

The interplay of labour, land, intermediate consumption and output: a decomposition of the agricultural labour productivity for the Baltic States

Vaida Sapolaite & Tomas Balezentis

To cite this article: Vaida Sapolaite & Tomas Balezentis (2022) The interplay of labour, land, intermediate consumption and output: a decomposition of the agricultural labour productivity for the Baltic States, Economic Research-Ekonomiska Istraživanja, 35:1, 3512-3532, DOI: [10.1080/1331677X.2021.1997622](https://doi.org/10.1080/1331677X.2021.1997622)

To link to this article: <https://doi.org/10.1080/1331677X.2021.1997622>



© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 22 Nov 2021.



[Submit your article to this journal](#)



Article views: 638



[View related articles](#)




[View Crossmark data](#)



Citing articles: 1 [View citing articles](#)

The interplay of labour, land, intermediate consumption and output: a decomposition of the agricultural labour productivity for the Baltic States

Vaida Sapolaite and Tomas Balezentis 

Lithuanian Centre for Social Sciences, Vilnius, Lithuania

ABSTRACT

This article proposes a decomposition approach for the agricultural labour productivity change that takes into account the land-to-labour ratio, intermediate consumption intensity and intermediate consumption productivity. The case of the three Baltic States (Estonia, Latvia, Lithuania) is considered which is interesting in the light of the European Union (E.U.) expansion and the structural change taking place in those countries. In addition, Poland, Germany and Denmark are included in the analysis as benchmark countries. To quantify the drivers of the agricultural labour change in the countries considered, the Index Decomposition Analysis (I.D.A.) is applied. The analysis proceeds in two directions: first, the cumulative change in the agricultural labour productivity over 1998–2018 is decomposed for each country under analysis; second, differences in the agricultural labour productivity for each country vis-à-vis Denmark (the highest productivity country) are decomposed. The results offer important policy implications as the intermediate consumption intensity appears as the critical factor that needs to be addressed via the support payments.

ARTICLE HISTORY

Received 28 January 2021
Accepted 20 October 2021

KEYWORDS

land-to-labour ratio; intermediate consumption; labour productivity; Baltic States; index decomposition analysis (I.D.A.); Logarithmic Mean Divisia Index (L.M.D.I.)

JEL CODES

C43; Q10

1. Introduction

The Baltic States appear among countries undergone collectivisation and de-collectivisation (Trzeciak-Duval, 1999) along with the recent implementation of the Common Agricultural Policy. Indeed, the Baltic States joined the European Union (E.U.) in 2004 and their agricultural sectors have seen remarkable changes in both absolute and relative terms. Therefore, it is important to discuss the development paths of agriculture in the Baltic States.

The economic activity seeks to provide the population with means of subsistence. Accordingly, the measures of the labour productivity are important in analysing the performance of any economic sector. This is particularly relevant in agriculture where

CONTACT Tomas Balezentis  tomas@laei.lt

© 2021 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

farmers also act as entrepreneurs and suppliers of agro-food products. The discussion on the labour productivity in the agriculture dates back to Hayami and Ruttan (1985) who proposed considering the two major sources of the growth in agricultural labour productivity: the increase in the land-to-labour ratio and land productivity gains. Obviously, the land-to-labour ratio can be increased by changing the agricultural technology and expanding the utilised agricultural area. As regards the land productivity, it is mostly related to agricultural technologies. However, both of these terms are linked to the situation in the agricultural goods markets (i.e., reasonable price recovery ratio induces the use of the intermediate inputs and allows increasing the land productivity and expanding the scale of operation).

The main sources of agricultural productivity growth are increasing agricultural production and reduction of labour other resource inputs. This may also lead to gains in farm income and decline in the price of agricultural products and food (Fuglie, 2012). In addition, Swinnen et al. (2012) stressed the importance of farm structure and the overall economic development of a country on agricultural productivity growth. Thus, multiple interrelated factors should be considered when explaining agricultural productivity growth.

In Western Europe, the agricultural labour productivity growth has slowed down since the end of the twentieth century (Wang et al., 2012). As Wang et al. (2012) argued, this could have been caused by the limited resource inputs in the agricultural production and increasing production costs. The Baltic States partially follow this path, yet they are still lagging behind Western European countries in terms of the productivity indicators (e.g., crop and milk yields) and scale of production. Indeed, the increasing scale of agricultural production in the Baltic States can be seen from growth in the absolute indicators (utilised agricultural area, agricultural output) and relative ones (average farm size). According to Zhao et al. (2012) and Zsarnóczai and Zéman (2019), performance analysis focuses on comparison of productivity growth rates between farms, industries, or regions. In the context of the EU, the differences between the new and old Member States are often evident due to a number of external and internal factors. Csaki and Jambor (2019) compared the partial productivity indicators for the Central and Eastern European countries (including the Baltic States) to those for the E.U.-15 countries and showed that the production volume did not increase significantly, yet land and labour productivity followed an upward trend for the Baltic States.

The objective of this research is to construct an index decomposition analysis (I.D.A.) model for decomposing the changes in agricultural labour productivity spatially and temporally taking into account land and labour endowments and intermediate consumption. This allows shedding more light on the development of the agricultural sectors of the Baltic States from the viewpoint of the labour productivity. The case of the Baltic States is interesting in that these countries are facing structural adjustments (mostly, phasing-out of small farms) and deeper integration in the commodity markets. Besides the two aforementioned factors (land productivity and land-to-labour ratio), this article introduces the intermediate consumption intensity (per land area unit) into the analysis. Indeed, the latter factor is important in the Baltic States as they are still improving their agricultural practices and increasing the use of

agrochemicals, among other inputs. The use of the C.A.P. payments allows improving the intermediate input use. Therefore, the article establishes a three-factor model for the agricultural labour productivity analysis.

The I.D.A. is used as the quantitative technique allowing for decomposition of changes in the agricultural labour productivity with respect to the explanatory terms (i.e., land-to-labour ratio, intermediate consumption intensity and intermediate consumption productivity). The use of the Logarithmic Mean Divisia Index (L.M.D.I.) for I.D.A. allows tracking the major sources of labour productivity growth without involving the residual term. The proposed approach is applied for the case of the three Baltic States – Estonia, Latvia and Lithuania. In addition, the developed countries – Denmark and Germany – are included in the analysis for sake of comparison. A neighbouring country – Poland – is also considered. The country-level data from Eurostat (E.E.A.) for the period of 1998–2018 are used.

The article proceeds as follows: Section 2 presents the earlier literature on agricultural labour productivity. Section 3 presents the IDA model used for the analysis. Section 4 proceeds with the discussion of the results obtained. Discussion is provided in Section 5. Conclusions are drawn in Section 6.

2. Literature review

The labour productivity growth was explained by Kumar and Russell (2002) in terms of the technological change, efficiency change and capital accumulation. Agricultural productivity has been a focal point of a number of studies dedicated to different regions (Ball et al., 1997). In general, the single and multiple (total) factor productivity measures can be applied (Schreyer & Pilat, 2001). The single factor productivity measures are the partial ones and indicate the extent to which a certain factor input is exploited (in terms of output per unit of the factor input). The multiple factor productivity measures (total factor productivity measures also belong to this category) take into account the overall use of the inputs and production of outputs when assessing the productivity. The latter group of measures relies on estimation of the production technology (via, e.g., Data Envelopment Analysis or econometric techniques) and is data-intensive.

The agricultural productivity growth also relates to structural policy and institutional changes. The researchers point out that farm structure influences the adoption of risk management measures and distinguish two main components of farm structure, namely, type of farming and farm size. Adopting specific risk management strategies differ due to the obvious differences in agricultural production, farm structure, farm income, farm financing and personal characteristics (Van Asseldonk et al., 2016). Therefore, farmers apply different strategies and measures to manage their income and risk. Njuki et al. (2019) argued that the ability to respond to the adverse effects of climate change appears as a significant factor of agricultural growth. Gaitán-Cremaschi et al. (2017) argued that the use of the productivity measures can guide policy debate by providing information on possible welfare gains. Researchers Ahmed and Bhatti (2020) provided a comprehensive overview of productivity

measurement methods, and concluded that average farm size has a positive effect on productivity growth.

The importance of technological innovations of agricultural productivity growth was stressed by Alston and Pardey (2014). As suggested by Barro (1991), countries with more human capital tend to grow faster, catch up better with the best available technology, and have a higher ratio of physical investment to G.D.P. In addition, poor countries tend to catch up with rich countries if a person has a large human capital in poor countries. Thus, the general level of socioeconomic development of a certain country is linked to the agricultural productivity growth.

In agricultural context, the notion of the labour productivity has received substantial attention as it relates to the economic and social viability of rural areas. As regards the single factor productivity measures, the study by Hayami and Ruttan (1985) concentrated on the two terms rendering the (partial) labour productivity indicator, viz., land-to-labour ratio and land productivity. Mugeru et al. (2012) applied the D.E.A. to establish a measure of labour productivity change based on the production function. In the latter case, the concept of the T.F.P. (or multi-factor productivity) was followed, as the labour productivity was measured by taking the use of the other inputs into account. However, such a setting is more data-intensive if compared to that for the single factor productivity measures. Most of the research (e.g., Baráth & Fertő, 2017) turn to the T.F.P. growth itself without focusing on the labour productivity. Giannakis and Bruggeman (2018) econometrically related agricultural labour productivity to a number of explanatory factors including technical efficiency.

International comparison of agricultural labour productivity is a topical issue. Indeed, the reasons behind the different labour productivity levels across the countries are explained by means of the quantitative tools. Hayami and Ruttan (1970) presented an early attempt to address the labour productivity differences by following a setting based on the production function. More recently, there has been a discussion on the accuracy of the measures of the agricultural labour productivity. This question is important as there has been huge variation in the agricultural labour productivity across countries and across sectors within a certain country. Herrendorf and Schoellman (2015) discussed the methodological issues underlying the calculation of the agricultural value in the light of the inter-sectoral differences. Gollin et al. (2014) compared the micro-level appraisals of the agricultural value added to those reported at the national level. Csaki and Jambor (2019) focused on the European and Asian countries in regards to the convergence in the agricultural labour productivity.

The impact of investment support on farms was studied by Kollár and Sojková (2015) who showed a positive impact of investment support on value added and productivity, measured as the ratio of gross value added to labour costs. Kijek et al. (2019) found that convergence has taken place among the E.U. Member States in terms of agricultural productivity. Irz et al. (2001) and Struik and Kuyper (2017) showed that agriculture and rural development are the key factors in reducing poverty and promoting agricultural growth.

Hayami and Ruttan (1970) stressed that resource endowments, fixed and working capital used, and human capital can be considered as the major driving forces behind the differences in agricultural labour productivity. Zhao and Tang (2018) applied the

growth accounting approach to assess agricultural labour productivity growth. The model included agricultural labour force, capital stock and intermediate consumption. Indeed, Zhao and Tang (2018) took the human quality into account as they considered labour force to employee number ratio.

Restuccia et al. (2008) included the intermediate consumption into the production function when analysis the variation in agricultural labour productivity. Thus, this article suggests extending the two-factor setting originating from Hayami and Ruttan (1985) by including the use of the intermediate inputs in the analysis. This will allow taking the changes in the underlying production technology into account during the analysis of the agricultural labour productivity.

3. Methods and data

3.1. Index decomposition analysis model

The agricultural labour productivity growth can be analysed by means of the IDA that allows linking the overall change in the variable of interest to the explanatory terms. The IDA is appealing in that it is not data-intensive, yet can quantify the underlying trends in the drivers of the agricultural labour productivity and the resulting calculations can be applied for international comparison. The I.D.A. originates from energy economics and was discussed by, e.g., Ang and Zhang (2000) and Ang et al. (2009).

The agricultural labour productivity can be defined as a product of terms suggested by Hayami and Ruttan (1985), i.e., land-to-labour ratio and land productivity. In this article, we further augment this approach by introducing the intermediate consumption into analysis. Therefore, the following decomposition of the agricultural labour productivity at time period t can be established:

$$\frac{Y_t}{L_t} = \frac{Y_t}{I_t} \frac{I_t}{A_t} \frac{A_t}{L_t} = y_t i_t a_t, \quad (1)$$

where Y_t , I_t , A_t and L_t are agricultural output, intermediate consumption, utilised agricultural area and labour input, respectively. The ratios y_t , i_t and a_t are intermediate consumption productivity (basically, it is related to profitability), intermediate consumption intensity (per land area) and land-to-labour ratio (land intensity), respectively. Y_t and I_t can be measured in the real monetary terms (i.e., implicit quantity indices). A_t can be measured in area units (e.g., hectares). L_t can be measured in labour hours, person-years or a similar dimension.

The changes in agricultural labour productivity can be measured by considering the base period 0 and the current period T :

$$\Delta \left(\frac{Y}{L} \right)_{0,T} = \frac{Y_T}{L_T} - \frac{Y_0}{L_0} = \Delta_y + \Delta_i + \Delta_a, \quad (2)$$

where Δ_y is the effect of the change in the intermediate consumption productivity, Δ_i is the effect associated with the change in the intermediate consumption intensity,

and Δ_a is the effect due to the change in land-to-labour ratio. The three effects given on the right-hand-side of Eq. 2 can be rendered by the means of the I.D.A. Among multiple techniques for decomposition, the L.M.D.I. is often preferred as it does not require complex calculations and satisfies multiple properties that are desirable for index numbers.

In this article, the dynamics of agricultural labour productivity is considered at the country level. As different countries are involved in the analysis, we assume they are not related in the sense of input sharing. Therefore, the decomposition is carried out independently for each country. The L.M.D.I. (Ang et al., 2009) can then be applied to assess the contribution of the three factors in Eq. 2 to the growth in the agricultural labour productivity (for a given country). The following calculations for the L.M.D.I. I method are applied:

$$\Delta_y = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{y_T}{y_0}\right), \quad (3)$$

$$\Delta_i = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{i_T}{i_0}\right), \quad (4)$$

$$\Delta_a = w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) \ln\left(\frac{a_T}{a_0}\right), \quad (5)$$

where the logarithmic mean operator $w\left(\frac{Y_T}{L_T}, \frac{Y_0}{L_0}\right) = \left(\frac{Y_T}{L_T} - \frac{Y_0}{L_0}\right) / \left(\ln \frac{Y_T}{L_T} - \ln \frac{Y_0}{L_0}\right)$ is applied to convert the relative growth into absolute change of the agricultural labour productivity indicator.

Up to now, we discussed the temporal decomposition of the agricultural labour productivity change. Such an approach allows one to unveil the effects behind the change in agricultural labour productivity within a certain country over time. For policy analysis, one more question warrants attention: what are the reasons behind the spatial differences. In order to tackle such a question, one needs to compare countries rather than time periods. This can be done by picking a certain country (or an average; see Ang et al., 2015) as a reference. Assuming one is interested in the differences between agricultural labour productivity in countries α and β , one needs to decompose the change $\Delta\left(\frac{Y}{L}\right)_{\alpha,\beta}$ (cf. Eq. 2). The calculations defined in Eqs. 3–5 are then applied.

3.2. Data

The article uses data from the economic accounts for agriculture provided by E.E.A. The agricultural output is measured at constant prices (2010 = 100). The agricultural output shows the overall production activity without taking the subsidies into account (producer prices are used). The agricultural output is chosen against the value added so as to avoid the double counting as the intermediate input enters the model as well. The intermediate consumption at constant prices is also taken from the E.E.A. This

variable shows the amount of the chemicals, fuels, seeds, etc. consumed in the agricultural production. The utilised agricultural area is taken from the crop production statistics (main area in 1000 ha) provided by Eurostat. The total labour force input is provided by the E.E.A. (agricultural labour input statistics) and measured in the Annual Working Units (A.W.U.). These absolute variables are used to construct the ratios defined in Section 3.1, namely labour productivity, intermediate consumption productivity, intermediate consumption intensity and land-to-labour ratio. The three Baltic States (Estonia, Latvia and Lithuania) are considered along with Germany, Denmark and Poland that provide possible pathways for development of the agriculture yet differ in terms of the average farm size and productivity.

4. Results

The Baltic States exhibit relatively small farm size and lower productivity if compared to the developed agricultural systems in, e.g., Denmark or Germany. The agricultural labour productivity is related to land productivity and farm size (per labour force unit) in Figure 1. Note that land-to-labour ratio not only represents the farm size, but also relates to the effectiveness of agricultural labour as more skilled and well-equipped labour force may exploit larger land areas than the unskilled and/or unequipped one.

In the output space, the Baltic States are spanned by the observations representing performance of the Danish and German Farms. Even though the Polish farms show lower distance from the Baltic States in the output space, they latter ones still outperform the former ones. This implies that the production possibility frontier currently

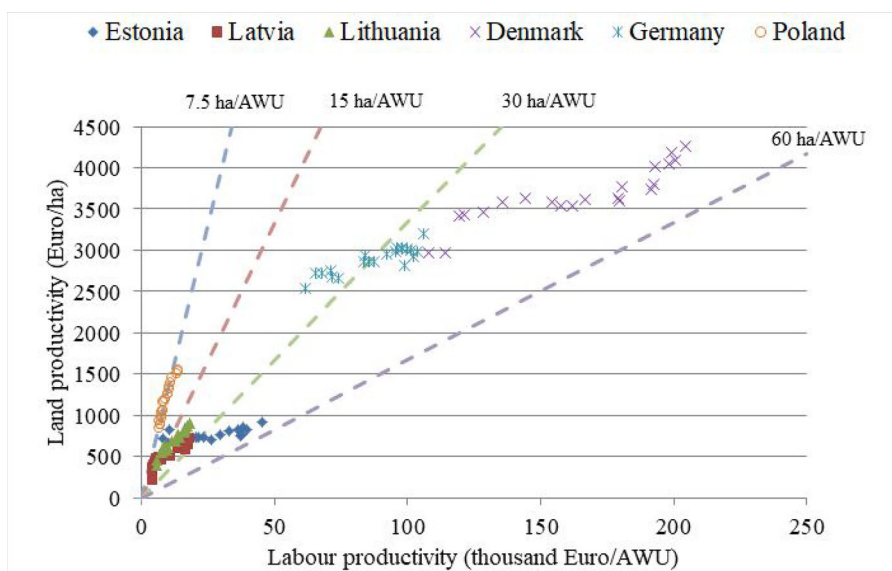


Figure 1. Partial agricultural productivity indicators (land and labour productivity) and land-to-labour ratio in the selected European countries, 1998–2018.

Note: dashed lines represent different levels of the land-to-labour ratio.

Source: The authors.

does not depend on the performance of the Baltic States. Noteworthy, all of the countries depicted in Figure 1 show an increasing farm size over time with exception of Poland. Indeed, Poland shows the smallest average farm size (land-to-labour ratio) slightly above 7.5 ha/A.W.U. The two most productive countries, Denmark and Germany, show an increasing farm size (Germany exceeds the level of 30 ha/A.W.U., whereas Germany is approaching 60 ha/A.W.U.). Out of the Baltic States, Estonia is comparable to these patterns as the average farm size is approaching 60 ha/A.W.U. there. Latvia is approaching the limit of 30 ha/A.W.U., yet its productivity levels are still beyond those observed for Lithuania and Estonia. These stylised facts imply the need for further analysis relating farm input intensity and productivity.

The dynamics in the major absolute indicators defining the agricultural labour productivity in the selected countries are presented in Table 1. As regards the total agricultural output, the Baltic States show the highest rates of growth (at least 2.4% per year) if compared to at most 1.7% per year for the other three countries. This suggests that the Baltic States are still on the way towards full exploitation of the agricultural resource endowments and adjustment of the production process.

The intermediate consumption tended to increase at higher rates in the Baltic States if compared to the other three countries. Indeed, Estonia and Latvia showed higher growth rates for intermediate consumption than it was the case for agricultural

Table 1. Dynamics in the absolute indicators for the agriculture of the selected countries, 1998–2018.

Country	Levels		Rate of growth, %
	1998	2018	
Total agricultural output, million euro of 2010			
Estonia	541	757	2.4
Latvia	675	1153	4.0
Lithuania	1577	2371	3.6
Denmark	8852	10776	1.0
Germany	44915	46856	0.5
Poland	17261	22619	1.7
Intermediate consumption, million euro of 2010			
Estonia	337	588	3.1
Latvia	478	865	4.3
Lithuania	1323	1715	2.3
Denmark	6314	6692	0.6
Germany	32418	36646	0.5
Poland	12443	13908	0.8
Utilised agricultural area, thousand ha			
Estonia	747	985	1.0
Latvia	2508	1938	0.0
Lithuania	3497	2947	0.3
Denmark	2976	2633	-0.4
Germany	17698	16645	-0.2
Poland	18229	14540	-1.3
Agricultural labour input, thousand AWU			
Estonia	67	20	-6.7
Latvia	165	71	-4.6
Lithuania	274	143	-2.3
Denmark	82	54	-2.2
Germany	727	474	-2.1
Poland	2856	1676	-2.3

Note: stochastic rates of growth are based on the log-lin model $\ln x_t = a + bt$, where b is the rate of growth and t is the time trend.

Source: The authors.

output. This indicates that the three Baltic States are attempting to catch-up with the developed countries. Still, the growth rates of 4% per year at most do not warrant approaching the level of, e.g., Denmark in the short or medium run.

The changes in the U.A.A. also differ across the two groups of countries: the Baltic States show slightly increasing trends (with exception if Latvia), whereas a decline is observed in Poland, Denmark and Germany. This indicates the increasing scarcity of land resources in the developed countries. Such trends are related to increasing opportunity costs for agricultural activity. As for the Baltic States, the introduction of CAP payments rendered an increase in the U.A.A.

Agricultural labour input declined in all the countries considered. Estonia and Latvia showed the steepest decline (-6.7% and -4.6% per year, respectively), whereas agricultural labour input tended to decline by 2% in the other countries. Obviously, declining agricultural labour force is caused by modernisation of agriculture.

Table 2 shows the dynamics in the relative indicators describing agricultural labour productivity. The Baltic States show the highest rates of growth in agricultural labour productivity (5.9% to 9.1% per year) if compared to the other countries (2.6% to 4% per year). The absolute levels of the agricultural labour productivity vary substantially across the countries: as of 2018, Latvia, Lithuania and Poland showed more than 10 times lower labour productivity if compared to Denmark. Thus, a faster convergence is needed in order to achieve reasonable agricultural labour productivity levels, especially in Poland, Latvia and Lithuania.

The intermediate consumption productivity is represented by the ratio of the total agricultural output to the intermediate consumption. This ratio seems to be rather similar across the countries analysed, e.g., it ranged in between 1.28 and 1.63 for 2018. This suggests that the intermediate inputs are similarly productive across the countries analysed. Thus, the production technologies existing in the countries analysed do not differ substantially in this regard. Furthermore, the rates of growth for this indicator do not show clear patterns suggesting that the technological change is uneven across the countries covered.

Intermediate consumption intensity varies substantially across the countries under analysis. Indeed, the Baltic States show much lower input rates per land area (450–600 Eur/ha as of 2018) if contrasted to Denmark or Germany (more than 2000 Eur/ha) or Poland (960 Eur/ha). Also, the Baltic States and Poland show higher rates of growth in the intermediate consumption intensity (2–4% per year) if compared to Denmark and Germany (less than 1% per year). These patterns indicate limited application of agrochemicals that may lead to reduced land and labour productivity.

The farm size (as measured by the land-to-labour ratio) indicates the scale of farming. The smallest farms are observed in Poland. Latvia and Lithuania come next and rank below Estonia, Denmark and Germany. Nevertheless, the three Baltic States show the rates growth exceeding 2.6% per year. Denmark and Germany show rates of growth of 1.9% per year.

The results show the presence of the structural changes and output growth in the agricultural sectors of the selected countries. The agricultural sector applies novel technologies and practices along with changes in the average farm size and specialisation. These developments have led to changes in the relative prices of the inputs and outputs and farm income (that further drive farmers' decisions).

Table 2. Dynamics in the relative indicators for the agriculture of the selected countries, 1998–2018.

Country	Levels		Rate of growth, %
	1998	2018	
Agricultural labour productivity, thousand euro of 2010/AWU			
Estonia	8.1	37.7	9.1
Latvia	4.1	16.4	8.6
Lithuania	5.8	16.5	5.9
Denmark	107.9	200.8	3.2
Germany	61.7	98.9	2.6
Poland	6.0	13.5	4.0
Agricultural output to intermediate consumption ratio			
Estonia	1.61	1.29	−0.7
Latvia	1.41	1.33	−0.3
Lithuania	1.19	1.38	1.3
Denmark	1.40	1.61	0.4
Germany	1.39	1.28	−0.1
Poland	1.39	1.63	0.9
Intermediate consumption intensity, thousand euro of 2010/ha			
Estonia	0.45	0.60	2.2
Latvia	0.19	0.45	4.3
Lithuania	0.38	0.58	2.0
Denmark	2.12	2.54	1.0
Germany	1.83	2.20	0.7
Poland	0.68	0.96	2.2
Land-to-labour ratio, ha/AWU			
Estonia	11.1	49.0	7.7
Latvia	15.2	27.5	4.6
Lithuania	12.7	20.6	2.6
Denmark	36.3	49.0	1.9
Germany	24.3	35.1	1.9
Poland	6.4	8.7	0.9

Note: stochastic rates of growth are based on the log-lin model as explained near [Table 1](#).

Source: The authors.

As this study focuses on growth in the agricultural labour productivity, [Figure 2](#) depicts its trends for the whole period of 1998–2018. As one can note, the three Baltic States showed a steep increase in the agricultural labour productivity. The sub-period of 2004–2018 marks a departure of the trajectories of growth for the Baltic States from those for the rest of countries. Therefore, the accession to the E.U. in 2004 can be considered as turning point in the development of the agricultural sectors of the Baltic States. However, the sub-period of 2015–2018 shows a decline in the growth rates of the agricultural labour productivity in the three Baltic States.

As shown in [Figure 2](#), the Estonian agricultural labour productivity stood at 468% in 2018 of its 1998 level. Latvia and Estonia showed somewhat lower growth and the figures for 2018 were 400% and 288%, respectively, if compared to the 1998 levels. The other countries covered in the analysis show the values at 2018 growth corresponding to 160% to 223% of the initial values at 1998. In absolute terms, these changes are provided in [Table 3](#). Even though the Baltic States showed the highest rates of growth, the absolute change in their agricultural labour productivity is rather low (only that for Poland is exceeded). The highest agricultural labour productivity gains during 1998–2018 are observed for Denmark and Germany.

[Table 3](#) presents the decomposition of the absolute changes in the agricultural labour productivity based on [Eqs. 3–5](#). Note that the cumulative values for 1998–2018

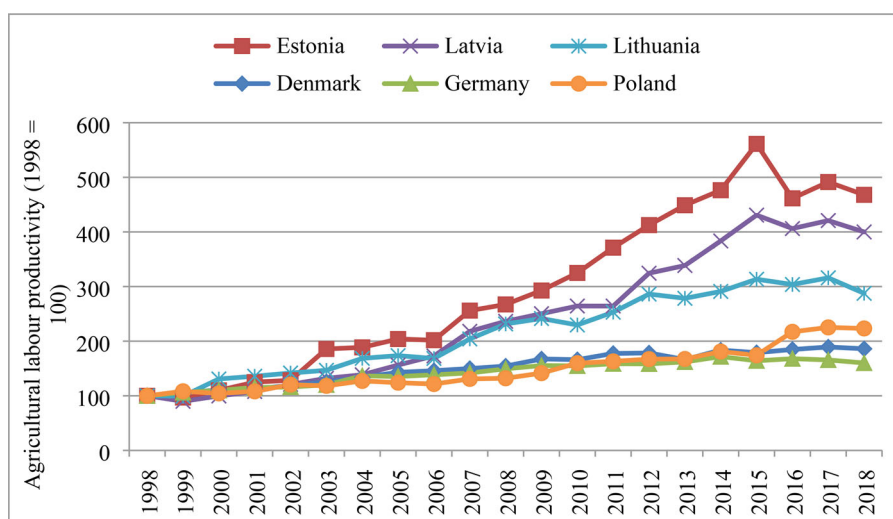


Figure 2. Growth in the agricultural labour productivity across the selected countries, 1998–2018. Source: The authors.

are considered. The effect of land-to-labour ratio (Δ_a) dominated in most of the countries. The exceptions include Lithuania and Poland where intermediate consumption intensity (Δ_i) was equally important as or more important than the land-to-labour ratio. Notably, intermediate consumption productivity effect (Δ_y) was negative in Estonia and Germany. Latvia also showed a slight decline in the agricultural labour productivity due to the latter effect.

As regards the three Baltic States, it is obvious that their agricultural productivity needs to be improved to improve the returns on intermediate consumption. In this context, the capital intensity and structure may play an important role. The increasing intermediate consumption contributed to the growth in the agricultural labour productivity in all the Baltic States. The increasing farm size (i.e., land-to-labour ratio) rendered the positive contribution to the growth in agricultural labour productivity. Estonia showed the highest impact of the increasing land-to-labour ratio which was similar to the corresponding effect observed for Germany.

Decomposition of the agricultural labour productivity change (in cumulative terms) for Estonia is provided in Figure 3. As one can note, the land-to-labour ratio was the only contribution factor to the labour productivity growth until 2011. Afterwards, the intermediate consumption intensity appeared as an increasingly important factor. Since 2016, the negative effect of the intermediate consumption productivity has entered into effect. This suggests that the increasing use of the intermediate inputs was not sufficient for boosting agricultural labour productivity in Estonia during 2015–2018.

Results of the cumulative decomposition of agricultural labour productivity change in Latvia (Figure 4). Latvia faced the negative effect of land-to-labour ratio until 2005. This coincides with period of pre-accession to the E.U. when agricultural activities were less attractive. The trend was overturned in 2006 and the positive contribution was observed ever since. Contrary to the case of Estonia, intermediate consumption intensity was increasing (with minor fluctuations) throughout 1998–2018 and

Table 3. The cumulative decomposition of the change in the agricultural labour productivity over 1998–2018 based on the LMDI.

Country	Change, thousand euro of 2010/AWU	Absolute contribution, thousand euro of 2010/AWU			Relative contribution, %		
		Δ_y	Δ_i	Δ_a	Δ_y	Δ_i	Δ_a
Estonia	29.6	−9.0	10.1	28.5	−30	34	96
Latvia	12.3	−0.2	4.6	7.9	−2	38	64
Lithuania	10.8	0.8	4.8	5.2	7	45	48
Denmark	92.9	23.4	23.6	45.8	25	25	49
Germany	37.1	−10.6	16.8	30.9	−28	45	83
Poland	7.5	1.3	3.2	2.9	18	43	39

Note: Δ_y , Δ_i , Δ_a stand for the effects of the intermediate consumption productivity, intermediate consumption intensity and land-to-labour ratio, respectively.

Source: The authors.

positively contributing to the growth in agricultural labour productivity in Latvia. The growth in intermediate consumption productivity remained rather limited in Latvia. This indicates that the use of the intermediate inputs needs to be further adjusted along with appropriate changes in the agricultural production technology (e.g., adjustment of the input structure). The sub-period of 2015–2018 saw a declining effect of the intermediate consumption intensity. This suggests that the Latvian farmers do not feel incentives to improve their farming intensity. Price levels (and price recovery rate) are one of the key factors in this regard.

Agricultural labour productivity growth in Lithuania was affected by multiple factors simultaneously (Figure 5). In general, the pattern observed for Latvia is followed. The major difference is that Lithuania had seen an increasingly high contribution of the intermediate consumption productivity up to 2015. Later on, the effect of the intermediate consumption intensity went up, while that of the intermediate consumption productivity declined. Therefore, the use of the intermediate inputs also needs to be adjusted in regards to the other inputs in Lithuania. The effect of the land-to-labour ratio has been increasing since the accession to the EU.

Denmark showed the highest agricultural labour productivity levels and growth rates among the countries considered in this study. The decomposition of the cumulative agricultural labour productivity growth in Denmark is provided in Figure 6. During 2004–2013, the effect of the intermediate consumption productivity was declining or close to zero. All the three effects have become important for Denmark's agricultural labour productivity growth since 2013. Thus, Denmark managed to exploit all the agricultural factor inputs when increasing farming intensity.

In Germany, the effect of the land-to-labour ratio kept steadily increasing over time, whereas those related to the intermediate input use varied over time (Figure 7). In general, the cumulative effect of the two terms related to the intermediate inputs remained stable throughout 2003–2017, yet the effect of intermediate consumption productivity was gradually replaced by the effect of the intermediate consumption intensity. This indicates that German farms have focused on a less sustainable mode of farming during the period covered. Therefore, the input use optimisation is also required in the agricultural sector of Germany.

Poland shows a stable increase in the agricultural labour productivity with positive contributions of the three terms (Figure 8). Prior to the accession to the E.U. in

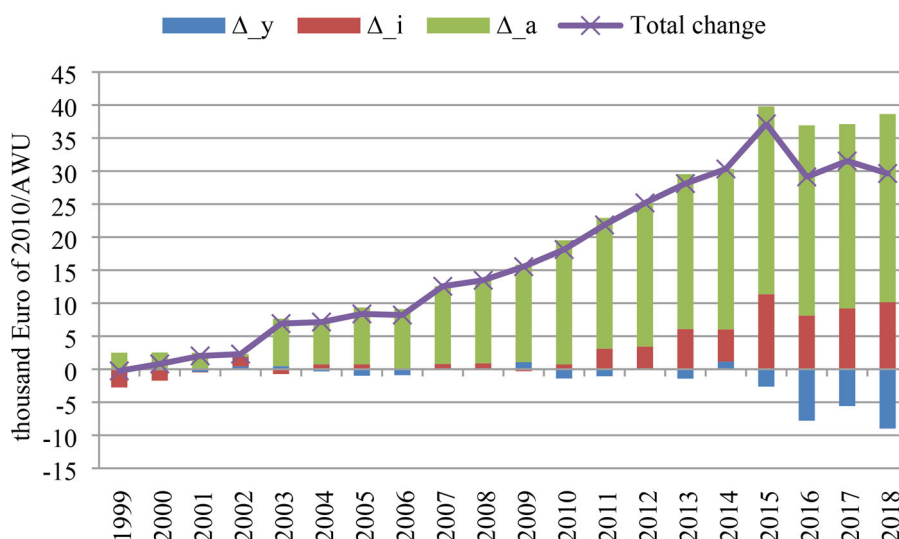


Figure 3. Decomposition of the cumulative agricultural labour productivity change in Estonia, 1998–2018.

Source: The authors.

2004, the growth in the labour productivity was rather sluggish and the effect of the intermediate consumption intensity tended to be negative. In spite of the increasing intermediate consumption intensity, the Polish farms also maintained intermediate consumption productivity growth. However, as of 2018, Poland showed the lowest agricultural labour productivity level among the states considered.

The spatial decomposition approach is applied to compare the countries against Denmark which showed the highest agricultural labour productivity in 2018 (Table 4). This allows identifying the key terms contributing to the agricultural labour productivity differentials. Germany shows the lowest difference from Denmark's agricultural labour productivity for 2018. In this case, the difference is caused by the lower land-to-labour ratio (47.2%). However, the intermediate consumption intensity and productivity also substantially contributed to the difference (20.3% and 32.6%, respectively). The three Baltic States rank next with intermediate consumption intensity causing the highest share of the differences (59.1% to 86.6%). For Estonia, the intermediate input productivity appears as a more important term causing agricultural labour productivity difference (in comparison to Denmark) than it is the case for the other Baltic States. Lithuania and Latvia show pronounced effects of the land-to-labour ratio. This indicates that farm structure can further be adjusted to match that observed in the developed E.U. Members States. Poland shows the smallest average farm size which renders the highest contribution of the land-to-labour ratio towards the labour productivity difference from Denmark.

In general, the carried out analysis implies that the intermediate consumption intensity is the major contributor preventing the growth in the agricultural labour productivity in the Baltic States (if compared to such developed countries as Germany or Denmark). The second most important factor for Lithuania and Latvia is the farm size. The support payments under the C.A.P. can be used to change the agricultural practices prevailing in the Baltic States and ensure convergence with the

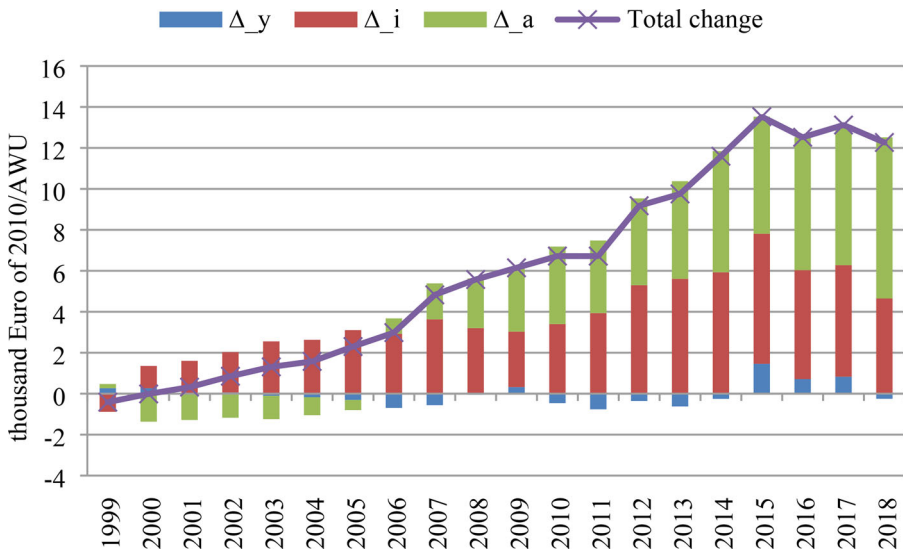


Figure 4. Decomposition of the cumulative agricultural labour productivity change in Latvia, 1998–2018. Source: The authors.

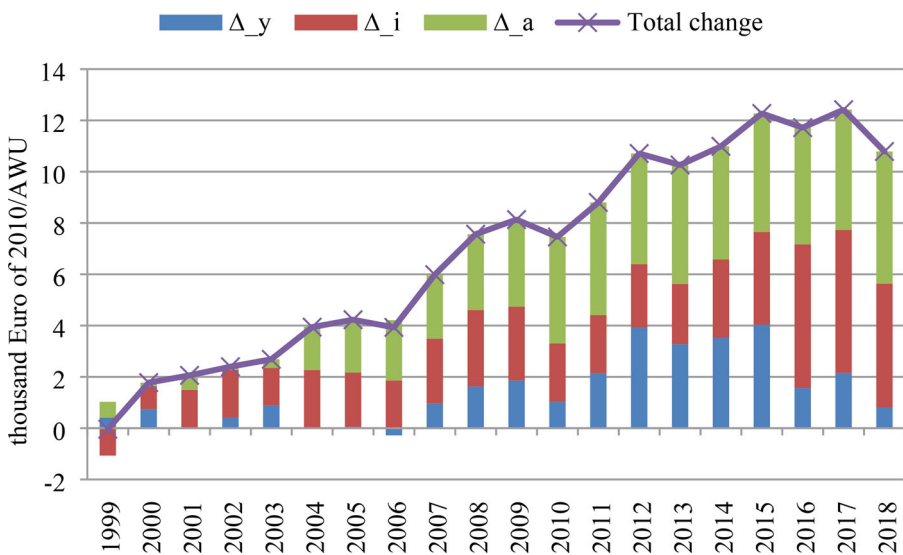


Figure 5. Decomposition of the cumulative agricultural labour productivity change in Lithuania, 1998–2018. Source: The authors.

old E.U. Member States. Investment support and direct payments should be adjusted in order to ensure that the support allows effectively employing the agricultural input factors and improving the intermediate consumption intensity.

5. Discussion

The present article presented a tripartite model for analysis of changes in agricultural labour productivity. In this regard, we further the decomposition discussed by, e.g.,

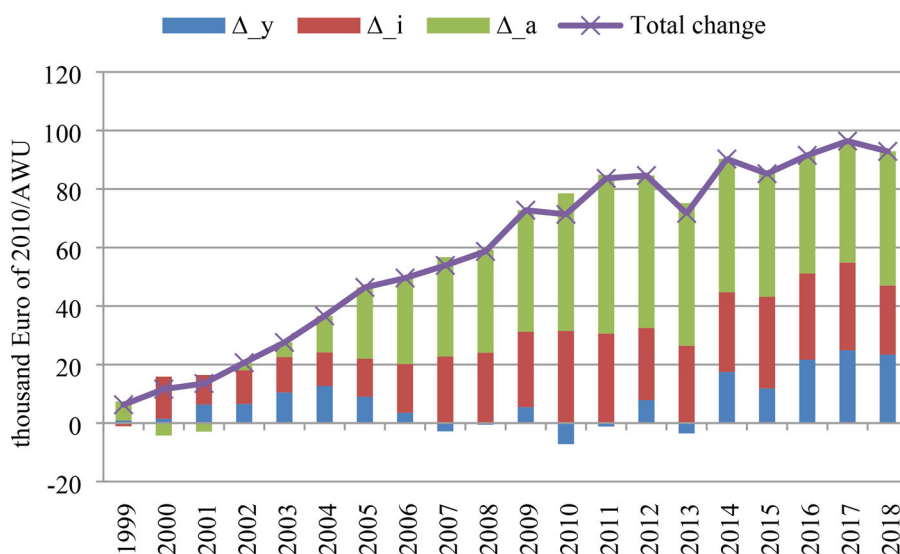


Figure 6. Decomposition of the cumulative agricultural labour productivity change in Denmark, 1998–2018.

Source: The authors.

Fuglie (2018), where only land-to-labour ratio and land productivity were taken into account. The approach presented in this article considers the intermediate consumption intensity as an additional factor. Indeed, the results showed it is the crucial factor determining the differences across the countries.

The article considered the three Baltic States (Estonia, Latvia and Lithuania) along with the peer countries (Poland, Germany and Denmark). Indeed, we found that Denmark and Germany were better off than the Baltic States in terms of the agricultural labour productivity. This can also be confirmed by looking at the total factor productivity analysis by Kijek et al. (2019) or labour productivity analysis by Csaki and Jambor (2019).

Our article contributes to the literature on the convergence of the agricultural labour productivity in the E.U. in that we established a tripartite index decomposition model and applied it in two ways: (1) longitudinal analysis; and (2) cross-country analysis. This allowed to unveil the dynamics and performance gaps for the Baltic States. The methods proposed in this article and the resulting calculations are useful for policy guiding.

The results indicate that the Baltic States should increase the use of intermediate inputs in the agricultural production. However, this may pose excessive environmental pressures in case the agrochemicals are used extensively. Amid such considerations, intermediate consumption level (intensity) and structure can be considered as the indicators suggesting directions for possible improvements in the agricultural productivity. We break the intermediate consumption variable down into its components (seeds, energy, agrochemicals, livestock-related expenses and others) in order to check the differences in the use of particular intermediate inputs across the countries analysed. The comparison of the intermediate consumption patterns across the selected countries is presented in Table 5.

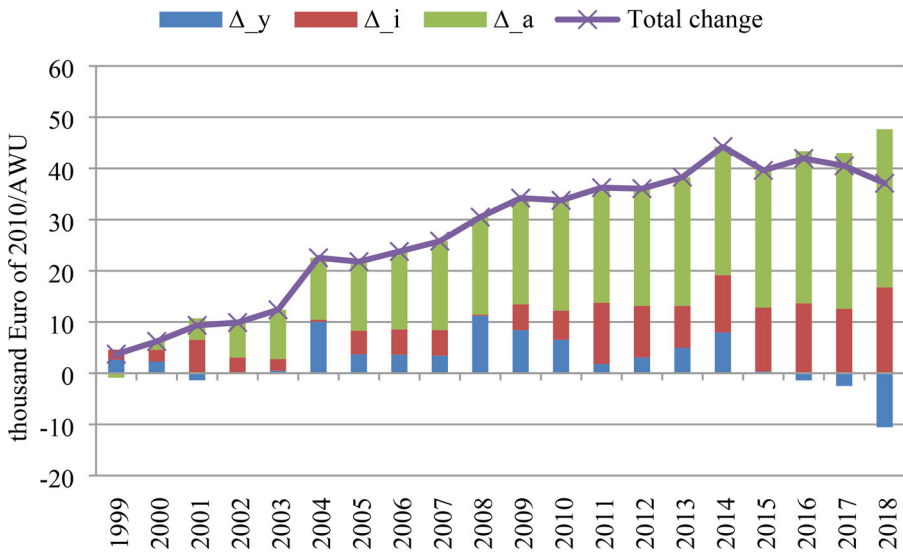


Figure 7. Decomposition of the cumulative agricultural labour productivity change in Germany, 1998–2018. Source: The authors.

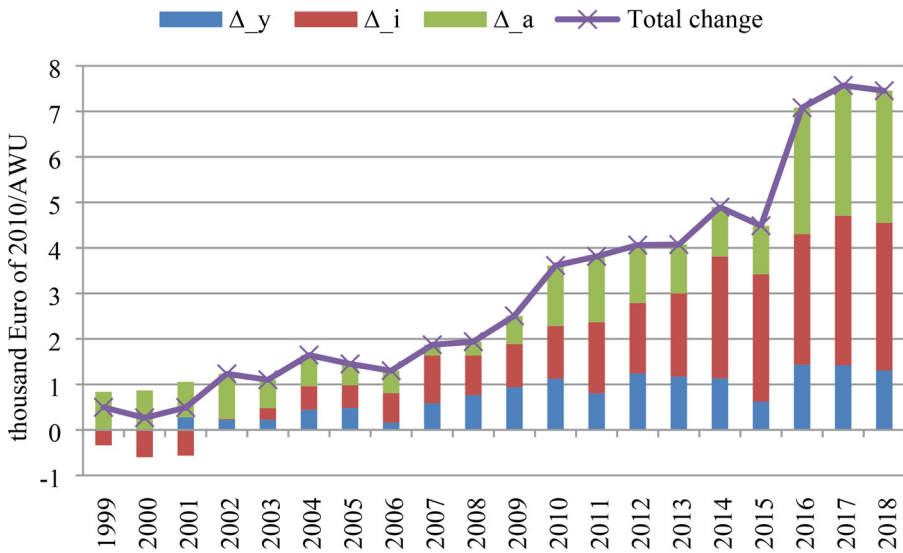


Figure 8. Decomposition of the cumulative agricultural labour productivity change in Poland, 1998–2018. Source: The authors.

First, the structure of the intermediate consumption is compared across the countries. The energy expenditure is obviously higher in the overall intermediate consumption for the new E.U. Member States if opposed to the well-developed ones (16–25% for the Baltic states and Poland and just 7–9% for Germany and Denmark). Denmark also shows substantially lower share of agrochemicals expenditure (6.7%) than the other countries (11.1–15.6%). The three Baltic states show negative trends

Table 4. Spatial decomposition of the agricultural labour productivity differences (compared to Denmark), 2018.

Country	2018 level, thousand euro of 2010/AWU	Absolute contribution, thousand euro of 2010/AWU			Relative contribution, %		
		Δ_y	Δ_i	Δ_a	Δ_y	Δ_i	Δ_a
Denmark	200.8						
Germany	98.9	-33.2	-20.7	-48.1	32.6	20.3	47.2
Estonia	37.7	-21.8	-141.2	-0.1	13.4	86.6	0.0
Lithuania	16.5	-11.2	-108.8	-64.2	6.1	59.1	34.8
Latvia	16.4	-13.9	-128.0	-42.6	7.5	69.4	23.1
Poland	13.5	0.7	-67.8	-120.2	-0.4	36.2	64.2

Source: The authors.

for the share of the energy expense in the intermediate consumption and positive ones for the agrochemicals. Thus, the intermediate input-mix is gradually converging among the analysed countries. Second, the average expenditure (normalised with respect to the utilised agricultural area) is considered to check the expenditure gaps. Generally, one can consider the most productive country, Denmark, as a benchmark. The results indicate that the energy expenditure in the three Baltic states is closest to the levels observed in Denmark or Germany if compared to the expenditures related to other input indicators. The expenses per hectare for intermediate inputs related both crop farming and livestock farming still lag behind. Thus, the results suggest that increasing the intermediate input intensity in the agriculture of the Baltic states requires integrated solutions leading to technical progress.

Several challenges are imminent for the E.U. agricultural policy. The major aims of the C.A.P. are to increase farm income and resilience. In many countries, E.U. farmers have seen their income falling relative to the average income at the national level in recent years. Member States may subsidise a risk management measures aimed at reducing the share of farms suffering from high income volatility. Furthermore, the new period of the CAP places emphasis on greater environmental and climate ambitions. The differences in the environmental standards need to be addressed in order to avoid the market distortions due to the subsidies and regulations.

6. Conclusions

This article proposed an I.D.A. model for isolating the drivers of agricultural labour productivity change. The L.M.D.I. was used to facilitate the decomposition. The proposed model included the intermediate consumption as a part of the explanatory terms in the model. Therefore, the traditional model conserving the land-to-labour ratio and land productivity has been extended.

The empirical case dealt with the three Baltic States (Estonia, Latvia and Lithuania) which deserve attention as the countries undergoing serious structural changes and demonstrating generally lower productivity levels if opposed to the old E.U. Member States. The results indicate that land-to-labour ratio appeared as the crucial factor contributing to the highest share of the agricultural labour productivity change in the Baltic States during 1998–2018. The accession to the E.U. marked an increasing agricultural activity which further implied increasing intermediate consumption intensity.

Table 5. The structure of intermediate consumption across selected European countries, 1998–2018.

Country	Seeds and planting stock	Energy: lubricants	Agrochemicals	Livestock farming	Other	Seeds and planting stock	Energy: lubricants	Agrochemicals	Livestock farming	Other
	Average, %					Trend, p.p. per year				
Estonia	2.8	15.1	11.1	47.8	23.2	0.2	-0.8	0.8	-1.1	0.9
Latvia	3.4	22.0	15.8	34.8	24.0	0.1	-0.7	0.5	-0.8	0.9
Lithuania	2.9	15.7	22.6	39.1	19.8	0.1	-0.3	0.3	-1.3	1.2
Denmark	3.7	6.8	6.7	47.1	35.7	0.1	-0.1	0.0	0.0	0.0
Germany	3.2	9.3	14.3	45.5	27.7	0.1	0.0	-0.4	0.2	0.1
Poland	1.9	24.8	15.6	38.9	18.9	0.0	-0.1	0.4	-0.2	-0.1
	Average, Eur/ha					Trend, % per year				
Estonia	15	72	58	232	119	10.6	-3.2	9.1	-0.5	5.5
Latvia	13	79	62	127	95	5.2	0.4	7.2	1.3	7.8
Lithuania	15	78	116	195	103	7.3	-0.2	2.6	-2.4	7.7
Denmark	88	161	159	1119	847	3.0	-1.0	1.0	0.8	0.7
Germany	65	185	286	911	555	2.0	0.5	-2.3	0.8	0.9
Poland	15	193	124	303	147	1.9	1.9	4.5	1.8	1.5

Note: *agrochemicals* comprise expenses for fertilisers, soil improvers and plant protection products; *livestock farming* includes expenses for veterinary services and feed; *other expenses* include maintenance of buildings and materials, services and the rest of expenses; stochastic rates of growth are used.

Source: The authors.

During the period covered, only Estonia approached the farm structure peculiar to the developed countries.

The spatial decomposition was carried out to contrast the agricultural labour productivity levels in the Baltic States to that in Denmark (which can be considered as a benchmark country with a developed agricultural sector). The spatial decomposition implies that intermediate consumption intensity (per land area unit) appears as the major obstacle for improving agricultural labour productivity. In addition, Latvia and Lithuania show slacks in terms of the labour productivity due to the relatively small farm size (and, hence, land-to-labour ratio).

The results suggest several policy implications. First, the agricultural restructuring is imminent in the agricultural sectors of Lithuania and Latvia. This means farm expansion that would allow increasing the agricultural labour productivity. Therefore, agricultural and rural development policy should take into account the imminent shifts in the agricultural labour force in the Baltic States. Indeed, it should either promote small farms producing high quality agri-food products or medium-size farms allowing for high productivity levels should be supported to the highest extent. The use of intermediate inputs (improved seeds, fertilisers, agrochemicals) needs to be improved by following the advanced farming practices. However, the extensive use of agrochemicals cannot be seen as the sole option for improving agricultural output and productivity. The input structure (capital, labour) needs to be adjusted in the agriculture of the Baltic States so as to ensure that the intermediate inputs are used to the fullest extent. The results indicate that the use of improved seeds and feed material remains important for agriculture of the Baltic states in the light of the example provided by the developed agricultural sectors of Denmark and Germany.

The present study embarked on a deterministic approach towards the I.D.A.. The further studies could exploit econometric techniques for filtering out random fluctuations when analysing the dynamics in agricultural labour productivity. Also, the frontier techniques can be integrated in the analysis in order to take production gap into consideration.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Tomas Balezentis  <http://orcid.org/0000-0002-3906-1711>

References

- Ang, B. W., Huang, H. C., & Mu, A. R. (2009). Properties and linkages of some index decomposition analysis methods. *Energy Policy*, 37(11), 4624–4632. <https://doi.org/10.1016/j.enpol.2009.06.017>
- Ang, B. W., Xu, X. Y., & Su, B. (2015). Multi-country comparisons of energy performance: The index decomposition analysis approach. *Energy Economics*, 47, 68–76. <https://doi.org/10.1016/j.eneco.2014.10.011>

- Ang, B. W., & Zhang, F. Q. (2000). A survey of index decomposition analysis in energy and environmental studies. *Energy*, 25(12), 1149–1176. [https://doi.org/10.1016/S0360-5442\(00\)00039-6](https://doi.org/10.1016/S0360-5442(00)00039-6)
- Ahmed, T., & Bhatti, A. A. (2020). Measurement and determinants of multi-factor productivity: A survey of literature. *Journal of Economic Surveys*, 34(2), 293–319. <https://doi.org/10.1111/joes.12360>
- Alston, J. M., & Pardey, P. G. (2014). Agriculture in the global economy. *Journal of Economic Perspectives*, 28(1), 121–146. <https://doi.org/10.1257/jep.28.1.121>
- Ball, V. E., Bureau, J. C., Nehring, R., & Somwaru, A. (1997). Agricultural productivity revisited. *American Journal of Agricultural Economics*, 79(4), 1045–1063. <https://doi.org/10.2307/1244263>
- Baráth, L., & Fertő, I. (2017). Productivity and convergence in European agriculture. *Journal of Agricultural Economics*, 68(1), 228–248. <https://doi.org/10.1111/1477-9552.12157>
- Barro, R. J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2), 407–443. <https://doi.org/10.2307/2937943>
- Csaki, C., & Jambor, A. (2019). Convergence or divergence – Transition in agriculture of Central and Eastern Europe and Commonwealth of Independent States revisited. *Agricultural Economics*, 65(No. 4), 160–174. <https://doi.org/10.17221/195/2018-AGRICECON>
- Fuglie, K. O. (2012). Productivity growth and technology capital in the global agricultural economy. In *Productivity growth in agriculture: an international perspective*, 335–368. CABI.
- Fuglie, K. O. (2018). Is agricultural productivity slowing?, Economic Research Service, US Department of Agriculture, Washington, DC, United States. *Global Food Security*, 17(2018), 73–83. <https://doi.org/10.1016/j.gfs.2018.05.001>
- Gaitán-Cremaschi, D., Meuwissen, M. P., & Oude Lansink, A. G. (2017). Total factor productivity: A framework for measuring agri-food supply chain performance towards sustainability. *Applied Economic Perspectives and Policy*, 39(2), 259–285. <https://doi.org/10.1093/aep/p/pxw008>
- Giannakis, E., & Bruggeman, A. (2018). Exploring the labour productivity of agricultural systems across European regions: A multilevel approach. *Land Use Policy*, 77, 94–106. <https://doi.org/10.1016/j.landusepol.2018.05.037>
- Gollin, D., Lagakos, D., & Waugh, M. E. (2014). Agricultural productivity differences across countries. *American Economic Review*, 104(5), 165–170. <https://doi.org/10.1257/aer.104.5.165>
- Hayami, Y., & Ruttan, V. W. (1970). Agricultural productivity differences among countries. *The American Economic Review*, 60, 895–911.
- Hayami, Y., & Ruttan, V. W. (1985). *Agricultural development: An international perspective*. Johns Hopkins University Press.
- Herrendorf, B., & Schoellman, T. (2015). Why is measured productivity so low in agriculture? *Review of Economic Dynamics*, 18(4), 1003–1022. <https://doi.org/10.1016/j.red.2014.10.006>
- Irz, X., Lin, L., Thirtle, C., & Wiggins, S. (2001). Development policy review. *Development Policy Review*, 19(4), 449–466. No <https://doi.org/10.1111/1467-7679.00144>
- Kijek, A., Kijek, T., Nowak, A., & Skrzypek, A. (2019). Productivity and its convergence in agriculture in new and old European Union member states. *Agricultural Economics*, 65(No. 1), 01–09. <https://doi.org/10.17221/262/2017-AGRICECON>
- Kollár, B., & Sojková, Z. (2015). *Impact of the investment subsidies on the efficiency of Slovak farms*. <https://www.semanticscholar.org/>
- Kumar, S., & Russell, R. R. (2002). Technological change, technological catch-up, and capital deepening: Relative contributions to growth and convergence. *American Economic Review*, 92(3), 527–548. <https://doi.org/10.1257/00028280260136381>
- Mugera, A. W., Langemeier, M. R., & Featherstone, A. M. (2012). Labor productivity growth in the Kansas farm sector: A tripartite decomposition using a non-parametric approach. *Agricultural and Resource Economics Review*, 41(3), 298–312. <https://doi.org/10.1017/S1068280500001271>

- Njuki, E., Bravo-Ureta, B. E., & O'Donnell, C. J. (2019). Decomposing agricultural productivity growth using a random-parameters stochastic production frontier. *Empirical Economics*, 57(3), 839–860. <https://doi.org/10.1007/s00181-018-1469-9>
- Restuccia, D., Yang, D. T., & Zhu, X. (2008). Agriculture and aggregate productivity: A quantitative cross-country analysis. *Journal of Monetary Economics*, 55(2), 234–250. <https://doi.org/10.1016/j.jmoneco.2007.11.006>
- Schreyer, P., & Pilat, D. (2001). Measuring productivity. *OECD Economic Studies*, 33(2), 127–170.
- Struik, P. C., & Kuyper, T. W. (2017). Sustainable intensification in agriculture: The richer shade of green. *Agronomy for Sustainable Development*, 37(5), 1–15. <https://doi.org/10.1007/s13593-017-0445-7>
- Swinnen, J., Van Herck, K., & Vranken, L. (2012). Agricultural productivity paths in Central and Eastern European Countries and the former Soviet Union: The role of reforms, initial conditions and induced technological change. In K.O. Fuglie, S. L. Wang, & V. E. Ball (Eds.), *Productivity growth in agriculture an international perspective* (pp. 127–144). CABI.
- Trzeciak-Duval, A. (1999). A decade of transition in central and eastern European agriculture. *European Review of Agriculture Economics*, 26(3), 283–304. <https://doi.org/10.1093/erae/26.3.283>
- Van Asseldonk, M., Tzouramani, I., Ge, L., & Vrolijk, H. (2016). Adoption of risk management strategies in European agriculture. *Studies in Agricultural Economics*, 118(3), 154–162. <https://doi.org/10.7896/j.1629>
- Wang, S. L., Schimmelpfennig, D., & Fuglie, K. O. (2012). Is agricultural productivity growth slowing in Western Europe. In K.O. Fuglie, S. L. Wang, & V. E. Ball (Eds.), *Productivity growth in agriculture: An international perspective* (pp. 109–125). CABI.
- Zhao, J., & Tang, J. (2018). Understanding agricultural growth in China: An international perspective. *Structural Change and Economic Dynamics*, 46, 43–51. <https://doi.org/10.1016/j.strueco.2018.03.006>
- Zhao, S., Sheng, Y., & Gray, E. M. (2012). Measuring productivity of the Australian Broadacre and Dairy Industries: Concepts, methodology and data. In K.O. Fuglie, S. L. Wang, & V. E. Ball (Eds.), *Productivity growth in agriculture: An international perspective* (pp. 73–108). CABI.
- Zsarnóczai, J. S., & Zéman, Z. (2019). Output value and productivity of agricultural industry in Central-East Europe. *Agricultural Economics*, 65(4), 185–193. <https://doi.org/10.17221/128/2018-AGRICECON>