Price Support, Efficiency and Technology Change of Ukrainian dairy farms: Spatial dependence in the components of productivity growth

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Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

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. In particular, both the recently approved WTO accession, and the ongoing negotiations on a free trade agreement with the EU will require improvements in productivity and competitiveness at the farm level. The evidence in the literature based on either data envelopment (DEA) or stochastic frontier analysis (SFA) in Ukraine points to significant heterogeneity of technical efficiency and TFP scores. However, the drivers underlying these patterns have not been explicitly studied yet. Using farm-level data for 2004-2005, this paper investigates the determinants of productivity growth in Ukrainian dairy farming. The results demonstrate significant spatial dependency in pure efficiency and technological components, meaning essentially 'imitating' behavior of the neighboring farms in their efficiency and technological progress. Price supports demonstrate negative impact on efficiency, and, however, much weaker positive impact on the technology progress of relatively small farm.

INTRODUCTION

Even after more than 15 years of transition from plan to market, agriculture in Ukraine still faces many challenges in terms of its structure. In particular, both the recently approved WTO accession, and the ongoing negotiations on a free trade agreement with the EU will require improvements in productivity and competitiveness at the farm level. The evidence in the literature based on either data envelopment (DEA) or stochastic frontier analysis (SFA) in Ukraine points to significant heterogeneity of technical efficiency and TFP scores, with strong regional differences in the distance from the frontier, as well as of technical change (e.g. Lissitsa and Odening, 2005; Galushko et al, 2004). However, the drivers underlying these patterns have not been explicitly studied yet. Using farm-level data for 2004-2005, this paper investigates the determinants of productivity growth in Ukrainian dairy farming. Dairy farming has been selected because it is one of the main income generating sources for the rural population, while the fast growing dairy processing needs stable and relatively cheap resource supply. Moreover, in a view of increased world demand for livestock products, Ukraine is seen as a place where supply could increase significantly (FAO/EBRD, 2008).

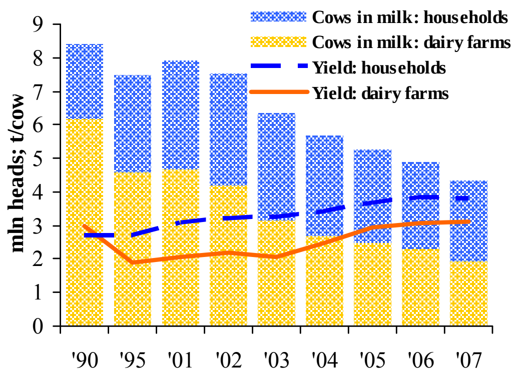
Particular attention is drawn to the impact of price supports and location on efficiency and productivity growth. Subsidies are of considerable interest to policy making in Ukraine in the light of WTO commitments as for the domestic support ceiling. On the other hand, the 'location economies' literature (Eberts and McMillen, 1999; Sunding and Zilberman, 2001) suggests different channels through which the neighborhood and proximity to the resources or consumers pools affects productivity growth and technology diffusion patterns. In particular, it is hypothesized that location near to milk processing facilities that have been modernized, will have a positive impact on productivity growth, mainly via improvements in technologies.

This paper is organized as follows. Section 2 briefly discuses some stylized facts about the dairy sector of Ukraine. Section 3 focuses on the methodology and data issues. Then we proceed with empirical findings, and section 5 wraps up the paper.

2. DAIRY SECTOR PROFILE IN UKRAINE

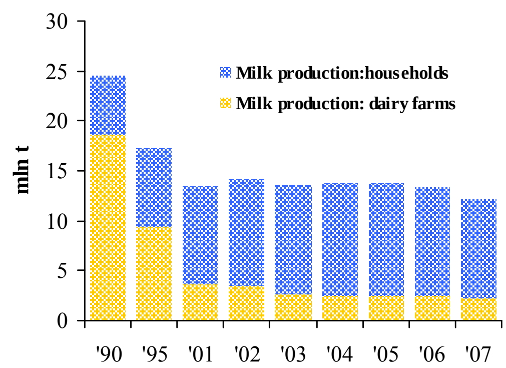
Ukraine annually produces about 13-14 m tons of raw milk. More than 60% of this amount is produced in households and the rest is on farms (see Figures 1-2), compared to only 24% in 1990. The rapid contraction of the share of commercial dairy farms ('farms' in the following) was a result of the transformation from the Soviet planned to the market economy. The under- and unemployed rural population, often members of former collective farms, used subsistence production of milk as a 'social buffer' against transformations taking place in the transition period.

Figure 1 Cows in milk and yields development in Ukraine



Source: State Statistic Committee of Ukraine

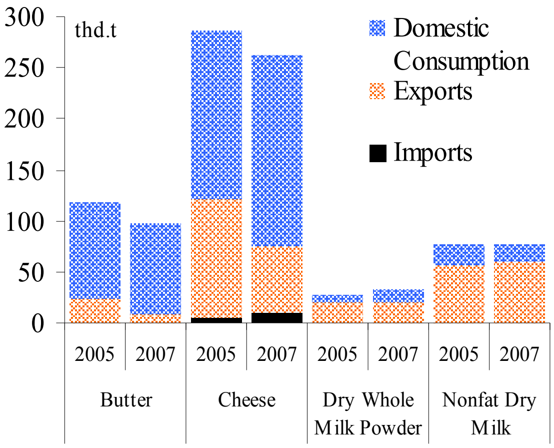
Figure 2 Fluid milk production development in Ukraine



Source: State Statistic Committee of Ukraine

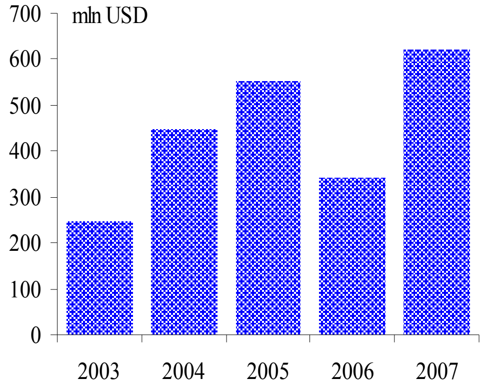
Productivity of cows per lactation is very low in Ukraine, comparing to, for example, 6-7 tons/year in Germany (see Figure 1). This reflects the huge scope for productivity improvements in Ukraine. In terms of geographical location, households and dairy farms reveal no clear 'belts' or 'zones' of production. A group of 'core' production regions is located in the North-Central-West (Nivievskyi and von Cramon-Taubadel, 2008).

Figure 3 Dairy Production/Export ratio in 2005



Source: USDA

Figure 4 Dairy Export from Ukraine



Source: State Statistic Committee of Ukraine

About half of the total raw milk in Ukraine is processed into the dairy products and a significant share of it is exported (Figure 3). However, Ukraine's export of dairy products has been destined mostly to former Soviet republics, with Russia accounting for 64% of Ukraine's total dairy exports in 2005. Since early 2006, when Russia banned imports of Ukrainian livestock products (including dairy), this share decreased considerably. Ukraine's dairy exports to Western countries are limited, and consist mostly of non-fat and skimmed milk powders used for non-human consumption.

Due to the lack of the data on household, in the following we focus exclusively on dairy farms.

3. METHODS AND DATA

3.1 Measurement of Individual Efficiency and Productivity Growth

In this paper the individual efficiency is estimated using *Farrell* (Farrell, 1957) **output oriented technical efficiency (TE)** and it is defined as $TE(x,y) \equiv \max\{\theta : (x,\theta y) \in T\}$, where T is a technology accessible to all enterprises. Whenever $TE(x,y)=1$, firm k is asserted to be *technically* efficient, otherwise, when $TE(x,y)>1$, it is *technically* inefficient. TE scores are estimated using Data Envelopment Analysis (DEA) method. TE of a firm can be represented in percentages, i.e. $[1/TE(x,y)]*100\%$ and its inefficiency score would then be $[1-1/TE(x,y)]*100\%$.

Productivity growth is measured by Malmquist Output-Based Productivity Index (TFP) and decomposed using Simar and Wilson (1998) methodology:

$$TFP_{ts}(x_k^s, y_k^s, x_k^t, y_k^t) = \underbrace{\left(\frac{TE^s(x_k^s, y_k^s | VRS)}{TE^t(x_k^t, y_k^t | VRS)} \right)}_{=\text{PEC}} \times \underbrace{\left(\frac{TE^t(x_k^t, y_k^t | VRS) \big/ TE^t(x_k^t, y_k^t | CRS)}{TE^s(x_k^s, y_k^s | VRS) \big/ TE^s(x_k^s, y_k^s | CRS)} \right)}_{=\text{SEC}}$$

$$\times \underbrace{\left(\frac{TE^t(x_k^t, y_k^t | VRS)}{TE^s(x_k^t, y_k^t | VRS)} \times \frac{TE^t(x_k^s, y_k^s | VRS)}{TE^s(x_k^s, y_k^s | VRS)} \right)^{1/2}}_{=\text{PTC}}$$

$$\times \underbrace{\left(\frac{TE^s(x_k^t, y_k^t | VRS) \big/ TE^s(x_k^t, y_k^t | CRS)}{TE^t(x_k^t, y_k^t | VRS) \big/ TE^t(x_k^t, y_k^t | CRS)} \times \frac{TE^s(x_k^s, y_k^s | VRS) \big/ TE^s(x_k^s, y_k^s | CRS)}{TE^t(x_k^s, y_k^s | VRS) \big/ TE^t(x_k^s, y_k^s | CRS)} \right)^{1/2}}_{=\text{CST}}$$

Pure Efficiency Change (PEC) component captures the change in the ‘pure’ technical efficiency between times s and t. The rest components reflect the change in production unit technology and its properties. Scale Efficiency Change (SEC) demonstrates whether production unit approaches or moves away from its optimal production scale, i.e. from the Constant Returns to Scale technology (CRS). Pure Technological Change (PTC) component measures the pure change (shift) of production technology. For these three components values greater than 1 indicate positive change, and negative otherwise. Finally, Change in the Scale of Technology (CST) indicates the change in the shape of the reference technology between times s and t. If CST <1, then production technology approaches CRS, and diverts otherwise.

3.2 Modeling the Spatial Dependence in Productivity Growth Components

In modeling the individual TFP scores to some explanatory variables, we explicitly allow for their spatial dependence that stems from hypothesized ‘location economies’. A standard tool for addressing this is the spatial lag model (SAR) (Aselin, 1988), where the observed outcomes are simultaneously determined with outcomes of the neighboring observations:

$$y = \rho \cdot Wy + X\beta + \varepsilon, \quad E(\varepsilon) = 0, \quad E(\varepsilon\varepsilon') = \sigma^2 I_n,$$

where y is a $n \times 1$ vector of observations on the dependent variable (TFP and its components in our case), W is a spatial weight matrix, X is a $n \times k$ design matrix with ones in the first column, and Wy is a spatial lag. The spatial weights matrix, W, is a positive and symmetric matrix which specifies neighbors for each observation; $w_{ij} = 1$ when i and j are neighbors, and $w_{ij} = 0$ otherwise. By convention, an observation is assumed not to be a neighbor to itself, so the diagonal elements of the weight matrix are set to zero ($w_{ii} = 0$). The spatial weights matrix is row-standardized so that the sum of elements in each row is one.

3.3 Data and Variable Description

The empirical analysis employs a Ukraine's farm level 2005-2004 accounting data on input-output, subsidies, and location information taken from the State Statistics Committee of Ukraine. The dataset contains 5970 in 2004 and 5067 milk producing farms in 2005. The other piece of data contains information on locations, processing capacities, and investments

(2001-2005) of 463 dairy plants, being compiled up from different sources (e.g., Holovko, 2003).

Dependent Variable

The dependant variables are the components of the TFP index, calculated using DEA model with one output (milk) and three inputs – cows herd size, milk production costs and labor.

Spill-over and Agglomeration variables

Localization economies (Eberts and McMillen, 1999) imply the existence of spillover and agglomeration effects in the sector. This view is consistent with Mansfield's (1963) models and others that viewed technology diffusion as a process of imitation wherein contacts with others led to the spread of technology (see Sunding and Zilberman, 2001; p.231). The spatial lag (S*pilloverEff*) is meant to proxy the existence of such spill-over effects.

The total county's farm livestock receipts less total raw milk receipts (*Rlivestock*) and county's total marketed silage (*Rsilage)* proxies agglomeration economies due to more general dairy and livestock or input-output supply infrastructure (Paul, 2003; Roe et al, 2002). 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. So the location near to investing dairy plants might have a positive impact on productivity growth. The dummy variable *InvDairy* will reflect whether the identified closest plant(s) invested or not over 2003-2005.

New technologies are more likely to be adopted near market centers where professional support is easily available, e.g. extension centers, dealers, and complementary inputs access (Sunding and Zilberman, 2001; p.249). Distance from a farm to the closest region center (*DistRegCenter*) is meant to capture this relationship.

Market access and Market Competition

Technical change in farms might be driven by food processing demand and consumers' market structure (Paul, 2003). The total number of dairy processing pants (*Dairies50km*) within 50 km from a dairy farm[1] measures the local competition among dairy plants for the raw milk. Also a-la Herfindahl index is included, were the market shares are approximated with the dairy plant capacities shares within 50 km from a dairy farm (*Cap50km*). Lower values of the index imply more competition among dairy plants for the raw milk.

Better market access has a positive impact on agricultural innovation process (Feder et.al., 1985). It is proxied by the distance to the nearest dairy plant (*MinDistance*) and by capacity of the closest plant(s) (*CapClosest*).

Farm Specific Variables

The threshold models of technology diffusion, first introduced by David (1969), conclude that only farms with a size greater than a certain threshold farm size will adopt innovations (Sunding and Zilberman, 2001; p.250). Herd size (*Herd*) proxies the farm size, and herd size squared (*HerdSqr*) allows us identifying the threshold farm size value.

[1] This is the average procurement radius of dairy plants in Ukraine (Popova, 2007: p.129)

Increase in farm productivity is partly associated with increased specialization (Chavas, 2001; p.275) via more focused application of managers' skills. The percentage of raw milk receipts in the total farm receipts, will proxy specialization (*Specialization*).

As Pingali (2007; p.2795) shows, the aggregate area expansion might be the driving force for a transition to more intensified mechanization thus generating benefits on productivity side. The total farm arable land (*ArableLand*) variable is included to tests for this.

Human capital is often identified as important factor for productivity growth (Huffman, 2001; Feder et.al., 1985). Therefore we included the unit production costs for grain (*FeedCost)*, assuming lower unit costs reflecting better quality of the management on a farm. The total amount of non-marketed silage and hay on a farm (*Fsilage, Fhay*) is meant to reflect the impact of feed availability on productivity growth.
Technical efficiency for 2004 (TE_{04}) is included to account for the starting positions of the farms and to see whether there is a productivity convergence among farms.

Price Supports

The whole literature starting from Leibenstein (1966) points to the negative impact of this support on efficiency, mainly via weakening the managerial efforts (e.g., Bergsman, 1974; Balassa, 1975; Lassaad, 1994; Giannakas et al., 2001). Kalaitzandonakes and Bredahl (1993, 1994) argued that protection may positively influence productivity growth for low income industries via encouraged investments and technical progress; however, for the high income industries, protection is likely to have an adverse effect by generating technical and scale inefficiencies. On the other hand, recently McCloud and Kumbhakar (2007) have found that subsidy has a positive impact on technical efficiency. Sunding and Zilberman (2001; p.250) emphasize on different mechanisms through which price supports impact the technology adoption of farms of different sizes (e.g., via better credit access when the ability to obtain credit depends on expected income). We included the total amount of subsidies a farm received in 2004 and 2005 (S*ubsidy*) and interacted it with farm's herd size (*Herd×Subsidy*), to differentiate the impact of the price support on farms of different sizes.

4. EMPIRICAL FINDINGS

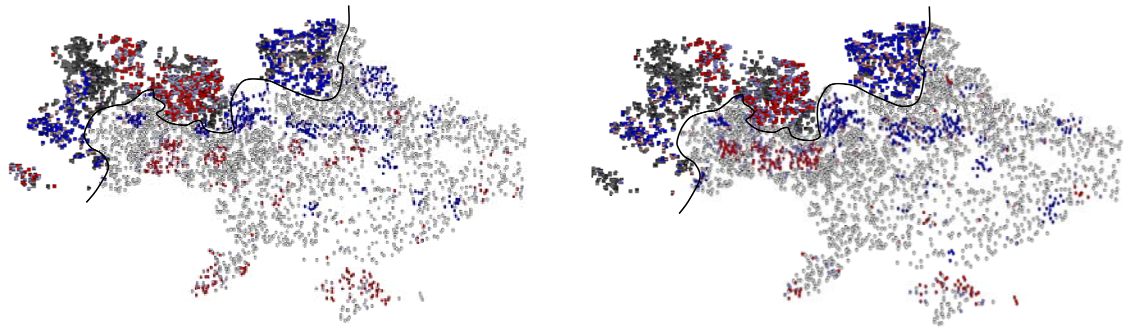
4.1 Spatial Clustering in Productivity Growth Components

The estimates of the simple Cob-Douglas production function identify two technologies (Table 1). They are beef-dairy cattle farming technology, and it is prevalent in the Steppe and Forest-Steppe (Non-Forest) agro-climatic zones; and a dairy cattle farming is prevalent in the Forest zone. In the following we perform the separate analysis for farms in each zone.

DEA frontier models, by construction, are very sensitive to the measurement errors. Using semi-automatic methodology proposed by Simar (2003), we cleared both subsets from the most extreme observations. In the annexed Table 2 we present the number of observations left for the technical efficiencies (TE) and TFP indexes estimations.

Figure 5 shows clusters of the TE scores, where observations are shaded in different colors to demonstrate whether the nearest neighbors have sufficiently similar (at 5% significance level) TE scores (Anselin, 1995). The Forest (North-West part) and Non-Forest zones are separated with the curly line. It is interesting to notice that the high efficiency clusters (blue dots) are mostly concentrated in the West and North-Center of Ukraine, while low efficiency ones (red dots) are mostly in the North-West and South, and this pattern preserves over time. The means of the technical efficiency scores distributions for both regions are about 2, or 50% for 2004 and 2005.

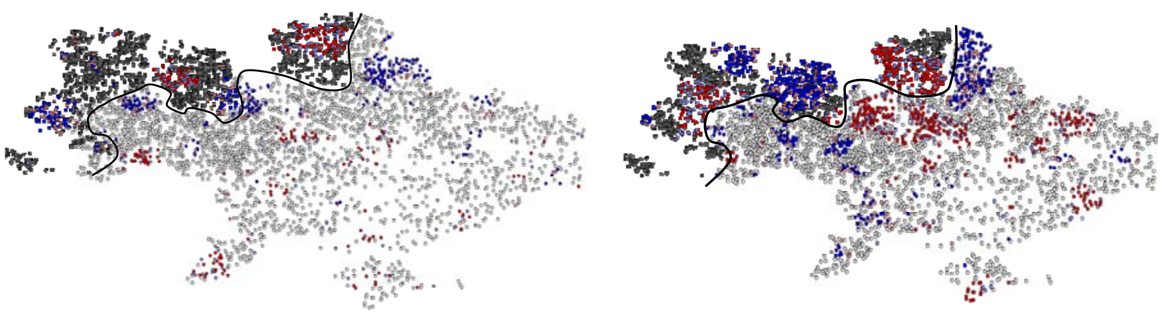
Figure 5 Spatial Clustering of Technical Efficiencies scores for 2004 and 2005



Source: own exposition using GeoDa software.

Notes: blue dots denote neighboring observations with significantly similar high efficiency scores; red dots denote neighboring observations with significantly similar low efficiency scores; the curly line approximately separates Forest (North-West part) from Non-Forest farms.

Figure 6 Spatial Clustering of Pure Efficiency and Technological Changes



Source: own exposition using GeoDa software.

Notes: blue dots denote neighboring observations with significantly similar low PEC or PTC scores; red dots denote neighboring observations with significantly similar high PEC or PTC scores; the curly line approximately separates Forest (North-West part) from Non-Forest farms.

PEC clusters in Figure 6 show that two neighboring regions (Chernihiv and Sumy, in the North) might experience an opposite efficiency changes. High PTC clusters (red dots) are located in the regions around the capital of Ukraine, Kyiv. These are, actually, the regions with high efficiency cluster in figure 5.

4.2 Model Selection and spatial lag model results

Spatial weight matrix is defined based on k nearest farms criteria (W_1). We choose k equal 4 based on the lowest AIC and BIC value. Table 3 shows the results of the SAR model with W_1. Another specification of the spatial weight matrix, used for consistency check, is based on distance-band criteria (W_2), when every farm has at least one neighbor (see Table 4).

The estimated coefficients on the spatial lag terms S*pilloverEff* demonstrate significant spatial dependency across all PEF and PTC models, meaning essentially that dairy farms, to some extent, ‘look over the fence’ and ‘imitate’ their neighbors. However, the magnitude of the estimated spatial spillovers is much bigger for models with W_2.

Distance to the closest region center (*DistRegCenter*) is strongly significant only for the PTC models, confirming the importance of proximity to the market centers for the technology diffusion. The effect of *Rlivestock* and *Rsilage* variables is rather blurred and so far difficult to summarize.

The location near to investing dairy plants (*InvDairy*) seems positively affects the scale components of the productivity growth. Dairy plants might help with extension or some equipment (e.g., cooling tanks) to fine-tune the scale of farms’ operation.

Although the market access variables (*MinDistance* and *CapClosest*) turned out to have expected signs, however, they are not significant in most of the cases. The significance of *CapClosest* in PTC model implies channeling the impact on productivity growth via technology improvements.

The increased local competition among dairy plants (*Cap50km, Dairies50km*) for the raw milk consistently shows a significantly negative impact on farms’ PEC. This might happen via weakening the farmers’ managerial efforts, since they don’t have to fight for the market in the environment of increased competition for their produces, as they would do otherwise.

The impact of the herd size (*Herd*) confirms the conclusions drawn from the threshold models of technology diffusion. Combining the estimated coefficients in the PTC models suggests that the farms with a size greater than 200-300 cows start making technological progress. The other channel of the impact is the scale components of productivity growth; however, the impact is opposite to the PTC case, and is rather intuitive from the production theory. For instance, the farms with a large herd size most likely have deceasing returns to scale technology. A further increase of the herd is likely to further reduce the farm’s returns to scale. The opposite is observed for the farms with increased returns to scale technology. The calculated turning points lie in the range 200-400 cows across the scale models.

Specialization, as expected, positively affects technology adoption by dairy farms across all PTC models. For example, the increase of the raw milk in the total farm receipts by 13% from the mean, increases PTC index by 0.7% for the Forest zone farms. Surprisingly, the impact of specialization is opposite and much stronger in the PEC case.

Arable land, as expected, contributes to productivity growth mainly via technological progress. Reduction of grain production costs (*FeedCost*),as expected, positively influences the scale and PTC components of productivity growth, but surprisingly it negatively affects PEC. Probably another proxy for the farm managerial quality has to be constructed.

The silage availability is significant mostly across PTC and PEC, where it positively contribute to PTC and negatively to PEC. In case of PEC the negative impact might be explained that the need in own feed production essentially broadens the scope of manager activities, thus probably less focused dairy farming would loose on the efficiency side.

The significant negative sign at TE_{04} across all PEC models implies divergence of the farms’ efficiencies, so that inefficient farms continue to stay inefficient. However, farms show convergence terms of the technology and scale. This finding probably reflects the glaring problem with farm management in Ukraine (von Cramon-Taubadel et. al., 2008).

Price support channels mainly via PEC and PTC components of productivity growth. For example, the increase of price support by USD25,000 at the mean heard size, decreases the pure efficiency of Forest zone dairy farms by almost 7%. This essentially confirms

Leibenstein (1966) thesis. On the technology progress side the impact of subsidies is much weaker. We observe a positive impact at the mean herd size, and this effect diminishes as the herd size increases.

CONCLUSIONS AND FURTHER STEPS

The successful completion of WTO negotiations, combined with expected FTA negotiations with the EU, take Ukraine's agriculture into a new phase of its development. These two big challenges imply significant structural changes in Ukraine's agriculture sector as well as adjustments at the farm level to achieve greater efficiency and competitiveness. Using the country-wide farm-level accounting data for 2004-2005, we study the determinants of the dairy farming productivity growth in Ukraine, with a particular emphasis on the locational economies (Eberts and McMillen, 1999) and price supports.

The spatial analysis of TFP components reveals consistent over time clusters of high performers in the North-Center and in the West. The spatial interaction of dairy farms generates spillover effects mainly via PEC and PTC, as evidenced by positive and significant spatial lags in the data. Farmers to some extent 'look over the fence' and 'imitate' their neighbors. The location near to investing dairy plants contributes to productivity growth mainly via its scale components. The models also confirm the importance of proximity to the market centers and of market access for the technology diffusion. On the other hand the increased local competition among dairy plants for the raw milk shows a negative impact on farms' efficiency.

Price support influences productivity growth mainly via PEC and PTC components. It negatively influences efficiency of the dairy farms of average herd size. On the technology side, the impact of subsidies is positive, but much weaker, and it diminishes as the herd size increases.

The impact of the herd size (*Herd*) confirms the conclusions from the threshold models of technology diffusion. Combining the estimated coefficients in the PTC models suggests that the farms with a size greater than 200-300 cows start making technological progress. However, this is countervailed by the negative scale effects as a result of farm size increase, and vise versa. Specialization and arable land available on a farm positively contribute to technological progress. The silage availability positively contributes to technology adoption and negatively to efficiency.

We have found divergence in terms of farms' technical efficiencies, but convergence in terms of the technology and scale. This reflects the glaring problem with farm management in Ukraine.

A further research step will consider the longer time frame and using the spatial panel regressions will hopefully allow us to refine the impact of some explanatory variables on productivity growth components. The other aspect is since all of the components of productivity index come from the decomposition of a single estimated measure; it might lead to some cross-equation restrictions. In the next step we are going to estimate the equations using Seemingly Unrelated Regressions, on the assumption that there will be cross-equation error correlations due to measurement error, unobserved components etc.

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ANNEX A

Table 1 Cobb-Douglas production function, 2005

Target Var. (Logged Milk output):				
	coefficient	95% conf. interval		p-value
const	2.419	2.374	2.463	0.00
Herd size, cows	0.242	0.221	0.263	0.00
Prod. Costs, ‘000UAH	0.719	0.698	0.739	0.00
Labor, ‘000 man-hours	0.129	0.109	0.148	0.00
Steppe zone, dummy	-0.069	-0.095	-0.044	0.00
Forest-steppe zone, dummy	-0.048	-0.070	-0.027	0.00
Rsquared	0.94			
Durbin-Watson statistics	1.81			
Number of observations	4859			

Table 2 Summary Statistics

	Units	Forest zone Mean	Forest zone Std.Dev.	Forest zone Min	Forest zone Max	Non-Forest zone Mean	Non-Forest zone Std.Dev.	Non-Forest zone Min	Non-Forest zone Max
DEA model variables:									
2004:									
Herd	Cows	126.0	123.3	5.0	869.0	169.6	166.5	5.0	1540.0
Prod. costs	'000 UAH	161.0	212.6	4.3	2022.6	312.4	397.9	2.1	4843.1
Labor	'000 man-hours	31.6	34.7	1.0	340.0	43.3	46.2	1.0	404.0
Milk	tons	247.9	356.2	2.4	3181.3	422.8	595.6	2.6	6221.5
No of obs.		1677				4025			
2005:									
Herd	Cows	128.9	131.9	4.0	1042.0	167.8	168.0	4.0	1681.0
Prod. costs	'000 UAH	218.4	322.7	2.6	3829.6	391.6	519.0	2.8	8272.5
Labor	'000 man-hours	32.7	38.5	1.0	574.0	43.5	48.1	1.0	476.0
Milk	tons	308.9	462.6	3.7	4536.0	497.6	694.3	4.0	7218.5
No of obs.		1466				3393			
Spatial regression variables:									
PEC	Index	1.02	0.27	0.43	2.91	1.07	0.30	0.27	4.37
SEC		1.00	0.06	0.44	1.69	1.01	0.05	0.56	1.78
PTC		1.00	0.06	0.63	1.49	0.96	0.06	0.74	1.28
STC		1.00	0.06	0.55	1.66	1.00	0.05	0.74	1.65
Herd	Cows	135.0	128.1	5.0	891.0	180.9	164.0	6.0	1159.0
Subsidy	'000 UAH	72.7	135.6	0.0	1380.4	152.8	1765.1	0.0	95115.0
LabInt	Labor to heard size ratio	0.3	0.2	0.0	1.5	0.3	0.1	0.0	1.6
Fsilage	Silage available on a farm, t	893.69	1574.3	0	14976	1880.1	2449.3	0	35439
Fhay	Hay available on a farm, t	269.93	568.4	0	4995.5	470.58	818.39	0	8435
FeedCost	unit costs for grain, UAH/kg	0.03	0.02	0.00	0.16	0.02	0.01	0.00	0.16
ArableLand	ha	978.4	934.7	0.0	12056.0	2256.8	1769.3	0.0	38127.0
Specialization	Share of milk in total farm revenues	0.2	0.1	0.0	0.9	0.1	0.1	0.0	0.8
Dairies50km	Number of dairy plants	5.5	2.7	0.0	13.0	5.9	2.4	0.0	15.0
MinDistance	arcdegree ($1^0 \approx 136$km)	0.2	0.1	0.0	0.9	0.2	0.1	0.0	0.5
CapClosest	milk processed per day, t	92.6	77.6	6.0	485.8	89.4	98.9	2.0	1151.1
Cap50km	milk processed per day, t	3102.2	1800.5	0.0	9868.0	2939.9	1558.6	0.0	9820.6
DistRegCenter	Distance to the closest region center, arcdegree ($1^0 \approx 136$km)	0.8	0.4	0.0	2.1	0.8	0.4	0.0	2.5
InvDairy	Dummy	0.4	0.5	0.0	1.0	0.4	0.5	0.0	1.0
Rlivestock	Total county livestock receipts less dairy receipts, '000UAH	3286.6	2777.9	6.6	16109.0	4854.9	4669.9	4.8	30988.0
Rsilage	Total county silage, t	13549	13685	0.0	56321	22974	23417	0.0	172940
TE_{04}	Technical efficiency	2.0	0.7	1.0	5.9	2.1	0.8	1.0	6.5
Assests	Farm's total assets, '000UAH	1978.7	2366.3	0.0	38453.0	2169.9	4960.0	0.0	150810

Source: Own presentation; Note: 1USD=5.3UAH

Table 3 SAR regression results with 4 nearest farms based Spatial weight matrix

	Pure Efficiency Change (PEF)		*Scale Efficiency Change (SEC)*		*Pure Technological Change (PTC)*		Scale of Technology Change (STC)	
	Forest zone	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*
Const.	-0.019	0.757***	-0.011	0.681***	0.036*	0.655***	-0.697***	-0.698***
Herd (std)	0.035	0.014	0.031***	-0.002	-0.026***	-0.019***	0.008**	0.008***
HerdSqr (std)	-0.038	-0.014	-0.023***	0.011***	0.017**	0.016***	-0.007*	-0.003*
Subsidy (std)	-0.069***	-0.062***	-0.007	0.014***	0.025***	0.024***	0.000	0.006
Herd(std)×Subsidy (std)	0.018***	0.045***	0.001	-0.010***	-0.005***	-0.017***	-0.001	-0.005
Fsilage (std)	-0.009	-0.016***	0.003	-0.004***	0.008**	0.006***	0.001	-0.002***
Fhay (std)	-0.010	-0.004	0.001	-0.001*	0.000	0.000	0.001	0.000
FeedCost (std)	0.033***	0.003	-0.006***	0.000	-0.005***	-0.001	-0.002**	-0.002
ArableLand (std)	-0.013	-0.006**	0.000	-0.001	0.009***	0.005***	0.000	0.001
Specialization (std)	-0.029***	-0.027***	0.008***	-0.001	0.007***	0.005***	0.003***	0.000
Dairies50km	-0.005**	-0.003***	0.000	0.000	0.000	0.000	0.000	0.000
MinDistance	-0.016	-0.013	-0.028	0.001	-0.021	-0.003	-0.011	-0.004
Log(CapClosest)	0.003	0.000	0.002	0.000	0.001	0.001**	0.001	0.000
Log(Cap50km)	0.003	-0.006***	-0.001	0.002***	-0.004**	0.002**	0.000	0.001**
DistRegCenter	0.001	0.010*	0.003	0.001	-0.010**	-0.005***	0.002	0.002**
InvDairy, dummy	-0.018	-0.001	0.007*	0.000	-0.002	0.002**	0.003*	0.000
Rlivestock (std)	0.015	-0.014***	-0.002	-0.001	-0.003	0.002*	-0.001	-0.001
Rsilage (std)	0.002	0.006	0.003	0.001	0.008*	0.000**	0.001	0.001
TE_{04} (std)	-0.115***	-0.063***	0.009***	0.000	0.009***	0.000	0.003***	0.002***
Assests (std)	0.006	0.006**	0.000	0.001	0.000	0.002***	0.001	0.000
SpilloverEff	0.031**	0.027**	-0.066	-0.001	0.123***	0.002	0.004	0.001
R squared	0.181	0.191	0.081	0.096	0.147	0.220	0.075	0.043
Rbar squared	0.167	0.185	0.066	0.089	0.133	0.215	0.059	0.036
Log-likelihood	574.460	3055.800	2211.100	7678.500	2282.900	7591.200	3413.100	7751.300

Source: Own estimation using LeSage spatial models package for Matlab, available at **www.spatial-econometrics.com**;
Note: ***, **, *: significance at 1%, 5%, 10%;

Table 3 SAR regression results with distance-band based Spatial weight matrix

	Pure Efficiency Change (PEF)		*Scale Efficiency Change (SEC)*		*Pure Technological Change (PTC)*		Scale of Technology Change (STC)	
	Forest zone	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*	*Forest zone*	*Non-Forest zone*
Const.	-0.003	0.607***	-0.004	0.619***	0.039**	0.386***	-0.009	-0.663***
Herd (std)	0.038	0.016*	0.031***	-0.002	-0.024***	-0.019***	0.017**	0.008***
HerdSqr (std)	-0.038	-0.015*	-0.023***	0.011***	0.014*	0.016***	-0.012*	-0.003*
Subsidy (std)	-0.067***	-0.061***	-0.007	0.014***	0.023***	0.023***	0.000	0.006
Herd(std)×Subsidy (std)	0.018***	0.044***	0.001	-0.010***	-0.005***	-0.017***	-0.001	-0.007
Fsilage (std)	-0.008	-0.017***	0.003	-0.004***	0.007**	0.006***	0.001	-0.002***
Fhay (std)	-0.007	-0.004	0.000	-0.001*	0.000	0.001*	0.002	0.000
FeedCost (std)	0.034***	0.004	-0.006***	-0.001	-0.005**	0.000	-0.004**	-0.002***
ArableLand (std)	-0.013	-0.007**	0.000	-0.001	0.007***	0.004***	0.000	0.001
Specialization (std)	-0.030***	-0.026***	0.008***	-0.001	0.007***	0.005***	0.005***	0.000
Dairies50km	-0.005*	-0.003*	0.000	0.000	0.000	0.000	0.000	0.000
MinDistance	-0.022	-0.012	-0.025	0.001	-0.017	-0.005	-0.021	-0.004*
Log(CapClosest)	0.004	0.000	0.001	0.000	0.002	0.001**	0.000	0.000
Log(Cap50km)	0.003	-0.005	-0.001	0.002	-0.004**	0.002	0.000	0.001
DistRegCenter	-0.004	0.008	0.004	0.001	-0.010**	-0.002	0.006	0.002**
InvDairy, dummy	-0.020	-0.001	0.008**	0.000	-0.002	0.001	0.006**	0.000
Rlivestock (std)	0.017	-0.014***	-0.002	-0.001	-0.003	0.002	-0.002	0.000
Rsilage (std)	-0.003	0.007	0.003	0.001	0.007**	-0.001	0.002	0.001
TE_{04} (std)	-0.115***	-0.063***	0.009***	0.000	0.009***	0.000	0.007***	0.002***
Assests (std)	-0.006	0.006**	0.002	0.001	0.005**	0.001**	0.002	0.000
SpilloverEff	0.406***	0.220***	-0.111	0.091*	0.332***	0.404***	-0.246	0.053
R squared	0.188	0.198	0.080	0.097	0.159	0.252	0.071	0.044
Log-likelihood	124.53	2043.11	1756	6659.17	1833.63	6617.08	2085.61	6730.9

Source: Own estimation using GeoDa software;

Note: ***, **, *: significance at 1%, 5%, 10%;