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MEASUREMENT OF DYNAMIC EFFICIENCY USING DATA ENVELOPMENT ANALYSIS – FIRST EVIDENCE FROM WEST GERMAN DAIRY FARMS*

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Keywords: efficiency**,** static and dynamic DEA, quasi-fixed inputs, dairy farms

1 Motivation

It is well known that efficiency is measured as the distance between an observed production point and an estimated ideal on the efficient frontier. The majority of efficiency analyses refers to static models and does not take inter-temporal adjustments of quasi-fixed inputs into account. Exceptions are found in NEMOTO and GOTO (1999, 2003); they enlarge a standard Data Envelopment Analysis (DEA) model and combine distance based measurement of efficiency with dynamic aspects of production. This is achieved by considering quasi-fixed inputs in the cost function since these factors cannot be adjusted in the same manner as variable factors. Moreover, they define additional output constraints for the quasi-fixed inputs such that they are treated as outputs at the end of the period and serve again as input in the subsequent period. The overall amount of quasi-fixed inputs is fixed unless the firm increases them, which comes at the cost of lower output quantities. This may be interpreted as additional costs attached to adjusting the overall capital stock. The main advantage of this dynamic DEA model compared to conventional static approaches is that the costs are fully considered. A first application to the agricultural sector is found in SVETLOV and HOCKMANN (2009) for Russian farms. Based on an output oriented model they find evidence that growing farms have a better performance. The objective of this paper is to measure dynamic efficiency of German dairy farms over time using the dynamic DEA approach. We thereby consider the number of cows and land as quasi-fixed inputs since they cannot be adjusted without additional costs measured in terms of forgone output immediately to their long-run optimal level. Milk production is characterized by high capital intensity and asset specifity leading to a high rate of irreversibility of investments thus it is very likely that installation and adjustment costs will occur. Our main intention is to find out whether inefficiency can be traced back to variable inputs or quasi-fixed inputs and hence might be explained by such additional costs attached to the adjustment of the capital stock measured in terms of forgone revenues.

2 Methods and Data

Since the European Union milk quota scheme limits the milk output quantity of each farm we refer to cost efficiency, i.e., the most efficient farm is the one with the lowest cost. Directly taking the dynamic DEA approach developed by NEMOTO and GOTO (2003) the objective of a representative farm is to minimize the costs for variable and quasi-fixed factor use for the annually observed level of output (revenues) over a finite time horizon. For all factors the regular DEA constraints are defined, i.e., the optimized farm-specific input quantities are all linear combinations of the total input quantities of all farms. Analogously, the output constraint restricts the produced output quantity to be expressed as a linear combination of the output levels of all farms in the sample. The dynamics are modelled through a further constraint: the quasi-fixed inputs are restricted such that they are treated as outputs at the end of the period serving as inputs in the following period. The overall amount of quasi-fixed inputs is fixed unless the firm increases its total capital stock. We further allow for variable returns to scale. The model is solved using standard linear programming techniques.[1]

[1] The model is fully programmed in GAMS 23.9 and we use the CBC-solver.

Based on the derived parameters the overall dynamic cost efficiency (ODE) score of each farm is calculated as the ratio of minimized costs and the actual costs for all years. ODE scores reflect the accumulated inefficiency for each farm over time. In order to decompose the overall dynamic cost efficiency, a static part is defined as the ratio of the efficient costs, derived by minimizing the variable costs but taking the observed quasi-fixed input level as given, to the actual cost level. Further, a dynamic part is defined as the ratio of ODE to the static part as described above.

For the empirical application we use a fully balanced panel of 1,213 West German specialized dairy farms from the German Farm Accountancy Data Network (FADN) covering the period 2004-2011.[2] These farms earn least 70 per cent of the total revenue from dairy operations by year. Output is defined as the annual revenues from milk. We define concentrates, electricity and diesel as variable inputs. Quasi-fixed inputs are land and the average number of dairy cows by year. Prices if not available in the FADN accounts are taken from the statistical offices.

3 Preliminary Results

We run the model for each Western Federal States separately due to memory limitations. We find overall dynamic cost efficiency (ODE) scores varying from 0.80 to 0.94 over the states. Further, we find that a sizable share varying from 0.71 to 0.90 of inefficiency is due to the sub-optimal use of quasi-fixed inputs as being measured by the dynamic part of the ODE. Comparing the ODE scores with the scores derived from the standard static DEA model – varying over the Federal States from 0.76 to 0.90 - shows that ignoring the fixity of quasi-fixed inputs in the short-run leads to lower efficiency scores. This result is in line with other studies (cf. NEMOTO and GOTO, 2003) and we conclude that standard static DEA models may underestimate the efficiency.

For one of the main milk producing states, Lower-Saxony, an average ODE score of about 0.86 is found, varying over the range from 0.68 to 1.00 over the 222 farms. This implies that total costs could be reduced without any loss of output level by a maximum of 32 per cent. The efficiency scores of the static part from the ODE are higher with a mean of about 0.98 varying from 0.90 to 1.00. This implies that the main share (85 per cent) of inefficiency can be referred to the sub-optimal use of quasi-fixed inputs. The average efficiency score derived by the conventional static DEA model is about 0.79 and thus, the efficiency is underestimated by ignoring quasi-fixed factors' specifity. The findings for Lower Saxony further reveal that farms with less than 20 cows are more efficient than farms with 20-50 cows, but from then on farm efficiency increases with herd size. The positive relation between herd size and efficiency is also found for other states; but the relatively more efficient small dairy farms with less than 20 cows could not be confirmed for other states.

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