Agglomeration Economies in Ukrainian Dairy Sector: a Marked Point Process Approach

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Abstract— **Even after more than 15 years of transition from plan to market, agriculture in Ukraine still faces many challenges in terms of its structure. The evidence in the literature points to significant heterogeneity of technical efficiency and productivity scores in Ukraine. Moreover, both the recently approved WTO accession, and the ongoing negotiations on a free trade agreement with the EU will require further improvements in productivity and competitiveness at the farm level. Using farm-level data for 2004-2005, we study the presence and possible causes of agglomeration economies in Ukrainian dairy sector. One of the most important results is that there are agglomeration effects in the sector. The performance of dairy farms is influenced by the performance of its neighbors. Furthermore, the dairy farms in the neighborhood of a dairy processor outperform the more distant ones, although the heterogeneity of this effect is substantial.**

Keywords— **Ukraine, dairy farming, order-m frontier, spatial dependence, agglomeration.**

I. INTRODUCTION

Even after more than 15 years of transition from plan to market economy, agriculture in Ukraine still faces many challenges in terms of its structure. The evidence in the empirical literature based on either data envelopment (DEA) or stochastic frontier analysis (SFA) points to significant heterogeneity of technical efficiency and total factor productivity (TFP) scores in Ukraine, with strong regional differences in the distance from the frontier (e.g. Lissitsa and Odening, 2005; Galushko et al, 2004). Moreover, both the recently approved WTO accession, and the ongoing negotiations on a free trade agreement with the EU will require further improvements in productivity and competitiveness at the farm level. However, the drivers underlying the performance and technological progress patterns in Ukrainian agriculture have not been explicitly studied yet. This issue is equally important in the global context. Given increasing world demand for food products, Ukraine is a place where food production could increase significantly at comparatively low environmental cost (FAO/EBRD, 2008).

Using farm-level data for 2004-2005, this paper studies the presence and possible causes the agglomeration economies in Ukrainian dairy sector. Dairy sector has been selected as the dairy farming is one of the main income generating sources for the rural population in Ukraine, while the dairy processing industry demonstrates high growth rates. The agglomeration economies literature suggests different channels through which neighborhood effects and proximity to resources or consumption centers affect performance and technical progress patterns. Agglomeration economies are traditionally divided into 'internal scale economies', 'localization' and 'urbanization economies' (Eberts and McMillen, 1999; World Bank/IBRD, 2009). Internal scale economies are the conventional economies of scale that arise from a more efficient use of fixed costs due to a larger size of operation. Localization economies imply that the performance of one dairy farm might be influenced by the behavior of its neighbors or some local environment. Such spill-over may happen because of the local, sector-specific infrastructure, information, and services that influence the performance of each neighboring dairy farm through the lower transactions costs and easier diffusion of financial, technology and market information. Urbanization economies benefits might arise from a more general livestock or up- and downstream infrastructure, allowing drawing from the same pool of technicians, specific services suppliers applicable for the entire dairy and livestock sector. In particular, in the analysis we expect that location near to milk processing facilities that have been modernized will have a positive impact on the performance of dairy farms.

The paper is organized as follows. Section 2 briefly discuses some stylized facts about the dairy sector of Ukraine. Section 3 focuses on methodology and data issues. Then we proceed with empirical findings, and conclusions wrap up the paper.

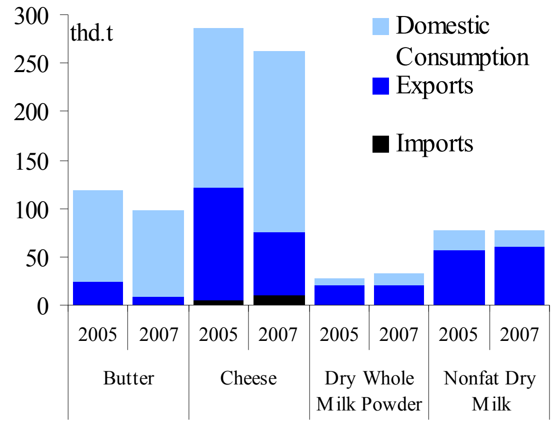
II. DAIRY SECTOR PROFILE IN UKRAINE

Ukraine produces about 13-14 m tons of raw milk per year. About half of the total raw milk supply in Ukraine is processed into dairy products and significant share of these products is exported (Figure 3). However, Ukraine's exports of dairy products have been destined mostly to the former Soviet republics, with Russia accounting for 64% of Ukraine's total dairy exports in 2005. Aside from a temporary interruption caused by a ban on livestock imports (including dairy) imposed by Russia in early 2006, Ukrainian dairy exports have grown steadily in recent years. Ukraine's dairy exports to Western countries are limited, and consist mostly of non-fat and skimmed milk powders for non-human consumption.

The average productivity of cows per lactation is low in Ukraine compared, for example, with 6-7 tons/year in Germany (see Figure 1). On the other hand, some dairy farms are able to reach Western yields levels (Nivievskyi and von Cramon-Taubadel, 2008), reflecting a huge scope for productivity improvements.

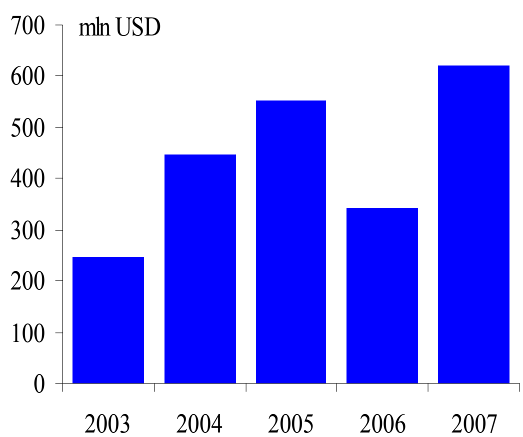
More than 60% of the total milk output is produced in households, and the rest is produced on commercial farms (see Figures 1-2). This low share of commercial farms is a legacy of the transformation from the Soviet planned to the market economy (Zorya and von Cramon-Taubadel, 1999). Households, however, are largely subsistence-oriented and cannot exploit economies of scale in production. They also make it more difficult to capture economies of scale up- and -downstream from dairy farming due to higher costs of collection. The pronounced seasonality and low quality of milk supply from households adds further costs to the value chain (Nivievskyi and von Cramon-Taubadel, 2008). Commercial farms, on the contrary, according to international experience, constitute a basis for competitive retail and export markets. As the growing dairy processing sector in Ukraine will require a stable and high-quality supply of raw milk, we expect that share of households in milk production will decline over the next decade, while commercial dairy farming regains its former dominance. Because of this in the following analysis we focus exclusively on commercial farms ('farms' in the following).

Figure 1 Dairy Production/Export ratio in 2005



Source: USDA

Figure 2 Dairy Export from Ukraine



Source: State Statistic Committee of Ukraine

III. METHODS AND DATA

A. Measurement of Individual Efficiency

The performance of dairy farms is measured by output technical efficiency. Assume n firms operate in the sector at question. Each firm k (k=$\overline{1,n}$) uses p inputs, $x^k = (x_1^k, ..., x_p^k)' \in \Re_+^p$, to produce q outputs, $y^k = (y_1^k, ..., y_q^k)' \in \Re_+^q$. We assume that all n firms have access to the same technology T, defined as $T \equiv \{(x^k, y^k) \ : \ x^k \ can\ produce\, y^k\}$, that satisfies standard regularity axioms of production theory (e.g. Chambers, 1988). Under these assumptions, the output technical efficiency can be measured by the output-oriented distance function $D_o^k : \Re_+^p \times \Re_+^q \rightarrow \Re_+^1 \cup \{\infty\}$, defined as $D_o^k(x^k, y^k) \equiv \inf\{\theta : \ (x^k, y^k / \theta) \in T\}$ (Shephard, 1970). This function measures how far each firm k produces from the best-practice frontier f(xk), the outer bound of the technology set T . The best-practice frontier, and hence distance functions, are commonly estimated using the Free Disposal Hull (FDH) method or the Data Envelopment Analysis (DEA) method (Daraio and Simar, 2007).

The main limitations of the FDH and DEA methods are the curse of dimensionality and sensitivity to outliers (e.g. Kneip et al, 2003; Daraio and Simar, 2007). As we estimate a relatively high dimensional model, these problems are potentially acute in our application. For instance, in one case we estimate 2 outputs and 5 inputs model on 1364 observations. Since the FDH estimator, for example, converges at rate of $n^{-1/(p+q)}$, it is not difficult to show that this nonparametric estimator is roughly equivalent to that of a corresponding fully parametric model estimated with only 17 observations.

As an alternative, partial or so-called robust frontiers can be estimated based on the order-m expected maximum output frontier proposed by Cazals et al (2002). The main idea of this method is to estimate a frontier which does not envelop all the data points. In the output-oriented case, the order-m frontier is defined as $\varphi_m(x) = E\left[\max(Y) \middle| X \le x\right]$. It represents the expected maximum value of the output among a fixed number of m farms drawn from the population of farms with at most the level x of input use. The parameter m can be treated as a trimming parameter. If m = 100, for example, then $\hat{\varphi}_{m,n}(x_i)$ is the estimated maximum possible output among 100 random farms that use no more than input level xi. As m increases, the order-m estimator approaches FDH estimator. These partial frontiers are robust to extreme points. Also since the order-m estimator converges at a rate of $n^{-1/2}$, it does not suffer from the curse of dimensionality problem shared by DEA and FDH estimators. The advantages of the order-m method are summarized in Daraio and Simar (2007).

B. Detecting spatial dependencies between dairy farms and dairy plants

We take a novel approach, considering the locations p of dairy plants as a realisation of a point process Φ, and the locations f of the farms including the efficiencies e as a realisation of a marked point process Ψ. See Stoyan et al. (1995), for instance, for an introduction to the theory and the statistics of point processes. To measure the strength and range of interactions between farms and plants, we generalise the functions in Schlather et al. (2004). That is, we consider the function Efp(h), i.e. the mean efficiency value of a farm given a dairy plant is a distance h apart. Formally, we look at the conditional expectation

$$E_{fp}(h) = E(e \,|\, p \in \Phi, \, f \in \Psi, \text{ and } |f - p| = h) \tag{1}$$

The quantity Efp(h) can readily be estimated by averaging e over all pairs (f, p) with $|f - p| \approx h$ (Schlather et al., 2004). Note that we do not condition on the fact that the respective dairy plant is the nearest one. Further quantities we look at in the study are:

- The variance of the efficiency of a farm given a dairy plant is a distance h away. This quantity measures the homogeneity among the farms around a plant.

$$V_{fp}(h) = E(e^2 \,|\, p \in \Phi, f \in \Psi, \text{ and } |f - p| = h) - E_{fp}^2(h) \quad 2)$$

- The variance of the efficiency of a farm given another farm is a distance h away. This quantity measures the homogeneity among the proximate farms.

$$V_{ff}(h) = E({e_1}^2 \,|\, (f_1, f_2) \in \Psi, \text{ and } |f_1 - f_2| = h) - E_{ff}^2(h) \quad 3)$$

- The variogram (Chiles and Delfiner, 1999), i.e. the mean square difference of the efficiency of two farms. It is a measure of correlation of the efficiencies among the dairy farms.

$$\gamma_{ff}(h) = E((e_1 - e_2)^2 \,|\, (f_1, f_2) \in \Psi, \text{ and } |f_1 - f_2| = h) \quad 4)$$

C. Data and Variables Description

The empirical analysis employs Ukraine-wide farm-level accounting data on input use and outputs for all commercial farms in 2004 and 2005. From this dataset we extracted a smaller dataset containing 5970 and 5067 milk producing farms in 2004 and 2005 respectively. The farms in the smaller dataset produce milk and generate revenues from this; they report non-zero milk production costs as well as positive numbers of cows. Also from different sources (e.g., Holovko, 2003) we have compiled information on the locations of these dairy farms as well as on the locations and investments (between 2001 and 2005) of 391 dairy plants.

The variable of interest is the dairy farms' performance and it is measures as an output technical efficiency. This measure is estimated using order-m frontier approach with a model with five inputs (herd size, agricultural land, labor costs, energy costs, and the aggregate of other costs) and two outputs (milk and revenue from other outputs). See Appendix Table 1 for more detailed description.

As it was already mentioned above, we expect that the behavior of dairy farms is influenced by the behavior of its neighbors or some local environment through lower transaction costs and easier diffusion of technical and market information. This view is consistent with Mansfield's (1963) models and others that viewed technical progress as a process of imitation wherein contacts with others led to the spread of technology (see Sunding and Zilberman, 2001; p.231). We detect the spatial dependence between the performance measures among the dairy farms using the tools (see expressions 3 and 4) introduced in the previous section.

Links between dairy farms and processors might give rise to urbanization economies (Paul, 2003). To secure a dependable supply of high quality raw milk, a processor might want to provide farms with extension, cooling tanks or some other assistance. Dairy plants that have invested in new processing equipment will be especially interested in securing a stable supply of high-quality milk. Hence, we hypothesize that location near to dairy plants that have been investing will have a positive impact on dairy farms performance. For each dairy plant with its total investment level we assign one to the dummy variable if investment activities on the plant were observed over 2003-2005. We detect this link between dairy farms and processors using the tools (see expressions 1 and 2) introduced in the previous section.

IV. EMPIRICAL FINDINGS

A. Dairy farms' performance and technical progress results

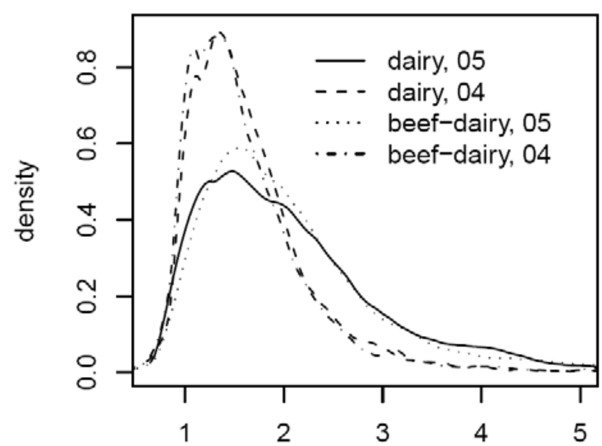
To begin we test whether all dairy farms have access to the same technology. From the literature on the livestock sector in Ukraine (e.g. Sabluck, 2003) we know that mainly dairy and beef-dairy cattle farming prevail in Ukraine. A dairy cattle farming is mainly located in the North-Western Forest agro-climatic zone where enough rich fodder is available, while beef-dairy farming is located on the rest of the territory, i.e. in the Forest-Steppe and Steppe zones to the South and East. To test for technological heterogeneity between the two zones (Forest versus pooled Forest-Steppe and Steppe zones), we estimate flexible trans-log production functions for the Forest, pooled Forest-Steppe and Steppe agro-climatic zones, as well as pooled model for all two zones1. The null hypothesis of poolability across zones is rejected using a LR-test at 1% significance level2. So in the following we perform a separate analysis for the farms in the Forest zone and for the farms in the Steppe and Forest-Steppe zones (dairy and beef-dairy zones/technologies in the following).

Dairy farms in Ukraine usually produce multiple outputs. So the incentives for efficient dairy farming might vary depending on, for example, farm specialization. To account for this, in the following we estimate efficiency based on 2 outputs (milk in physical units and revenue generated by other outputs) and 5 inputs (labour, energy and other production costs, as well as the herd size and agricultural land; see Appendix Table 2 for details). Using this 7-dimensional model, we first check our dataset for outliers using the Simar (2003) method. The percentage of the identified outliers identified in this manner is far less than 1% in both 2004 and 2005.

Next, we compute order-m efficiency scores for the dairy and beef-dairy groups of farms in 2004 and in 2005 using the FEAR package in R (Wilson, 2008). The important point here is choosing an appropriate value of m. Since we have a relatively large-dimensional problem, the approach suggested in Cazals et al (2002) is not really informative3 because almost all farms in the two groups have FDH efficiency estimates equal to 1. So in the order-m frontier framework almost all farms lay above the frontier and the percentage of outlying farms approaches 0 as m increases, but efficiency scores approach 1. That is why we follow the approach of Wheelock and Wilson (2003) and study the distributions of order-m efficiency estimates as m ranges from 10 to 300. Based on this we chose m = 15 and m = 40 for the dairy and beef-dairy zones respectively, which is about 1% of the sample size in the corresponding group.

Figure 5 shows the distributions of order-m efficiency estimates. The estimated distributions look very similar for both groups of farms in both periods. In 2005 there was a noticeable shift/improvement of efficiency distributions in both groups compared to 2004. The 2005 distributions become wider with more probability mass (more farms) in the higher efficiency region.

Figure 3 Order-m efficiency estimates distributions



Source: own calculation.

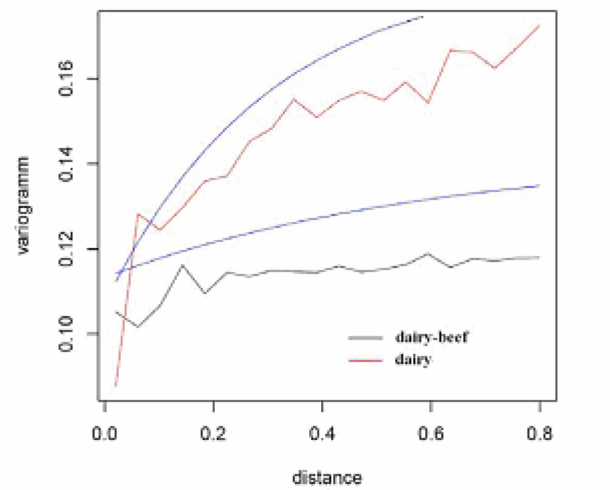
B. The results of detecting agglomeration economies

In this section we present the results of analyzing the agglomeration effects in the dairy sector of Ukraine using the marked point process approach. Figure 6 shows the results of estimating the variograms $\gamma_{ff}(h)$ of dairy farms efficiency scores. Both plots on the figure clearly demonstrate the existence of spatial dependence between the (logged) efficiency scores of the dairy farms. This finding confirms our expectation in the beginning that the performance of a dairy farm is influenced by the behavior of its neighbors. Interesting to note that the

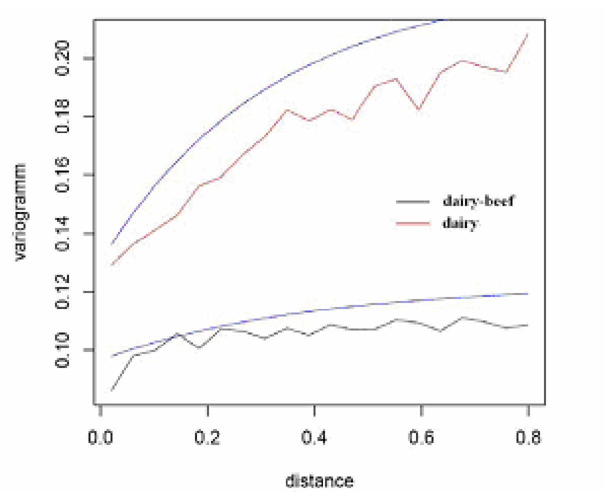
1. Our database contains information on milk output and specific inputs (herd size, gross variable costs, and labor) at the farm level. With these variables we are able to estimate a parametric production function to test for the presense of a unique technology. In subsequent steps, however, we employ the non-parametric efficiency estimation techniques outlined above (m-order) to better account for multi-output nature of the dairy farms in Ukraine.
2. See Brümmer et al (2002) for details of the test.
3. Cazals et al (2002) and Simar (2003) propose choosing m based on the percentage of observations lying outside the frontier, and m should be a relatively small number.

range of spatial dependency of efficiency scores differs remarkably across zones.

Figure 4 Variograms of the (logged) efficiency values of the dairy farms depending on the distance to another farm



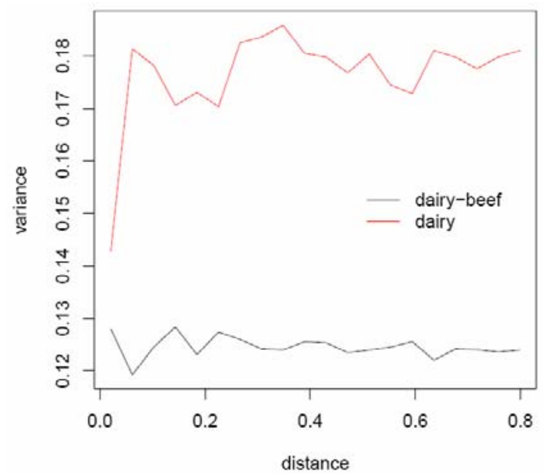
a) 2004



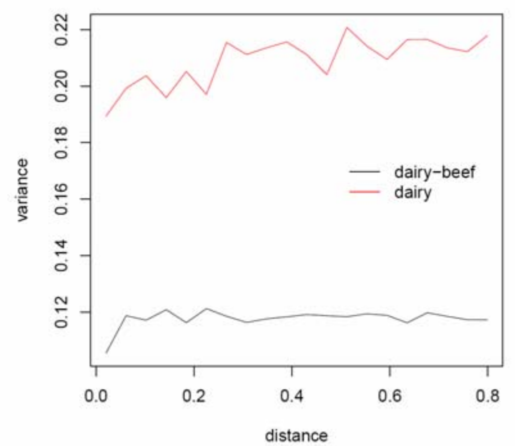
b) 2005

Source: Own estimations

Figure 5 Variance of the (logged) efficiency values of the dairy farms depending on the distance to another farm



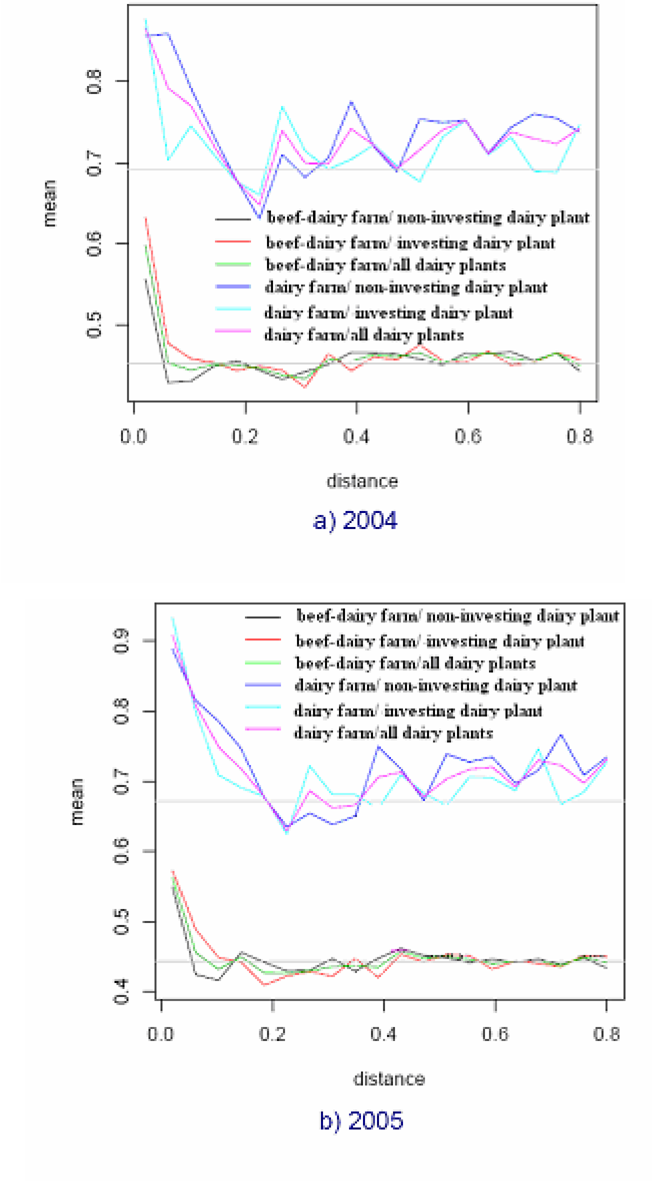
a) 2004



b) 2005

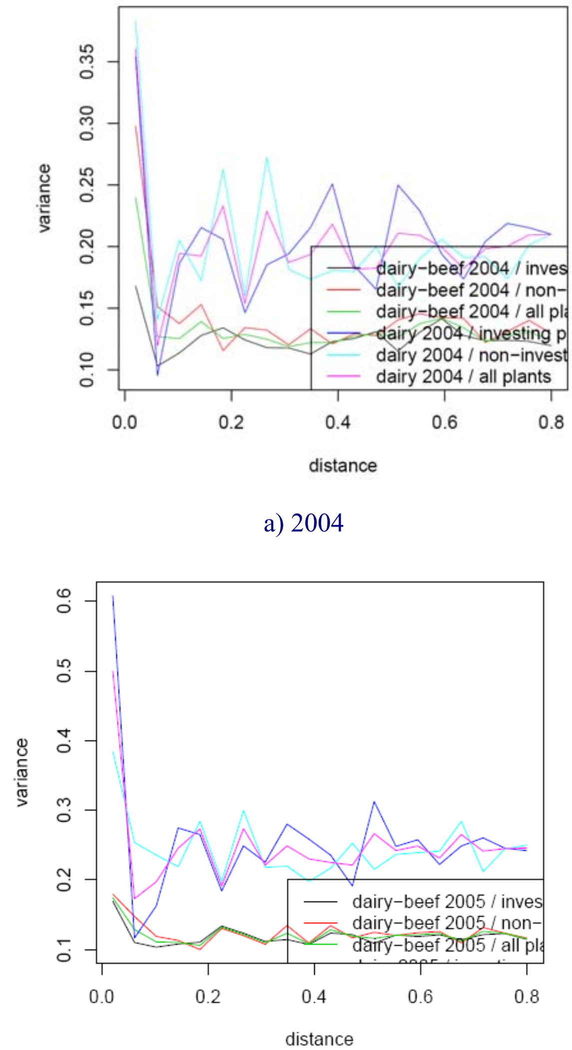
Source: Own estimations

Figure 6 Mean efficiency value (logged) of the dairy farms depending on the distance to a dairy plant



Source: Own estimations

Figure 7 Variance of the (logged) efficiency values of the dairy farms depending on the distance to a dairy plant



a) 2004

b) 2005

Source: Own estimations

The blue curves on the plots are the fitted exponential variograms using maximum likelihood estimation method. Moreover, as the plots on Figure 7 shows, the variance $V_{ff}(h)$ of the efficiency scores is slightly smaller for the very proximate farms.

Figure 8 plots the mean efficiency function $E_{fp}(h)$ for both zones. Both plots demonstrate a remarkable increase of the (logged) efficiency scores in the neighborhood of a dairy plant. The curves on the plots show higher efficiency scores (on average) up to about 10 km for the beef-dairy farms, and up to 20 km for the dairy farms. Moreover, both plots show that this relationship is persistent over time. However, both plots show no impact of the investment activity of plants. The 'non-investing plants', 'investing plants', and 'all plants' curves show no remarkable difference in the behavior. This might witness about the quality of the investment data. Remember that for each dairy plant with its total investment level we assign one to the dummy variable if investment activities on the plant were observed over 2003-2005. We do it in the analysis, since we can only assume that a certain share of the investment funds is allocated to dairy farms.

Overall, however, our finding at least shows that the location near to milk processing facilities has a positive impact on the performance of dairy farms. Also, as Figure 9 it demonstrates, the variance of efficiency scores increases remarkably in the neighborhood of a dairy plant. This points to a significant degree of heterogeneity among the farms.

V. CONCLUSIONS

The successful completion of WTO negotiations, combined with expected FTA negotiations with the EU, will take Ukraine's agriculture into a new phase of its development. These two big challenges imply further significant structural changes in Ukraine's agriculture sector as well as adjustments at the farm level to achieve greater efficiency and productivity levels. Using the dataset of 11,353 farms producing raw milk over the period 2004-2005, we analyse the presence and possible causes of agglomeration economies in the dairy sector of Ukraine. We differentiate between the performance spillovers due to 'location and urbanization economies'. Location economies arise from farms' proximity and some local, sector-specific infrastructure, information and services, while urbanization economies arise from a more general livestock infrastructure, as well as from up- and downstream linkages. In the later context we test whether the location near to dairy plants that have been investing has a positive impact on dairy farms performance.

In the empirical analysis we measure the performance of dairy farms by order-m output technical efficiency. Also we differentiate between two technologies (dairy and beef-dairy technologies) that are identified according to agro-climatic zones. The distributions of the resulting estimated efficiency scores demonstrate a noticeable improvement in the performance between 2004 and 2005. Further empirical analysis shows that the performance of dairy farms is influenced by the performance of its neighbors. And the closer farms demonstrate less variation in the efficiency scores. Furthermore, the dairy farms in the neighborhood of a dairy processor outperform the more distant ones, although the heterogeneity of this effect is substantial.

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APPENDIX

Annex Table 1: Order-m frontier estimation - summary statistics

		Dairy zone				Beef-dairy zone			
	Units, description	Mean	Std.	Min	Max	Mean	Std	Min	Max
2004:									
Labor costs	'000 UAH, own labor costs	191.3	266.6	4.0	5394.0	429.3	531.7	2.0	13517.0
Energy costs	'000 man-hours, includes: electricity and fossil fuel costs	187.8	284.8	0.1	4313.5	447.6	556.0	2.4	15789.0
Other costs	'000 UAH, includes: purchased feed, seeds, fertilizers, agrochemicals, amortization, side labor costs etc	458.1	766.1	1.7	10106.0	1331.5	2702.5	2.5	120421.1
Agricultural land	ha	1320.8	3663.9	5.0	143498.0	2471.4	2559.9	15.0	91121.0
Herd size	Number of cows	129.0	139.3	2.0	2477.0	175.7	270.5	1.0	2400.0
Milk	tons	2725.9	4589.7	24.0	82597.0	4548.4	7623.3	11.0	167471.0
Other outputs	'000 UAH, revenue	664.0	1317.6	2.3	18474.2	1999.5	3057.2	3.8	80935.0
2005:									
Labor costs	See above	251.9	389.3	2.9	7313.0	561.5	847.6	5.3	22967.2
Energy costs	-//-	243.5	359.6	1.3	4126.2	586.6	867.7	1.0	22885.9
Other costs	-//-	519.2	1031.8	2.5	16304.0	1504.5	3241.9	3.0	122029
Agricultural land	-//-	1269.8	1246.1	1.0	18126.0	2566.2	3100.4	10.0	88612.0
Herd size	-//-	131.6	150.0	2.0	2705.0	174.6	209.6	1.0	5374.0
Milk	-//-	3315.5	5716.3	18.0	109612	5427.5	9292.2	27.0	197911
Other outputs	-//-	757.6	1609.1	1.5	21591.2	2342.9	3642.2	9.0	96154.2

Source: Own presentation.