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THE DIFFERENCES IN COST EFFICIENCY OF DAIRY FARMS IN FOUR REGIONS OF POLAND

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Abstract

The cost efficiency of the dairy subsector has been analyzed using data for four FADN regions in Poland for the period 2004/05-2007/08. The cost inefficiency indexes have been calculated for each farm from each region. Overall, all applied measures have been statistically significant in the heteroskedasticity consistent estimation except for the farmer's age. Regional differences have been pronounced and the benchmark Mazowsze and Podlaskie region showing higher cost efficiency than two other major regions, but not a minor, in terms of dairy production, Małopolska and Pogórze region. It is likely that the regional specialization will continue with the benchmark region gaining further advantage. A sub-regional analysis has been recommended for the future study.

Keywords: FADN data, cost frontier function, fixed effects, inefficiency, cost efficiency index

1. Introduction

The discussion surrounding Polish agriculture in the 1990s centered on the large size of the sector in terms of employment, yet its relatively limited contribution to the GDP. The number of employed in agriculture is subject to debate and affected by the changing methodology of estimating agricultural employment (GUS, p. 181, 2007; GUS, pp 46-47, 2011). Numerous experts lamented low productivity and compared the state of the agricultural sector in Poland unfavorably to that in other countries in the 1990s. But the sector has been undergoing rapid changes due to new, accessible technology embodied in equipment and biological inputs.

The discussion about employment subsided because of rapid modernization in Polish agriculture. Modernization advances faster in specialized farms and among the specialized farms, dairy farms have probably changed most. Dairy farms increased their efficiency by adopting new farm organization practices, modern technology, improved cow productivity, and improved milk quality. Their growing average size offers permanent job opportunities to hired labor because the seasonality of milk production is less pronounced than in the past. However, commercial dairy production has been increasingly concentrated in selected regions because the cost competitiveness eliminates many small producers, especially in areas with unfavorable natural conditions for dairy production or lacking processing infrastructure. In recent years, there has been a notable concentration of processing capacity as the dairy processing cooperative sector undergoes cost-induced re-structuring.

The objective of this paper is to examine the cost efficiency of dairy farms, while accounting for possible regional differences. Regional differences implicitly indicate the ability of dairy farms to create additional jobs in rural areas, which suffer from a higher unemployment rate than the towns and cities in Poland. The increasing concentration of land and mechanization of production reduces the need for human labor. The rural population is less dependent on agriculture for jobs,

but non-farm jobs are limited, especially in certain areas (Klepacka, 2012). Several regions of Poland experience depopulation and a major contributing factor is outmigration. Migration has intensified after Poland's accession to the European Union (EU) in 2004 and the opening of labor markets in many of the older EU member-countries. As a result, the local labor availability changes because the young, skilled laborers can find better paying jobs abroad. Increasingly concentrated and efficient agricultural production is not likely to stem the outflow of people, but the regional differences in the type of production allow higher employment levels than others. Therefore, the focus of the paper is on dairy farms, which typically use more labor than farms specialized in other livestock or plant production.

The Polish farm sector situation was not a priority of national economic policy, except in the early 1990s when the government abolished the state farm sector and transferred the operation of former state farms to individuals or companies through sales or lease agreements. The effect was a rapid reduction of government subsidies to maintain and operate the inefficient farms. The result was a dramatic decline in livestock production reflected in the decline in animal herds. The average number of cows in Poland between 1996 and 2000 was 340,200 and has been declining, reaching 279,500 in 2005 and 265,000 in 2010. The decline in livestock numbers was followed by a decline in employment, although the figures are blurred by the changes in the methodology of calculating farm employment.

The adjustments were substantial in the dairy sector, which enjoyed a privileged position under the centrally planned economy. Dairy products including butter were given a high priority because of the high demand resulting to some extent from the administered pricing mechanism. Once prices were allowed to adjust to market supply and demand conditions, the shortages experienced for decades disappeared. In spite of declining cow numbers and farm sector size, consumers did not experience shortages of dairy products or food in general. The private farm sector responded to market prices and changed economic conditions by undergoing re-structuring and eliminating the inefficient producers. The elimination was limited to the withdrawal from milk production, and less so from agricultural production overall, as job opportunities were scarce for rural labor. The economic policy treated agriculture as the "holding tank" for surplus labor, accepting the underemployment rather than accelerating the replacement of labor by capital in agriculture.

The cost pressure has been forcing dairy farms to continually adopt cost-cutting measures. In the dairy sector, the production scale has been steadily increasing and encouraged growth in areas with suitable natural conditions. Such conditions are particularly suitable in the northeastern regions of Poland, in parts of Mazowieckie Voivodship and Podlaskie Voivodship. The soil type and quality better fits dairy production than commercial field crop production. The location of Warsaw, the largest city in Poland, also represents a major market for dairy products. An area that remained competitive in dairy production was Wielkopolskie Voivodship, especially some of its areas located in the river valleys to the south and north of Poznan, the regional capital. The dairy sector fully recovered from the early 1990s downturn, but the increased efficiency forced many small herds out of commercial production and continues to encourage the expansion of herds as well as per cow milk production. Some studies that applied national-level analysis found the productivity of Polish dairy farms surprisingly high (Barnes, Revoredo-Giha, and Sauer, 2011).

2. Cost frontier estimation approach

A stochastic cost frontier using a panel data fixed effects model was used in the estimation (i.e., the within estimator (Hsiao, 1993)). This considers inefficiency as a time invariant (Schmidt and Sickles, 1984; Kumbakhar and Knox Lovell, 2003; Greene, 2005). In addition, in order to test the presence of possible technical change, we included a quadratic trend in the cost equation. The trend variable took the value of one in 1995, two in 1996, and so forth.

The fixed effects stochastic cost frontier model can be written in the following way (Kumbakhar and Knox Lovell, 2003), where i denotes farms and t the periods:

$$\ln E_{it} = \ln C(Q_{it}, W_{it}, \tau_t; \Omega) + v_{it} + u_i \quad (1)$$

In equation (1), $\ln E_{it}$ is the logarithm of the observed expenditure and $\ln C(Q_{it}, W_{it}; \Omega)$ is the logarithm of the deterministic cost function that depends on the outputs Q_{it} , the input prices W_{it} , a deterministic trend τ_t to capture technological change, and a vector of parameters Ω . The statistical error is represented by v_{it} , which is assumed to be independent and identically distributed with mean zero and variance σ_v^2 . The time invariant inefficiency term u_i is positive.

The estimation of the stochastic cost frontier (i.e., $\ln C(Q_{it}, W_{it}, \tau_t; \Omega) + v_{it}$ and the inefficiency terms (i.e., u_i) requires the choice of a functional form for the deterministic part of the stochastic cost frontier (i.e., $\ln C(Q_{it}, W_{it}, \tau_t; \Omega)$). A generalized multiproduct translog cost function (Caves, Christensen, and Tretheway, 1980) was selected because it imposes fewer a-priori restrictions than other functional forms commonly used for the task. As explained by Caves, Christensen, and Tretheway in the context of multiproduct estimation, some outputs might not be present on a farm, and therefore the logarithm used in the translog function will produce an error. Instead, they propose the use of a Box-Cox transformation to substitute for the logarithm of the output terms. It should be noted that the Box-Cox transformation is only one of the possibilities. Instead, in this paper we use $f(Q) = Q$, which provides a hybrid between the translog function and the quadratic function. Thus, for the case of n inputs and m outputs, the cost function is given by:

$$\begin{aligned} \ln C(Q_{it}, W_{it}; \Omega) = & \alpha_0 + \varphi_0 \tau_t + \varphi_0 \tau_t^2 + \sum_{j=1}^n \alpha_j \ln W_{jt} + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n \beta_{jk} \ln W_{jt} \ln W_{kt} \\ & + \frac{1}{2} \sum_{j=1}^m \sum_{k=1}^m \delta_{jk} f(Q_{jit}) \ln W_{kt} + \sum_{j=1}^m \gamma_j f(Q_{jit}) + \frac{1}{2} \sum_{j=1}^m \sum_{k=1}^m \rho_{jk} f(Q_{jit}) \cdot f(Q_{kit}) \end{aligned} \quad (2)$$

As the stochastic cost frontier is a cost function, it has to satisfy the properties of any cost function (Chambers, 1988). Price homogeneity and symmetry were directly imposed in (2) through the following restrictions to the parameters (3):

$$\sum_{j=1}^n \alpha_j = 1; \sum_{j=1}^n \delta_{jk} = 0; \sum_{j=1}^n \beta_{jk} = 0; \sum_{k=1}^n \beta_{jk} = 0; \sum_{j=1}^n \sum_{k=1}^n \beta_{jk} = 0; \beta_{jk} = \beta_{kj} \quad (3)$$

As previously noted, the dataset does not contain input prices for each farm. In the context of cross section estimation, the approach is to assume that all farmers face the same prices (e.g., Alvarez and Arias, 2003). However, for estimating a cost function using panel data it is possible to introduce prices, assuming that all the farmers face the same input prices within a year (i.e., across farms), but that prices change over time.¹ A common problem in the estimation of produc-

1 In a different context, similar assumptions can be found in the estimation of demand systems, where price elasticities are sometime estimated from time series because of the lack of variability of prices in cross section datasets (Hsiao, 1993, p.206).

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tion stochastic frontiers is that the use of a fixed effect model precludes the use of time invariant variables. However, in the context of cost function estimation, this can be overcome due to the fact that the parameters associated with input prices can be estimated from the cost share equations, where the inefficiency term (i.e., the fixed effect terms) do not appear. Then, the equation to be estimated is presented in (4), where the intercept in (4) is $\alpha_{0i} = \alpha_0 + u_i$.

$$\ln E_i = \alpha_{0i} + \varphi_0 \tau_i + \varphi_0 \tau_i^2 + \sum_{j=1}^n \alpha_j \ln W_j + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n \beta_{jk} \ln W_j \ln W_k + \frac{1}{2} \sum_{j=1}^m \sum_{k=1}^m \delta_{jk} f(Q_{jit}) \ln W_k + \sum_{j=1}^m \gamma_j f(Q_{jit}) + \frac{1}{2} \sum_{j=1}^m \sum_{k=1}^m \rho_{jk} f(Q_{jit}) \cdot f(Q_{kit}) + v_{it} \quad (4)$$

Equation (4) was estimated for five inputs (i.e., n) and three outputs (i.e., m). Given the high number of parameters to be estimated, the following econometric procedure was employed. First, the system of (n – 1) cost shares was computed, using Iterative Seemingly Unrelated Regression Equations (ISURE) and imposing the constraints in (3). This step provided the values for all the terms in (4) that were associated to input prices. Second, all the remaining parameters of the cost function, except the fixed effect terms (i.e., output terms not associated with prices) were estimated using the within estimator (ordinary least square applied to the variables expressed as deviations of the means by farm as in Hsiao, 1993). Finally, the fixed effect terms used in the construction of the relative cost efficiency indices were estimated from equation (4) by evaluating the function at the mean value of the variables by farm (Atkinson and Cornwell, 1993; Kumbakhar and Knox Lovell, 2003; Pierani and Rizzi, 2003)².

As shown in Kumbakhar and Knox Lovell (2003), the relative cost efficiency index (CEI_i) for a sample size N was computed as equation (5) based on the estimated fixed effect intercepts (i.e., $\hat{\alpha}_{0i}$), where for the most cost efficient producers it has a value equal to one:

$$CEI_i = \exp \{ -(\hat{\alpha}_{0i} - \min_i \{ \hat{\alpha}_{0i} \}) \} \quad i = 1, \dots, N. \quad (5)$$

The results of the cost function estimations are presented in Table 1.

Table 1. Estimation Results of Dairy Farm Cost Efficiency, Poland, 2004/05-2007/08

Variable name	OLS	
	Estimated coefficient	Std. error ^a
Intercept	0.1227	0.3668
Total debt to asset ratio	0.3078**	0.1124
Long-term debt to total debt ratio	0.3189**	0.0407
Farmer's year of birth	0.0012	0.0020
Total labor to unpaid labor ratio	-0.9808*	0.2483
Total subsidies to output	-1.6742**	0.1325
Pomorze and Mazury	0.0922**	0.0255
Wielkopolska and Śląsk	0.1712**	0.0211
Małopolska and Pogórze	-0.1196**	0.0298
Number of observations	2245	
R-square	0.3528	

^a Standard errors are heteroscedasticity consistent; Note: *,** denote significant at 5% and 1% levels, respectively.

² The farm level estimated fixed effects used to compute the relative cost efficiency indices were assumed to be constant over time due to the short period covered by the sample (in the best case, information was available for some farms for eight years) (Kumbakhar and Knox Lovell, 2003, p. 170).

3. Data

Data used in this paper is from the Farm Accounts Data Network (FADN) database. The FADN annually records a wide range of financial and non-financial data for a selection of full-time farms across the EU. The data used were available only since 2004/05. This resulted in an unbalanced panel dataset.

Costs and outputs by farm type were computed directly from the FADN data. Costs were allocated to one of five groups: materials (e.g., feed, fertilizer); energy; labor (i.e., all labor used including that of the farmer, farm family, business partners, and hired workers); land (owned and rented) and capital (e.g., rent, depreciation). The three outputs were considered: crops, livestock, and other outputs, all of them in real terms.

The estimation of cost functions requires input prices. However, a shortcoming of the FADN data for the estimation of cost functions is that it only presents input expenditures and not the prices paid for inputs (or quantities used). Therefore, Eurostat's input price indices data (base year 2004) were used for agricultural materials, energy, and capital as an estimate of those prices paid by farmers over the study period. The labor and land input prices were estimated from the FADN data.

Poland has created a panel of farms including dairy farms. The panel may not be fully reflective of Poland's dairy sector. It is likely that farms with a single cow or very small herds are under-represented. However, the interest of the authors is the competitiveness of producers and their ability to create jobs in rural areas, and not in self-supply of milk, which is the primary reason for keeping a single animal.

The data are annual observations for the period 2004/05-2007/08. The unbalanced panel included 2,245 farms, but a total of 4,755 observations is used in this study. Farms were located in a number of administrative regions, which were grouped by the national reporting agency in four large regions including the Mazowieckie-Podlaskie (1,364 farms), Pomorze-Mazury (341 farms), Małopolska-Podgórze (159 farms), and Wielkopolska-Śląsk (382). The reported farm data included all standard information in the FADN data base.

4. Estimation results

Overall, the explanatory power of the used set of data has been confirmed by the F-test results and the adjusted R-square value is 0.3528. With one exception, all explanatory variables are statistically significantly influencing the depended variable, which is the fixed cost coefficient. Two measures of debt lead to an increase in the costs of production. The elasticities are of similar size and the effect of long-term debt has a slightly higher effect. Dairy farms had to heavily invest, enlarge herds, and expand production to stay competitive and the effects of that approach are confirmed by the results. The shrinking of the cow herd in the early 1990s was the reflection of cost adjustment after decades of responding to administrative pressures to engage and increase milk production to satisfy the demand stimulated by unrealistic retail prices and a limited availability of consumer goods in general.

The effect of gross investment to total output also leads to cost increases, but the effect is rather small. In the case of a dairy farm, the output effects may not occur in the year investment takes place because of the nature of the production. Typically, the output will increase but over time, especially if the investment leads to adding animals or increasing cow productivity.

The three regional dummies indicate that cost efficiency in the regions differs from the benchmark region of Mazowsze-Podlaskie. Mazowsze-Podlaskie is the area where a number of very large dairy processing companies are located and where the natural conditions are particularly suitable for dairy production. Large areas of meadows and pasture are located north and northeast of Warsaw, the capital of Mazowsze. The region has witnessed a major expansion of dairying in the area in the last two decades. Because the soil quality tends to be lower than in other parts of the country, dairy farms could convert some arable land to pasture. The signs of the dummy regional indicators suggest that two regions to the west and northwest of the benchmark region are characterized by higher costs. The particular aggregation of regional data applied in the Polish FADN may, in part, contribute to the result. The combination of Wielkopolska and Śląsk into a single area may obscure the efficiency of Wielkopolska dairy farms. Historically, the region has been known for the highest farm management level, while many farmers in Śląsk have less experience. Results also indicate that the southeastern areas of Małopolska and Pogórze have been more cost efficient. This result is interesting, but not likely to change the commercial face of the Polish dairy sector. First, the number of dairy farms in that region is small. Second, the topography and the amount of agricultural land is inadequate for the expansion of many farms. Other factors that limit potential expansion are milk processing capacity constraints and the fragmented land ownership, which could be costly in case of any attempt to expand production.

5. Implications

The potential practical consequences of the cost efficiency differences across regions are illustrated in Figures 1 through 4. The benchmark region distribution of farms (Figure 1) shows a fairly tight distribution and indicates that there are some farms that are relatively high-cost producers. These farms will likely cease to produce milk and possibly their land will be consolidated into larger farms. The illustration is particularly realistic because of the large number of farms in that region, which justified selecting it as the benchmark as well. But interestingly, there are more cost-efficient farms in the region shown in Figure 3 if one considers the relative share of farms at each cost efficiency level. As mentioned above, Wielkopolska and Śląsk were combined into a single FADN area, while being very different in nature and the strength of their agriculture. That artificial combination can be seen in Figure 3, where the distribution resembles that of combining two different distributions, one with lesser cost efficiency. The result suggests the need for further disaggregation of the analysis to the level of sub-region. The cost-efficient region of Małopolska and Pogórze shows many diversified levels of efficiency (Figure 4). Moreover, the number of farms is considerably smaller than in the case of other regions suggesting that although the farm may be efficient, they are too few in number and have a very localized effect.

The regional differences in cost of living, which have not been explicitly accounted for in this study, suggest that the benchmark region will continue to improve its competitive position against other regions except of Małopolska and Pogórze, but the latter is unlikely to witness dairy farming expansion (at least not in terms of cow milk production). The full effect of cost of living differences cannot be considered given the aggregation into four regions because the relatively low labor cost area of Podlaskie is combined with the highest labor cost area of Mazowsze, whereas the effect of high labor costs in Warsaw distort the discrepancy between outlying rural areas and the city.

Similarly, the unemployment rate, especially rural unemployment, varies greatly within the benchmark area and across regions. The relatively high unemployment and lower than national

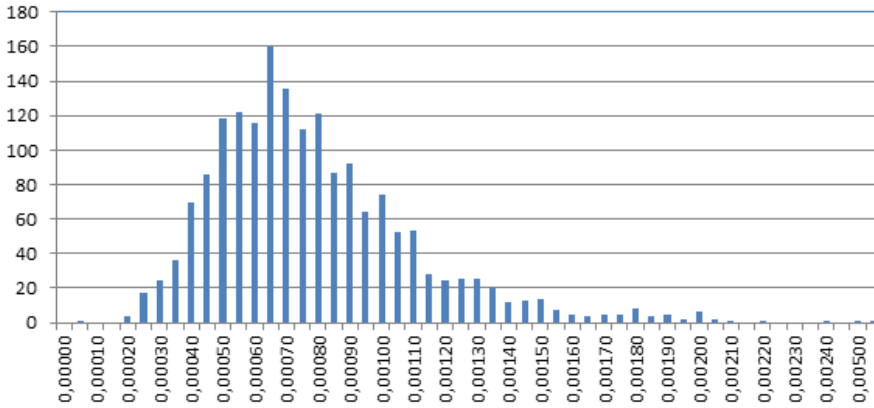


Figure 1. The distribution of dairy farms in terms of cost efficiency in Podlasie and Mazowsze FADN area, Poland
Source: Authors' calculations based on estimation results using the FADN data

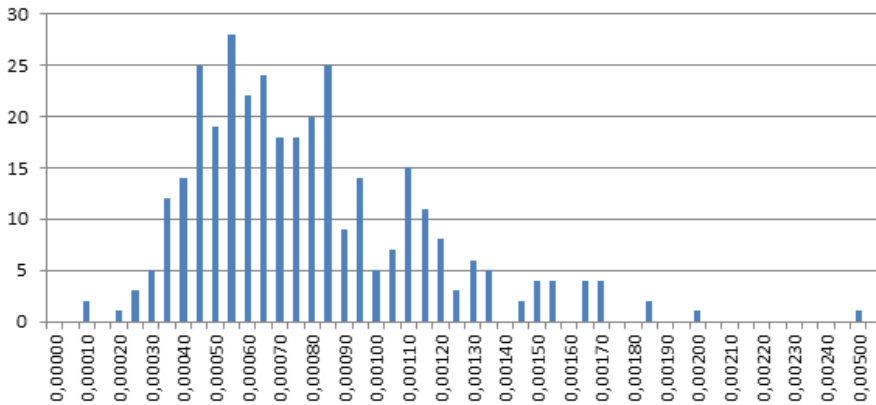


Figure 2. The distribution of dairy farms in terms of cost efficiency in Pomorze and Mazury FADN area, Poland
Source: Authors' calculations based on estimation results using the FADN data

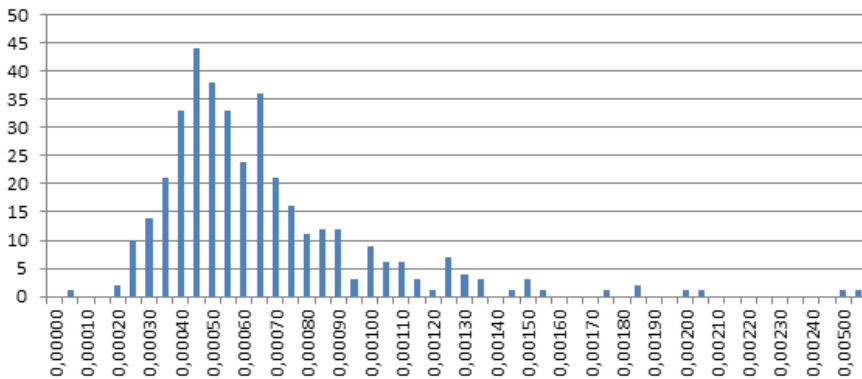


Figure 3. The distribution of dairy farms in terms of cost efficiency in Wielkopolska and Śląsk FADN area, Poland
Source: Authors' calculations based on estimation results using the FADN data

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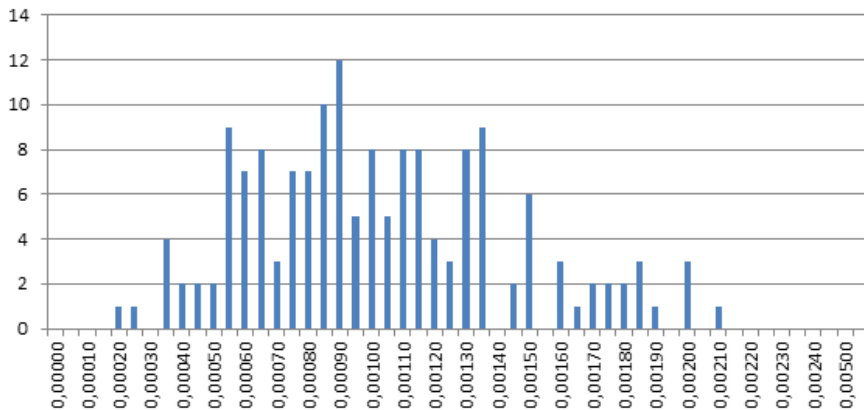


Figure 4. The distribution of dairy farms in terms of cost efficiency in Małopolska and Pogórze FADN area, Poland

Source: Authors' calculations based on estimation results using the FADN data

average incomes, contribute to the migration in search of better economic opportunities. Podlaskie is one of the regions which has experienced outmigration for a long time and the accession to the European Union further contributed to this phenomenon. Dairy farms utilize more labor than field crop farms and the continuing development of that subsector of agriculture could offer, however limited, job opportunities. Estimation results suggest that those utilizing primarily their own labor were more cost efficient, but enlargement of herds eventually will require hired labor to improve economic returns. The speed with which the changes will take place is expected to accelerate in the dairy industry after April 1, 2013, when milk quotas will be abolished. Nevertheless, the noticeable effect on employment will likely be quite small.

6. Concluding comments

Farmers in Poland gained access to investment funds under the EU *Common Agricultural Policy* programs, which also permitted expansion of production. Investment funds have been particularly useful for livestock operations including dairy. Dairy farm production expansion could benefit from additional labor. Between 2009 and 2010, the employment in agriculture increased by about 2,400 jobs (GUS, 2011), but the data do not provide details about the farm type or geographical area where the new jobs were added. However, the general trend of an increase in agricultural employment is consistent with both the demographic changes and reversal of migration due to the shrinking job market in other EU countries. The full demonstration of the financial crisis in 2008 and the subsequent economic slowdown in many EU countries led to a decrease in demand for labor. Lower labor demand and the lack of prospects for a speedy recovery caused many job-seeking migrants from Poland to return home. The reverse migration increased the supply of labor, including the labor in rural areas and areas where outmigration was largest.

Within Poland, regional competitiveness is affected by other factors as well and labor costs could shift jobs across regions. The northeastern areas may strengthen the competitive position of their dairy sector due to natural resource endowment and less expensive labor. Such tendencies will further delineate the specialization and limit the farm types found in individual regions. To obtain a fuller picture of cost efficiencies in dairy production, a sub-regional analysis is warranted.

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