Structural change and aggregate efficiency in Lithuanian dairy farms: An application of the Olley-Pakes decomposition

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Kuriame Lietuvos ateitį
2014–2020 metų Europos Sąjungos fondų investicijų veiksmų programa

This research is funded by the European Social Fund according to the activity 'Improvement of researchers' qualification by implementing world-class R&D projects' of Measure No. 09.3.3-LMT-K-712

Outline

- Introduction
- Theoretical Preliminaries
- Data Used
- Results

Motivation

- The measurement of the aggregate efficiency is useful to quantify the gains (or losses) in the sector-level productivity due to
  - re-structuring (as represented by the covariance term) and
  - actual productivity gains at the firm level (as represented by the average efficiency).
- In this sense, the aggregate efficiency can show the degree to which output is produced at the benchmark level of productivity.
- Färe and Zelenyuk (2003) discussed the issue of the aggregate efficiency, whereas Färe and Karagiannis (2017) further derived the general principles for theoretically consistent aggregation of the efficiency scores. Karagiannis (2015) also related the aggregate, average and structural efficiency.
- Lithuanian dairying sector has faced important changes in several directions which basically correspond to those observed in the other Central and Eastern European countries:
  - The entrance to the European Union (EU) in 2004 marked an increasing support for the livestock farming, yet the intensity of support has been higher for the crop farms in general due to the Single Area payment Scheme.
  - The phasing-out of small dairy farms has been continuing due to relatively low profitability and relatively high labour intensity (if compared to the other farming types).

Research Framework

- The relationships between farm size and performance (TE) are important in identifying the sources of changes in the aggregate efficiency.
- In our case, we adapt the covariance decomposition approach by Olley and Pakes (1996) in order to unveil the relationships between farm size and performance.
- Data envelopment analysis is used to calculate the technical efficiency measures.
- We identify the most influential farms in the context of the OP decomposition.
- The farm-level data from Farm Accountancy Data Network (FADN) are applied. The data cover the period of 2004-2016.

Technology and Efficiency

- Technology set $T = \{(x, y) \mid x \text{ can produce } y\}$
- DEA approximations of *T*

$$\hat{T}^{CRS}_{DEA} = \left\{ (x,y) \mid \sum_{k=1}^{K} \lambda_k x^k \le x, \sum_{k=1}^{K} \lambda_k y^k \ge y, \lambda_k \ge 0, k = 1,2,\dots,K \right\}$$

$$\hat{T}^{VRS}_{DEA} = \left\{ (x,y) \mid \sum_{k=1}^{K} \lambda_k x^k \le x, \sum_{k=1}^{K} \lambda_k y^k \ge y, \sum_{k=1}^{K} \lambda_k = 1, \lambda_k \ge 0, k = 1,2,\dots,K \right\}$$

$$\hat{T}^{NIRS}_{DEA} = \left\{ (x,y) \mid \sum_{k=1}^{K} \lambda_k x^k \le x, \sum_{k=1}^{K} \lambda_k y^k \ge y, \sum_{k=1}^{K} \lambda_k \le 1, \lambda_k \ge 0, k = 1,2,\dots,K \right\}$$

- Output distance function $D_O(x,y) = \left(\min \phi \mid \left(x, \frac{y}{\phi} \right) \in T \right)$
- ODF is obtained via

$$\phi^{CRS}_{k_0} = \min \left\{ \phi \left| \begin{array}{l} \sum_{k=1}^{K} \lambda_k x_i^k \le x_i^{k_0}, i = 1,2,\dots,m; \\ \sum_{k=1}^{K} \lambda_k y_j^k \ge \frac{y_j^{k_0}}{\phi}, j = 1,2,\dots,n; \\ \lambda_k \ge 0, k = 1,2,\dots,K \end{array} \right. \right\}$$

Aggregate efficiency and Olley-Pakes decomposition

- Following the rule of denominator (Färe, Karagiannis, 2017), the aggregate efficiency is calculated as:

$$\phi = \frac{\sum_{k=1}^{K} \left(y^k / \phi_k^{VRS} \right) \phi_k^{VRS}}{\sum_{k=1}^{K} \left(y^k / \phi_k^{VRS} \right)} = \frac{\sum_{k=1}^{K} y^k}{\sum_{k=1}^{K} y^{k,*}}$$

- The aggregate efficiency can be decomposed in the spirit of Olley and Pakes (1996) as follows

$$\phi = \sum_{k=1}^{K} \theta_k \phi_k^{VRS} = \bar{\phi} + \sum_{k=1}^{K} \left(\theta_k - \bar{\theta} \right) \left(\phi_k^{VRS} - \bar{\phi} \right)$$
$$= \bar{\phi} + \sum_{k=1}^{K} \tilde{\theta}_k \tilde{\phi}_k^{VRS}$$

- The covariance term decomposes as

$$\sum_{k=1}^{K} \tilde{\theta}_k \tilde{\phi}_k^{VRS} = \sum_{\substack{\tilde{\theta}_k < 0 \\ \tilde{\phi}_k^{VRS} < 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k < 0 \\ \tilde{\phi}_k^{VRS} = 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k < 0 \\ \tilde{\phi}_k^{VRS} > 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS}$$
$$+ \sum_{\substack{\tilde{\theta}_k = 0 \\ \tilde{\phi}_k^{VRS} < 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k = 0 \\ \tilde{\phi}_k^{VRS} = 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k = 0 \\ \tilde{\phi}_k^{VRS} > 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS}$$
$$+ \sum_{\substack{\tilde{\theta}_k > 0 \\ \tilde{\phi}_k^{VRS} < 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k > 0 \\ \tilde{\phi}_k^{VRS} = 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS} + \sum_{\substack{\tilde{\theta}_k > 0 \\ \tilde{\phi}_k^{VRS} > 0}} \tilde{\theta}_k \tilde{\phi}_k^{VRS}$$

Influencial observations

- Number of times a certain efficient farm acts as a peer for inefficient farms
- Number of times an efficient farm is assigned with the highest value of the intensity variable (weight)
- Reference share (Torgensen et al., 1996) is defined as the share of the output gap that is due to a particular efficient farm:

$$\rho^{k^*} = \frac{\sum_{k=1}^{K} \lambda_{k^*}^{k} \left(\hat{y}^{k} - y^{k} \right)}{\sum_{k=1}^{K} \hat{y}^{k} - \sum_{k=1}^{K} y^{k}}$$

- Benchmarking share (Johnson, Zhu, 2003):

$$\rho^{k^*} = \frac{\sum_{k=1}^{K} \lambda_{k^*}^{k}}{\#\left(\phi_k < 1\right)}$$

Data Used

- The research relies on the FADN data for Lithuanian specialist dairy farms.
- The productive technology is modelled by considering the four inputs:
  - Labour is measured in hours worked and includes both family and hired labour.
  - Herd size is measured in livestock units (LSU).
  - Intermediate consumption includes specific costs (feed, veterinary expenses etc.) and overheads.
  - Capital assets include the value of machinery and buildings.
- A single output is considered, i.e. total output which includes crop, livestock and other outputs.
- Intermediate consumption, capital assets and output are measured in monetary terms (Euro). The technology is defined for each time period independently, thus, we do not apply deflation.

Descriptives

Year	Labour, hours	Herd size, LSU	Intermediate consumption, Euro	Assets, Euro	Output, Euro
Average					
2004	5071	48.4	26338	43807	50049
2005	5692	50.2	31849	46316	63578
2006	5614	51.2	34060	64750	64029
2007	5807	49.9	35443	83290	71684
2008	6292	60.1	49250	69850	89538
2009	5967	57.3	44436	112860	71298
2010	6141	59.0	48304	120849	87987
2011	5901	56.6	54562	117802	96116
2012	6097	57.7	59934	130456	102277
2013	6293	60.3	65115	127129	114803
2014	6432	66.9	73633	125969	118356
2015	5682	60.9	60115	108221	90213
2016	5678	62.1	61687	115093	91774

TE Scores

	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Efficiency score	1	44	42	31	36	46	39	59	42	53	51	57	46	53
	(0.9, 1)	33	16	21	23	22	13	49	22	33	42	30	26	29
	(0.8, 0.9]	49	30	24	26	37	25	61	56	61	63	52	46	44
	(0.7, 0.8]	46	33	23	35	29	44	59	59	78	68	57	67	42
	(0.6, 0.7]	30	30	14	28	37	34	46	77	50	49	55	50	70
	(0.5, 0.6]	27	12	8	19	21	25	22	41	29	26	26	41	31
	(0.4, 0.5]	6	2	2	6	2	9	5	13	4	10	6	19	24
	[0.2, 0.4]	1						2			1	2	2	3
No of obs.		236	165	123	173	194	189	303	310	308	310	285	297	296
Summary statistics														
Average		0.80	0.81	0.84	0.80	0.80	0.77	0.81	0.75	0.80	0.80	0.79	0.76	0.76
Min		0.37	0.40	0.45	0.44	0.40	0.42	0.34	0.41	0.45	0.37	0.37	0.39	0.25

SE and RTS

Year	RTS	Average efficiency VRS TE	Average efficiency SE	No of farms	Year	RTS	Average efficiency VRS TE	Average efficiency SE	No of farms
	IRS	0.79	0.90	146		IRS	0.75	0.90	128
2004	CRS	1.00	1.00	18	2011	CRS	1.00	1.00	18
	DRS	0.77	0.97	72		DRS	0.73	0.96	164
	IRS	0.79	0.87	101		IRS	0.78	0.93	226
2005	CRS	1.00	1.00	12	2012	CRS	1.00	1.00	19
	DRS	0.81	0.96	52		DRS	0.80	0.96	63
	IRS	0.82	0.88	90		IRS	0.77	0.92	201
2006	CRS	1.00	1.00	9	2013	CRS	1.00	1.00	20
	DRS	0.85	0.96	24		DRS	0.82	0.97	89
	IRS	0.79	0.90	114		IRS	0.78	0.92	183
2007	CRS	1.00	1.00	13	2014	CRS	1.00	1.00	25
	DRS	0.74	0.96	46		DRS	0.77	0.98	77
	IRS	0.77	0.90	129		IRS	0.74	0.89	177
2008	CRS	1.00	1.00	19	2015	CRS	1.00	1.00	19
	DRS	0.82	0.96	46		DRS	0.74	0.96	101
	IRS	0.77	0.89	96		IRS	0.72	0.91	171
2009	CRS	1.00	1.00	13	2016	CRS	1.00	1.00	20
	DRS	0.74	0.97	80		DRS	0.76	0.96	105
	IRS	0.79	0.91	209					
2010	CRS	1.00	1.00	16					
	DRS	[illegible]	0.96	78					

Decomposition of the aggregate TE

Year	Aggregate TE	Average TE Level	Average TE Contribution (%)	Covariance term Level	Covariance term Contribution (%)
2004	0.816	0.803	98.4	0.013	1.6
2005	0.832	0.814	97.8	0.019	2.2
2006	0.862	0.838	97.3	0.023	2.7
2007	0.817	0.795	97.3	0.022	2.7
2008	0.831	0.805	96.9	0.026	3.1
2009	0.818	0.771	94.2	0.047	5.8
2010	0.839	0.811	96.7	0.028	3.3
2011	0.803	0.752	93.8	0.050	6.2
2012	0.830	0.797	96.1	0.032	3.9
2013	0.843	0.796	94.4	0.047	5.6
2014	0.836	0.794	95.0	0.042	5.0
2015	0.802	0.756	94.2	0.046	5.8
2016	0.816	0.756	92.6	0.061	7.4

Decomposition of the covariance term

Year	$\tilde{\theta}_{kt} < 0$				$\tilde{\theta}_{kt} > 0$				Size
	$\tilde{\phi}_{kt} < 0$		$\tilde{\phi}_{kt} > 0$		$\tilde{\phi}_{kt} < 0$		$\tilde{\phi}_{kt} > 0$		Eff.
	Eff.	Peer	Eff.	Peer	Eff.	Peer	Eff.	Peer	
2004	–	–	11.0	8.5	–	–	7.6	7.2	
2005	–	–	12.7	9.1	–	–	12.7	9.7	
2006	–	–	17.9	14.6	–	–	7.3	6.5	
2007	–	–	13.9	12.1	–	–	6.9	6.9	
2008	–	–	13.4	10.8	–	–	10.3	9.8	
2009	–	–	12.7	10.1	–	–	7.9	6.3	
2010	–	–	11.6	9.2	–	–	7.9	7.6	
2011	–	–	8.1	6.5	–	–	5.5	4.8	
2012	–	–	12.0	9.1	–	–	5.2	4.9	
2013	–	–	10.3	7.4	–	–	6.1	5.8	
2014	–	–	13.7	12.6	–	–	6.3	5.6	
2015	–	–	11.4	9.1	–	–	4.0	3.7	
2016	–	–	12.8	9.5	–	–	5.1	4.7	

Average input/output values for the most influential peer farms

Year	$\tilde{\phi}_{kt} > 0$									
	$\tilde{\theta}_{kt} < 0$					$\tilde{\theta}_{kt} > 0$				
	Labour (hours)	Herd size (LSU)	Intermediate consumption, Eur	Assets, Eur	Output, Eur	Labour (hours)	Herd size (LSU)	Intermediate consumption, Eur	Assets, Eur	Output, Eur
2004	2835	20.9	11727	19831	31386	3411	56.0	23639	37032	71685
2005	2976	26.8	12660	16311	37100	5750	64.5	34697	32088	102340
2006	4468	24.9	14171	45234	37470	6672	118.9	79850	66560	194969
2007	4378	18.0	10173	25504	35138	5310	56.1	35533	65114	105989
2008	2859	15.0	11895	10226	26847	5963	72.3	54010	82226	147812
2009	3590	32.3	17798	24867	43845	10726	113.8	121734	222167	234467
2010	3185	15.1	11594	32068	30241	5221	66.1	63377	88859	141858
2011	3091	25.1	20799	46269	57423	10642	81.8	74220	168725	201077
2013	3724	27.0	26411	38863	62681	12520	93.1	104507	181289	262466
2014	3687	38.4	35219	45160	75374	14130	148.5	147855	250469	322980
2015	3463	32.0	20309	36413	52059	14102	196.4	258268	428715	488091
2016	3621	29.2	19068	17473	43563	7529	107.1	143422	157285	256035
Rate of growth	0.7	3.9	7.7	4.4	5.7	9.6	7.4	16.8	19.2	12.8

The characteristics of the most influential peer farms

Year	$\tilde{\phi}_{it} > 0$									
	$\tilde{\theta}_{it} < 0$					$\tilde{\theta}_{it} > 0$				
	Output/LSU (Eur/LSU)	Assets/labour (Eur/hour)	Intermediate consumption per LSU (Eur/LSU)	Share of hired labour	Farmer's age	Output/LSU (Eur/LSU)	Assets/labour (Eur/hour)	Intermediate consumption per LSU (Eur/LSU)	Share of hired labour	Farmer's age
2004	1504	7	562	0.0	46	1280	11	422	11.7	49
2005	1384	5	472	0.0	39	1588	6	538	0.0	56
2006	1505	10	569	0.0	48	1639	10	671	57.6	54
2007	1952	6	565	0.0	34	1889	12	633	12.7	49
2008	1793	4	794	13.0	45	2044	14	747	24.7	48
2009	1358	7	551	0.0	51	2060	21	1070	58.5	48
2010	2009	10	770	0.0	43	2146	17	959	3.0	60
2011	2287	15	828	0.0	38	2457	16	907	56.8	48
2013	2318	10	977	0.0	46	2821	14	1123	69.5	50
2014	1965	12	918	3.5	52	2175	18	996	67.2	53
2015	1625	11	634	0.0	46	2485	30	1315	75.3	58
2016	1492	5	653	1.5	58	2391	21	1339	36.4	41
Trend	32.28	0.34	25.47	0.01	0.89	105.03	1.40	77.52	4.69	-0.18

The distribution of Lithuanian milk farms with respect to prevailing RTS and size/efficiency combinations

Year	$\tilde{\theta}_{it} < 0$						$\tilde{\theta}_{it} > 0$					
	$\tilde{\phi}_{it} < 0$			$\tilde{\phi}_{it} > 0$			$\tilde{\phi}_{it} < 0$			$\tilde{\phi}_{it} > 0$		
	IRS	CRS	DRS	IRS	CRS	DRS	IRS	CRS	DRS	IRS	CRS	DRS
2004	29.7	–	1.3	26.3	2.5	2.1	2.1	–	13.6	3.8	5.1	13.6
2005	27.9	–	3.6	27.9	2.4	1.8	4.8	–	12.7	0.6	4.8	13.3
2006	28.5	–	0.8	30.9	2.4	1.6	9.8	–	5.7	4.1	4.9	11.4
2007	25.4	–	8.1	25.4	2.3	3.5	6.9	–	8.7	8.1	5.2	6.4
2008	31.4	–	1.0	25.8	3.6	1.0	5.7	–	8.2	3.6	6.2	13.4
2009	22.2	–	17.5	20.6	2.6	4.2	4.2	–	9.0	3.7	4.2	11.6
2010	29.4	–	4.3	29.0	1.7	2.3	5.9	–	7.3	4.6	3.6	11.9
2011	21.9	–	21.9	15.2	3.2	6.1	1.0	–	9.0	3.2	2.6	15.8
2012	34.7	–	2.9	25.6	2.9	0.6	7.1	–	6.5	5.8	3.2	10.4
2013	29.4	–	5.8	25.2	2.9	4.8	6.1	–	6.8	4.2	3.5	11.3
2014	28.4	–	9.1	23.9	4.6	2.5	5.3	–	6.3	6.7	4.2	9.1
2015	27.9	–	9.8	24.9	4.0	2.4	2.4	–	8.8	4.4	2.4	13.1
2016	33.8	–	8.8	18.2	4.4	3.0	2.4	–	9.1	3.4	2.4	14.5
Trend	0.24	–	0.61	-0.54	0.16	0.09	-0.17	–	-0.29	0.10	-0.24	0.05

Conclusions

- The identification of the most influential peer dairy farms allowed to describe the two models to follow in Lithuanian dairy farms, i.e. small- and large-scale farms. The average herd size for the relatively large farms of up to 200 livestock units was observed, whereas the corresponding limit for the relatively small farms was some 40 livestock units. The increased herd size was related to higher share of the hired labour.
- Following reasonable farm structure may allow ensuring successful operation of Lithuanian dairy farms which have access to resource endowments needed for this type of farming (grasslands and water resources).
- The decomposition of the aggregate efficiency confirmed the impact of the restructuring on the sector-level efficiency. Specifically, the covariance term tended to increase during 2004-2016 thus indicating the increasing importance of the linkages between farm size and technical efficiency.
- The decomposition showed that the relatively small low-efficiency efficiency farms contributed to the covariance term thus confirming the phasing out of inefficient farms.

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Monday

Monday, 10:30-12:00

MB-09: DEA applications in Education
Stream: **Data Envelopment Analysis and Performance Measurement**
Room: B006
Chair(s): Giovanna D'Inverno

- **Managerial Efficiency and Efficiency Differentials in Adult Education: A Conditional and Bias-Corrected Efficiency Analysis**
  Deni Mazrekaj
- **Incorporating quality considerations in DEA-based benchmarking of higher education**
  Margareta Gardijan Kedžo, Ozana Nadoveza Jelić
- **Non-compensatory Efficiency Measures for a balanced comparison of European Higher Education institutions**
  Thyago Nepomuceno, Ana Paula Costa, Cinzia Daraio
- **Impact evaluation in a multi-input multi-output setting: Evidence on the effect of additional resources for schools**
  Giovanna D'Inverno, Mike Smet, Kristof De Witte

Monday, 12:30-14:00

MC-09: DEA applications in Banking and Finance
Stream: **Data Envelopment Analysis and Performance Measurement**
Room: B006
Chair(s): Joseph Paradi

- **Measuring the employee productivity in a retail bank – an axiomatic non-parametric approach**
  Juha Eskelinen, Markku Kuula
- **An analysis of the bank merger gains using the directional distance function model with undesirable outputs**
  Takayoshi Nakaoka
- **Data Envelopment Analysis of Indian Public-Sector-Undertaking Banks and their Current Ranking**
  Badri Toppur, Ramamurthy Ramakrishnan
- **Leveling the Playing Field for Cultural Differences in Bank Branch Analysis**
  Joseph Paradi

Monday, 14:30-16:00

MD-09: DEA applications in Agriculture and Food
Stream: **Data Envelopment Analysis and Performance Measurement**
Room: B006

Chair(s): Magdalena Kapelko

- **Combining nonparametric efficiency measures and parametric inference to assess technological progress for the Brazilian agriculture**
  Geraldo Souza, Eliane Gomes, Eliseu Alves, José Gasques
- **Structural change and aggregate efficiency in Lithuanian dairy farms: An application of the Olley-Pakes decomposition**
  Tomas Balezentis, Giannis Karagiannis
- **The effect of subsidies on agricultural efficiency in the EU**
  Lukas Fryd, Ondřej Sokol
- **The Relationship between Corporate Social Responsibility and Input- and Investment-Specific Dynamic Productivity Change in the US Food and Beverage Manufacturing Industry**
  Magdalena Kapelko, Alfons Oude Lansink, Encarna Guillamon-Saorin

Tuesday

Tuesday, 8:30-10:00

TA-09: DEA theory and methodological developments
Stream: **Data Envelopment Analysis and Performance Measurement**
Room: B006
Chair(s): Antonio Peyrache

- **The Cost Metafrontier is Nonconvex in the Outputs since the Metafrontier is Nonconvex: The Price of a Convexification Strategy**
  Kristiaan Kerstens, Christopher O'Donnell, Ignace Van de Woestyne
- **Defining cone extensions of nonparametric production technologies**
  Victor Podinovski
- **Benchmarking: An approach for performance evaluation based on DEA**
  Inmaculada Sirvent, José L. Ruiz, Nuria Ramón
- **Variable Selection in Data Envelopment Analysis**
  Antonio Peyrache, Christiern Rose, Gabriela Sicilia

Tuesday, 10:30-12:00

TB-09: DEA applications to Sustainability and Development
Stream: **Data Envelopment Analysis and Performance Measurement**
Room: B006
Chair(s): Chris Tofallis

- **A Longitudinal Analysis of the Social Performance of Mining Firms**
  Ana Camanho, Renata Oliveira, Andreia Zanella
- **Performance evaluation under "Zero-Waste" strategy: evidence on waste management in Tuscan municipalities**
  Laura Carosi, Giovanna D'Inverno, Giulia Romano