Management Theory and Studies for Rural Business and Infrastructure Development
ISSN 1822–6760 / eISSN 2345–0355. Doi: 10.15544/mts.2015.01
2015. Vol. 37. No. 1: 8–16.

THE FACTORS OF MILK REVENUE CHANGE IN LITHUANIA: INDEX DECOMPOSITION ANALYSIS BASED ON THE SHAPLEY VALUE

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Received 13 02 2015; accepted 30 02 2015

The paper aims to analyse the main driving forces behind the changes in milk revenue in Lithuania during 1993–2013 by the virtue of the index decomposition analysis. Specifically, an index decomposition model based upon Shapley value is introduced to account for dynamics in endogenous and exogenous factors underlying dynamics of the revenue. Particularly, the number of cows, average milk yield, market integration, milk composition, and milk price are considered as the main factors causing variation in milk revenue. The country level data are used for the analysis. Results show that such practices as animal recording and application of improved fodder have increased milk revenue by 67 million EUR and 75 million EUR during 1993–2004 and 2004–2013, respectively, due to increase in milk yield and fat.
Keywords: index decomposition analysis, milk revenue, Shapley value.
JEL codes: C43, Q11.

1. Introduction

Agricultural performance is affected by both endogenous and exogenous factors. Therefore there is a need to identify the sources in variation of the agricultural output or revenue. Indeed, in order to disentangle the impact of such endogenous factors as productivity growth, it is necessary to isolate the effects of various endogenous factors (e. g. price fluctuations) and endogenous factors related to the scale of operation (i. e. harvested area, number of cows etc.). As regards agricultural revenue, identification of the key drivers in the variation might enable to identify and quantify the most important sources of changes and, possibly, to mitigate the associated risks.

These aims require application of appropriate mathematical techniques. Index number theory has been widely employed in the area. T. Baležentis et al. (2012) applied index decomposition analysis (IDA) model based on the Logarithmic Mean Divisia Index to analyse the performance of Lithuanian rural tourism farms. A similar approach was taken by A. Kozlovskaja (2013), who applied variance decomposition analysis to analyse risk associated with crop farming in Lithuania.

The “ideal” method for index decomposition analysis should satisfy such properties as time reversal, factor reversal, and perfect decomposition (Ang, 2009).

Whereas such methods as the Logarithmic Mean Divisia Index satisfy the properties of time reversal and perfect decomposition, the order factors enter into the IDA model remains important (i. e. factor reversal is important). To overcome the drawback, the Shapley decomposition was proposed (Albrecht, 2002; Ang, 2009). Indeed, it is due to P. De Boer (2009) that the Shapley index number can be traced back to Siegel index number. Energy economics remains as the primary area of application of the Shapley index (Yu, 2014; Han, 2014; Zhang, 2014).

Dairy sector is rather important across the Baltic States in terms of output and inputs (for instance, labour force). A. Gapšys et al. (2009) analysed the trends in distribution of shares of the value chain in the dairying sector. J. Ozolins (2012) identified the key development paths for dairy processing industry in the Baltic States. However, the literature still lacks a discussion in regards to the underlying factors of milk production and revenue in Lithuania. Especially, the use of IDA ensuring such previously mentioned properties as factor reversal needs to be implemented in order to identify the most important sources of revenue growth and the related implications. This paper aims to quantify the factors of milk revenue change by the means of index decomposition analysis. The following tasks are therefore set: 1) to define the index decomposition analysis model for milk revenue; 2) to describe the Shapley decomposition; 3) to decompose the changes in milk revenue in Lithuania. The paper relies on the country level data for Lithuania covering the period of 1993–2013 (Statistics Lithuania, 2015).

2. Methodology

We define milk revenue as a product of the selling price per tonne of milk of basic fatness (3.4%) and the amount of milk sold. Then, the following equation factorizes milk revenue in terms of the explanatory factors:

$$R_t = C_t \frac{Y_t}{C_t} \frac{M_t}{Y_t} \frac{B_t}{M_t} P_t = C_t y_t m_t b_t P_t , \qquad (1)$$

where the following notations are used: t – period t, R – milk revenue, C – the number of cows at the end of period, Y – the total milk production (natural fat), M – the sold (marketed) milk (natural fat), B – the amount of sold milk (basic fat), and P – the price of milk of basic fatness. Some relative indicators can be considered on the basis of the aforementioned absolute ones (cf. Eq. 1): y is average milk yield, m is the degree of market integration, and b is a factor related to milk composition.

In a dynamic setting, we can focus at the two time periods, 0 and t. Then, the change in the total milk revenue is decomposed as follows:

$$\begin{aligned}\Delta R &= R_t - R_0 \\ &= C_t y_t m_t b_t P_t - C_0 y_0 m_0 b_0 P_0 \\ &= \Delta R_C + \Delta R_y + \Delta R_m + \Delta R_b + \Delta R_P\end{aligned}, \tag{2}$$

where $\Delta R_C, \Delta R_y, \Delta R_m, \Delta R_b, \Delta R_P$ are the effects associated with respective factors. The effects need to be estimated via IDA in order to reveal their influence on the change in overall revenue.

As it was already said, the Shapley value can be employed in IDA to allow for some appealing properties. In our case, it is important to ensure the property of factor reversal. The Shapley value, indeed, accounts for all possible patterns of changes in factors causing variation of milk revenue.

The Shapley value (Shapley, 1953; Ang, 2009) is defined as a marginal contribution of a factor of interest to the overall change in milk revenue:

$$\Delta R_{x_i} = \sum_{s=1}^{n} \frac{(s-1)!(n-s)!}{n!} \sum_{S: x_j \in S, |S|=s} \left(V(S) - V(S \setminus x_i) \right), \tag{3}$$

where the following notations are used: n – the number of factors of interest, S – a set of factors which obtain new values in period t, i. e. $V(S) = \prod_{j \in S} x_j^t \prod_{j \notin S} x_j^0$, for $j \subseteq i$. In our case, $x_i = \{C, y, m, b, P\}$ is a certain factor of interest. To illustrate, let us expand Eq. 3 to estimate ΔR_C:

$$\begin{aligned}\Delta R_C &= \frac{1}{5}\left(C_t y_0 m_0 b_0 P_0 - C_0 y_0 m_0 b_0 P_0\right) \\ &+ \frac{1}{20}\left[\left(C_t y_t m_0 b_0 P_0 - C_0 y_t m_0 b_0 P_0\right) + \left(C_t y_0 m_t b_0 P_0 - C_0 y_0 m_t b_0 P_0\right)\right. \\ &\left. + \left(C_t y_0 m_0 b_t P_0 - C_0 y_0 m_0 b_t P_0\right) + \left(C_t y_0 m_0 b_0 P_t - C_0 y_0 m_0 b_0 P_t\right)\right] \\ &+ \frac{1}{30}\left[\left(C_t y_t m_t b_0 P_0 - C_0 y_t m_t b_0 P_0\right) + \left(C_t y_0 m_t b_t P_0 - C_0 y_0 m_t b_t P_0\right)\right. \\ &+ \left(C_t y_0 m_0 b_t P_t - C_0 y_0 m_0 b_t P_t\right) + \left(C_t y_t m_0 b_t P_0 - C_0 y_t m_0 b_t P_0\right) \\ &\left. + \left(C_t y_t m_0 b_0 P_t - C_0 y_t m_0 b_0 P_t\right) + \left(C_t y_0 m_t b_0 P_t - C_0 y_0 m_t b_0 P_t\right)\right] \\ &+ \frac{1}{20}\left[\left(C_t y_t m_t b_t P_0 - C_0 y_t m_t b_t P_0\right) + \left(C_t y_t m_t b_0 P_t - C_0 y_t m_t b_0 P_t\right)\right. \\ &\left. + \left(C_t y_0 m_t b_t P_t - C_0 y_0 m_t b_t P_t\right) + \left(C_t y_t m_0 b_t P_t - C_0 y_t m_0 b_t P_t\right)\right] \\ &+ \frac{1}{5}\left(C_t y_t m_t b_t P_t - C_0 y_t m_t b_t P_t\right)\end{aligned}. \tag{4}$$

The proposed decomposition model takes into account an exogenous factor (viz. milk price) and endogenous ones (namely the number of cows, average milk yield, the degree of market integration, and milk composition). Indeed, endogeneity of the milk price might be questioned as it is also dependent on the quantity of milk sold, yet, under the quota system, the latter impact might be not as important. Given no deflatory measures are included in the model, the price effect also accounts for inflation. The effect of number of cows mainly represents extensive development of dairying sector.

Milk yield effect indicates whether the productivity of dairying is increasing. Market integration factor is quite ambiguous: on the one hand it represents involvement in the value chain, on the other hand direct marketing might be neglected. The latter case might be especially relevant for small farms. Milk composition component and milk yield component capture the changes in breeding and feed quality. Therefore, the latter factors are important when assessing intensive development of dairying sector. In particular, such practices as animal recording might have a positive impact upon these variables. Note that the proposed model does not encompass all the possible factors affecting milk price and, therefore, revenue. For instance, protein content could also be included in the model to account in differences of milk composition. The model rests on the aggregate data for Lithuania (Statistics Lithuania, 2015). The research covers the period of 1993–2013. Indeed, we look at two consecutive periods, viz. pre–EU period of 1993–2004 and post–EU period of 2004–2013.

3. Results

IDA has is carried out for the two periods separately. First, the pre–EU period covering years 1993–2004 is analysed. Second, the post–EU period of 2004–2013 is analysed. Indeed, accession to the European Union is related to changes in support policy and price variation. In the sequel, we will focus on the dynamics of the main indicators related to milk revenue and present the results of IDA. In order to look at the changes of the importance of the different factors within the IDA model, the IDA is conducted in both a chain-linked and a period-wise manner. The period of 1993–2004 marked an increase of 59% in the total milk revenue in Lithuania. As one can note, the absolute indicators like herd size, total output and marketed output (Table 1) had decreased during the said period. Therefore, there had been no extensive developments in the dairying sector. The milk price, though, followed an upward trend in general. Indeed, it was the number of cows and milk price that showed the highest variation among the absolute indicators – coefficient of variation (CV) for the latter two variables exceeded 16%.

Table 1. Absolute indicators of milk revenue, 1993–2004

	Dairy cows, thousand	Milk output, thousand t	Milk sold, thousand t	Milk sold (base fat), thousand t	Price, EUR/t	Revenue, million EUR
Year 1993	678.1	2066.7	1366.7	1517.8	80	121.4
Year 2004	433.9	1848.7	1140	1370.8	141	193.3
Rate of change	–244	–218	–227	–147	61	71.9
Rate of growth, %	–36	–11	–17	–10	76	59
Rate of growth*,%	–44	–11	–18	–10	55	46
Average	524	1840	1104	1280	131	168.2
SD	85	106	129	138	27	40.1
CV	0.16	0.06	0.12	0.11	0.20	0.24

* the adjusted rate of growth relative to the midpoint of the sample

Looking at the relative indicators (Table 2) reveals somehow different story. The two indicators related to dairying productivity, viz. milk yield and milk composition factor, exhibited positive trends. Specifically, average milk yield went up from 3.05 t/cow up to 4.26 t/cow, i. e. the increase of 40% had been achieved. As regards the milk composition factor, its value increase at a margin of 8%. Note that increase in the latter indicators implies increase in milk fat.

Considering the market integration, one can see that a decrease of 4 percentage points had been observed during 1993–2004. This can be explained in two ways: first, relatively lower amount of milk output used to be sold for dairy processing sector due to unfavourable pricing, second, a certain part of milk output might have been marketed informally (what, in fact, does not necessarily imply income loss).

Table 2. Relative indicators on milk revenue, 1993–2004

	Milk yield, t/cow	Market integration factor	Milk composition factor
Year 1993	3.05	0.66	1.11
Year 2004	4.26	0.62	1.20
Rate of change	1.21	–0.04	0.09
Rate of growth, %	40	–7	8
Rate of growth*, %	33	–7	8
Average	3.57	0.60	1.16
SD	0.44	0.04	0.03
CV	0.12	0.07	0.02

* the adjusted rate of growth relative to the midpoint of the sample

Results of IDA for 1993–2004 (chain-linked analysis) are presented in Fig. 1. Note that the periods of 1993–1994, 1998–2000, and 2001–2003 showed a decrease in the total milk revenue. The IDA suggests that the decrease of 1993–1994 was mainly driven by the decreasing number of cows and market integration (i. e. lower share of milk output was sold). As for 1998–2000, a negative milk price effect was observed besides the two aforementioned factors. Indeed, a decreasing number of cows had virtually the same absolute impact on change in milk revenue throughout 1997–2000. The decrease of 2001–2003 was mainly fuelled by decreasing milk prices.

The period of 2004–2013 was specific with somewhat lower variation in absolute variables (Table 3) if opposed to the preceding period. However, the total milk revenue maintained the same CV mainly due to changes in milk price. Both the number of cows and milk output were specific with negative growth rates of – 27% and –7%, respectively. The amount of milk sold, though, tended to increase by some 18%. These findings imply that the dairying sector evolved in terms of farm structure and the said developments generally contributed to increase in productivity.

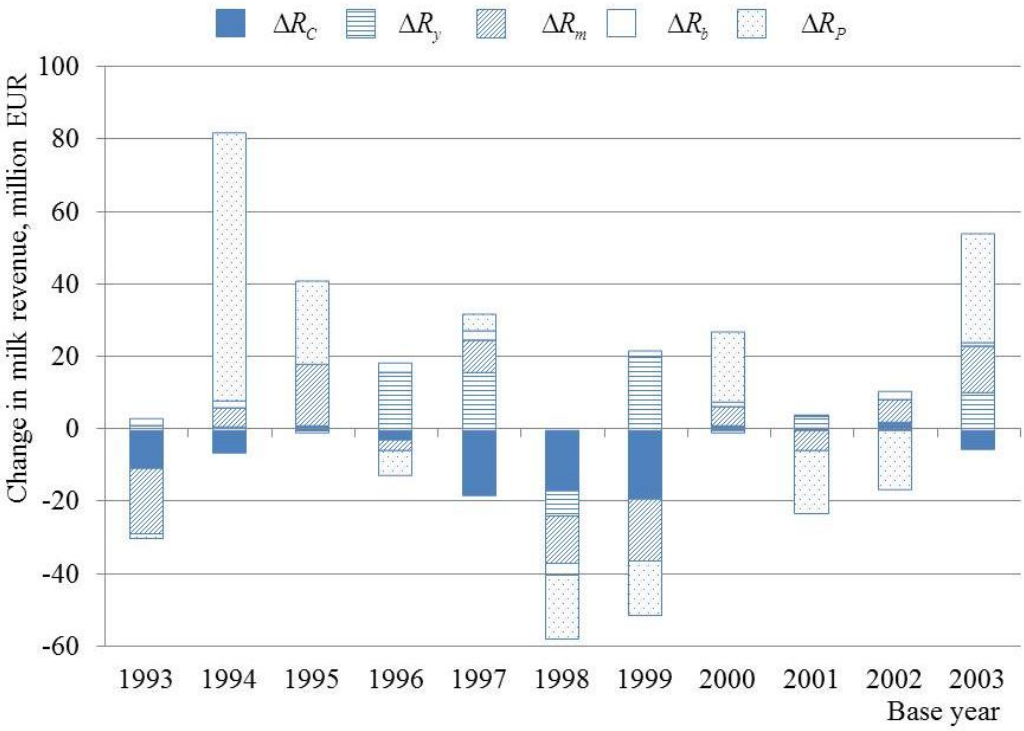

Fig. 1. Index decomposition for 1993–2004 (chain-linked analysis)

Indeed, decrease in the share of milk produced by small farms might have yielded decrease in a number of cows, whereas expansion of larger farms partially alleviated that decrease and fuelled increase in the amount of milk sold. Note that milk price and revenue featured the highest CVs with other variables being specific with much lower values of the said indicator.

Table 3. Absolute indicators on milk revenue, 2004–2013

	Dairy cows, thousand	Milk output, thousand t	Milk sold, thousand t	Milk sold (base fat), thousand t	Price, EUR/t	Revenue, million EUR
Year 2004	433.9	1848.7	1140	1370.8	141	193.3
Year 2013	315.7	1723.1	1339.5	1611.5	263	423.8
Rate of change	–118	–126	200	241	122	230.5
Rate of growth, %	–27	–7	18	18	87	119
Rate of growth*, %	–32	–7	16	16	60	75
Average	378	1824	1293	1556	195	305.9
SD	38	71	74	93	39	73.8
CV	0.10	0.04	0.06	0.06	0.20	0.24

* the adjusted rate of growth relative to the midpoint of the sample

Milk yield continued to grow during 2004–2013 and went up by some 28%. Another important change was increase in the market integration factor of some 16 percentage points. As regards the milk composition factor, it remained virtually unchanged. Therefore, the period of 2004–2013 featured intensive development in terms of milk yield growth, yet changes in milk composition were close to nil. Indeed, the decrease in the growth rate of the milk composition factor indicates that the herd structure might have been optimised in terms of breeds in Lithuania and further improvements in this direction are not that important. However, fodder can still be an important factor as milk yield is still increasing.

Table 4. Relative indicators on milk revenue, 2004–2013

	Milk yield, t/cow	Market integration factor	Milk composition factor
Year 2004	4.2	0.62	1.2
Year 2013	5.5	0.78	1.2
Rate of change	1.20	0.16	0.00
Rate of growth, %	28	26	0
Rate of growth*, %	25	23	0
Average	4.86	0.71	1.20
SD	0.37	0.05	0.00
CV	0.08	0.07	0.00

* the adjusted rate of growth relative to the midpoint of the sample

Fig. 2 presents results of the chain-linked IDA for 2004–2013. As one can note, the changes in the total milk revenue were positive for most of the periods save those of 2008–2009 and 2011–2012. In both of the latter cases, milk price was the key reason for decline of the milk revenue. However, it was milk price that kept income growing throughout the other periods. A decrease in number of cows caused losses in the revenue, yet these had been compensated by other factors. The presence of a positive influence of the market integration remained evident throughout most of the periods, however their absolute size remained stable irrespectively of the overall change in the milk revenue. Yield effect was also positive in most of the periods with exception for 2007–2010.

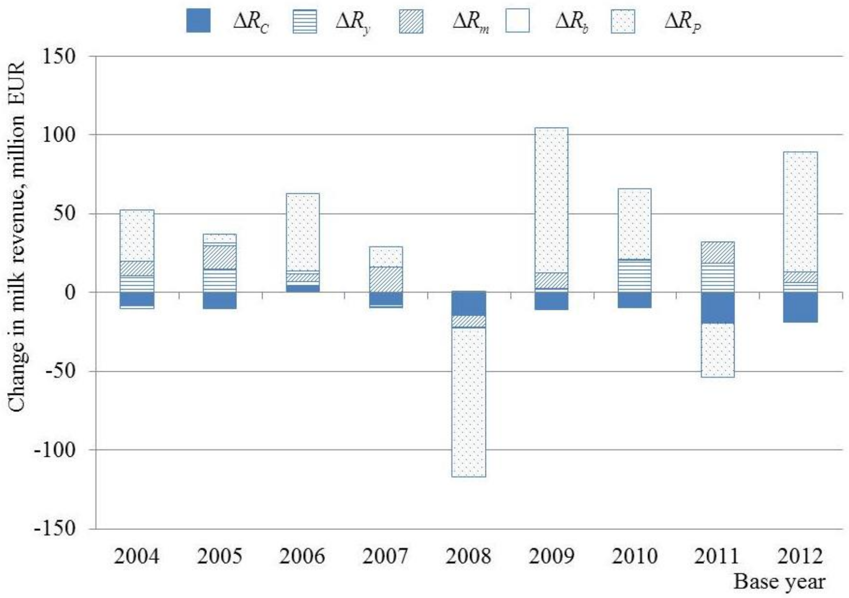

Fig. 2. Index decomposition for 2004–2013 (chain-linked analysis)

In order to summarise the effects of different factors in terms of changes in the milk revenue, a period–wise analysis was carried out for the two periods of 1993–

2004 and 2004–2013. The results are presented in Table 5. Both absolute and relative estimates are presented.

Table 5. The period-wise IDA for the two periods (in EUR unless noted otherwise)

Period	ΔR	ΔR_C	ΔR_y	ΔR_m	ΔR_b	ΔR_P
1993–2004	71858800	– 73996833	53933994	– 11427347	12924721	90424266
		– 103%	75%	– 16%	18%	126%
2004–2013	230541700	– 100067307	75214326	70415479	155095	184824108
		– 43%	33%	31%	0.1%	80%

The results show that in case other factors had remained fixed, the total milk revenue would have decreased by some 74 million EUR due to decrease in the number of cows during 1993–2004. However, the latter effect was solely compensated by the price effect. Indeed, these two effects were the most significant ones in both of the considered periods. The relative importance of the extensive development, as identified by ΔR_C, has decreased in the second period even though the absolute value has increased. The period of 2004–2013 shows a steep increase in the market integration effect, which marks a transition towards commercial dairy farming if opposed to subsistence dairying. It can also be concluded that increase in milk yield and fat rendered increases in the total revenue of 67 million EUR and 75 million EUR during 1993–2004 and 2004–2013, respectively. These gains can be considered as a direct result of technical change (innovations) occurred in the dairying sector.

4. Conclusions

1. A new index decomposition analysis model for milk revenue analysis has been introduced. The proposed model satisfies several desirable properties such as factor reversal and thus provides a means for a multi–factor analysis of milk revenue.
2. Application of the proposed technique suggests that the changes in the number of cows and milk price were the most decisive factors influencing milk revenue. Indeed, they were active in opposite directions with increase in milk prices causing a positive change in milk revenue. Therefore, it can be concluded that such practices as animal recording and application of improved fodder have increased milk revenue by 67 million EUR and 75 million EUR during 1993–2004 and 2004–2013, respectively.
3. It is evident that exit of small farms lead to increase in the market integration factor. However, the economic impact of this development requires further research as the share of the intra–farm use of the milk output needs to be estimated.
4. The proposed model could be employed at different levels of agricultural sector. Farm–level analysis might reveal certain patterns within different regions, farm size groups etc. International comparison would yield the same information and thus certain insights into sources of competitiveness prevailing across certain countries.

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PAJAMŲ UŽ PIENĄ POKYČIŲ VEIKSNIAI LIETUVOJE: INDEKSINIO IŠSKAIDYMO ANALIZĖ TAIKANT SHAPLEY VERTĘ

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Įteikta 2015 02 13; priimta 2015 02 30

Straipsnio tikslas – pasiūlius indeksinio išskaidymo modelį, įvertinti pagrindinius pajamų už parduotą (supirktą) pieną pokyčių veiksnius Lietuvoje 1993–2013 m. Endogeninių ir egzogeninių veiksnių, lemiančių pajamų už pieną kaitą, vertinimas atliekamas taikant indeksinio išskaidymo analizės modelį, paremtą Shapley vertės koncepcija. Pagrindiniai indeksinės analizės elementai yra karvių skaičius, vidutinis karvių produktyvumas, integracijos į rinką laipsnis, pieno sudėtis (riebumas) ir pieno kaina. Tyrimui naudojami respublikos lygio duomenys. Tyrimo rezultatai rodo, kad tokios priemonės kaip gyvulių produktyvumo kontrolė ir raciono tobulinimas padidino karvių produktyvumą ir pieno riebumą. Dėl to pajamos už parduotą pieną padidėjo 67 mln. eurų 1993–2004 m. laikotarpiu ir 75 mln. eurų 2004–2013 m. laikotarpiu.

Raktiniai žodžiai: indeksinio išskaidymo analizė, pajamos už pieną, Shapley vertė.

JEL kodai: C43, Q11.