with little inefficiency is possible and a difference in means is sufficient for the impact analysis (Ho et al., 2007). This characteristic has led Sekhon (2009) to describe the direct-covariates matching approach as the most straightforward matching approach.

The used matching algorithm is a caliper algorithm with replacement. These calipers define the maximum allowed divergence within the matched pair in the case of continuous variables. Exact cut-off values are applied for dummy and multinomial variables. If there is no control unit within the predefined boundaries, the treated farm is dropped from the sample. In the DCM procedure we control for the following observable variables potentially influencing farm income and/or the

decision to select a certain milk production strategy: as proxies for site quality and other site conditions we apply mountain farm cadastre points, mountain farm zone, the share of grassland and the value for taxing real-estate based on government valuation (“Einheitswert”) per hectare land. Furthermore we control for the size of the farm by using utilized agricultural area (UAA).

Based on these covariates, pairs consisting of treated (farms with low-inputs) and controls (other farms) are built, and a control group which is similar to the participant group is generated. Therefore the effects, measured as an average treatment effect on the treated (ATT) can be computed, as the difference of the mean outcome of participants and controls:

$$ATT = \sum_{A=1}^n (Y_A^1) \mid Z/n_A - \sum_{B=1}^n (Y_B^0) \mid Z/n_B \quad (2)$$

where Y_A^1 is the outcome for a treated unit, Z the vector of observable covariates and n_A the number of treated units (A). The second term expresses the same, but for controls (B). A positive (negative) ATT indicates a better (worse) development of outcome variables for treated farms in comparison with control farms. The cluster and matching analysis is based on the average data of the years 2005 and 2006, but differences of treated and control group are also computed for every year in the time period 2007-10. As outcome variables we use work load, farm income per family work unit and share of net worth as outcome variables, in order to show the economic performance of farms.

3. Results

The cluster analysis yields four clusters which show varying combinations of the three cluster variables “expenses for concentrate feed”, “expenses for machinery” and “expenses for energy” (see Table 1): Cluster 1 (small-sized average-input farms) embraces farms with average expenses for concentrate feed per livestock unit but high expenses for energy and machinery per UAA. The high expenses are amongst other factors caused through the rather small size of these farms. Cluster 2 (medium-sized low-input farms) is the biggest cluster, and shows with regard to all three cluster variables mean values below the respective averages. This is due to small total expenses for all inputs, especially for concentrate feed. In average, the Cluster 2 farms are larger than the in Cluster 1 and 4 and smaller than Cluster 3 farms. Farms in cluster 3 (large-sized high-input farms) have the highest expenses for concentrate feed, but relatively low expenses for machinery and energy. In particular machinery expenses per UAA are low due to the large farm size. Cluster 4 (small-sized high-input farms) are with regard to all cluster variables above the average. The high expenses for machinery and energy can be traced back to the small farm size, which allows a bad utilization of their machinery but also force the farms to buy roughage in quite high quantities. The characteristics regarding structure and economics of these clusters are displayed in Table 1. The results indicate that we are able to identify one low-input cluster, which shows low total input, labor

input and milk production. There are three clusters with rather higher input levels, but also higher milk production and output levels. Those three clusters differ in site conditions and farm size. When looking at total input and total output the biggest differences occur between cluster 2 and cluster 4. Cluster 1 and 3 are in between of those two. Even though those differences occur, all four clusters have similar mean values and distributions for the variables farm income and farm income per family labor.

Table 1: Cluster variables as well as structural and monetary values for the four identified clusters from the cluster analysis.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Number of farms	155	174	135	45
Expenses for concentrate feed per LU (€)	262 (80)	179 (46)	333 (84)	298 (101) ***
Expenses for machinery per UAA (€)	696 (241)	468 (146)	448 (132)	792 (344) ***
Expenses for energy per UAA (€)	272 (39)	154 (44)	184 (45)	419 (86) ***
Mountain farm cadastre points	83 (73)	93 (73)	86 (64)	86 (83)
Organic Farming (%)	19 (40)	31 (46)	21 (41)	20 (40)
UAA (ha)	25.52 (10.43)	30.51 (12.17)	34.93 (14.45)	25.27 (12.99) ***
Total livestock units (LU)	36.56 (14.89)	33.72 (12.54)	40.74 (19.43)	41.81 (26.08) **
Dairy cows (LU)	22.35 (9.41)	18.26 (7.18)	23.18 (10.46)	25.35 (16.06) ***
Produced milk (kg)	148164 (76020)	105721 (47369)	164029 (84690)	182504 (133570) ***
Total output (€)	107241 (42201)	89942 (33119)	117828 (48801)	129186 (63376) ***
Total input (€)	69754 (27837)	52036 (21340)	75993 (34760)	88478 (43221) ***
Family labor input (WU)	1.89 (0.5)	1.76 (0.45)	1.91 (0.53)	2.00 (0.65) *
Farm income per family labor input(€)	20680 (13728)	22034 (9747)	22240 (11559)	20945 (12331) ***
Share of net worth on total assets (%)	90 (15)	94 (10)	86 (19)	87 (19)

Numbers in parentheses are standard deviations. LU = Livestock Unit, UAA = Utilized Agricultural Area, WU = Working Unit; Kruskal-Wallis rank sum test is used for equality of distributions: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 1 Source: Own calculations

Since we are interested in effects of choosing a low-input system, we apply the matching analysis for cluster 2 and compare economic values of cluster 2 farms with economic values of their corresponding control farms. As matching (or control) variables we use site conditions and farm

size. Through that, eight farms from the low-input cluster were dropped because no comparable control exists. Whereas matching is applied for the average data of 2005/06, the comparison ranges from 2005/06 to 2010, so that we can assess the development of cluster 2 farms in relation to the development of their control farms. The mean effects are displayed in Table 2.

Cluster 2 farms have a similar size as their control farms; the differences remain small and not significant over the complete observation period. This is contrary for livestock units, dairy cows and milk production where farms choosing the low-input system show significant lower values than their control farms in the initial situation (2005/06). Complementary to these findings we observe a statistical significant lower input of family labor on farms of cluster 2 over the complete observation period. As expected, the group of low-input farms has significantly lower total inputs. The effect is significantly growing over the observation period which is mainly due to increasing input prices. Highest effects occur in the year 2008. This raise comes especially from a higher increase on high-input control farms for concentrate feed and machinery expenses. But on the other hand, there is also a significant effect with regard to total output. The development of this distance is also clearly influenced by the general price developments. With regard to farm income per family labor input results are not statistically significant different between low-input farms and their control farms. A final aspect we want to mention is the share of equity. Even though share of net worth on total assets is generally high in Austrian agriculture, low-input farms still have a higher share of net worth on total assets than their control farm group.

Table 2: Mean effects between low-input-farms and their controls, identified through the matching procedure.

	2005/06 ¹	2007	2008	2009	2010
Number of farms	166	166	166	166	166
Family labor input (WU)	-0.16 (0.66)	-0.15 (0.69)	-0.14 (0.64)	-0.14 (0.64)	-0.13 (0.63)
Farm income per family labor input(€)	-509 (16982)	2786 (19452)	240 (18446)	502 (16298)	-1985 (17909)
Share of net worth on total assets (%)	5 (18)	5 (19)	4 (23)	4 (22)	3 (22)

1) Mean values from the years 2005 and 2006; Numbers in parentheses are standard deviations; LU = Livestock Unit, UAA = Utilized Agricultural Area, WU = Working Unit; t-test is used for equality of means: Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; Source: Own calculations

4. Discussion and conclusion

In our study we use three cluster variables which indicate on one hand the intensity of concentrate use in feeding, on the other hand the external input use in land cultivation on a dairy farm. The applied cluster variables are good indicators for intensity of input use on the total dairy farm, as those clusters with the highest values in the cluster variables show high values in total input

variables and milk production. The cluster analysis identifies three farm groups which have higher expenses for inputs and one group with lower. Next to the differences in those input expenses, the clusters differ in farm size. There are two clusters with relatively small UAA and quite high expenses for machinery and energy per UAA. Even though the UAA in the low-input cluster is relatively big, total input and output are still lower than in all other clusters. All in all, the cluster analysis clearly shows that farms successfully apply different strategies to generate a sufficient family income.

The result from the impact estimation of a low-input system selection indicates that no continuous growth in husbandry is needed to remain competitive, which goes in line with the findings of van der Ploeg (2003). Through non-intensification in husbandry, labor and total input quantity on low-input farms do not increase as much as on their high-input controls, which make them less depending on external and volatile input price markets. van der Ploeg (2003) also describes low-input, or so-called economical, farms rather autonomous to external markets, whereas high-input, or so-called intensive, farms have rather strong external market linkages. Through that low-input farms are even under the price scenarios of 2008 competitive regarding farm income. Furthermore the lower labor input on low-input farms gives those farms the potential to increase non-farm activities. The used approach makes it possible to capture farmers' attitudes and strategic management and its impacts on farm competitiveness in dairy farming. However, there is still high variance in farm income impact estimates, which indicates that there are more variables influencing farm income. However, due to missing data we have either no information on these variables or variables are in general unobservable. It therefore might be necessary to go beyond classical statistical sources and to include qualitative aspects in the analysis by conducting qualitative in-depth research. This type of analysis might also give more detailed information on the individual motivation of farmers to apply a low-input system.

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