Structural decomposition analysis of Latvian agrifood sector as integral part of global market

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Abstract

Research background: the Latvian agrifood sector is continuously becoming more integrated in global markets. Imports and exports of agricultural commodities grow every year. At the same time, changes in output from agriculture and food processing are moderate. The main factors that can be used to characterize these sectors are employment, gross value added and income. The main causes of the changes of these three factors could be estimated by structural decomposition analysis.
Purpose of the article: the objective of the research is the decomposition of the percentage changes over time in employment, gross value added and income in Latvian economy by their source: changes in intensities per unit of output, changes in the intermediate consumption and changes in the final demand structure.
Methods: the traditional methods of the Input-Output framework, such as multipliers, elasticities, causative matrices enable the estimation of structural trends in economy sectors. However, they do not provide the share in the total impact of various factors on the changes in the economy. Structural decomposition analysis estimates the relative size of the impact of these factors within the total impact.
Findings & Value added: the research results show rather large positive impact of final demand factor on employment, gross value added and income changes in both sectors. The impact of the intensities (reverse factor productivities), in turn, is large and negative. The impact of the intermediate demand is less marked. As the growth in final demand can be attributed solely to increase in export demand, this combined with the growth in labor productivity are the main drivers of employment changes in agriculture. The method can be effectively applied to other variables of interest for which the calculated intensities per unit of output make sense, such as carbon emissions, greenhouse gas emissions or energy input.

Keywords: *structural decomposition; Leontief framework; agrifood; reverse factor productivities*

JEL Classification: *C01; C67; E17*

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1 Introduction

The estimation of sectoral interdependence within an economy is important issue in development planning for policy-makers. Sectors with relatively intensive interindustry links are the main facilitators of extensive rounds of economy-wide effects caused by changes in final demand. An input-output framework has been extensively used in analyzing structural economic changes over time. Jackson et al (1974) define structural economic change as temporal changes in interactions among economic sectors.

The decomposition analyses have been developed and extensively used in recent decades. The properties of two broad categories of decomposition analyses - structural decomposition and index decomposition are described and compared by de Boer and Rodriguez (2020). Initially, analyses were focused on output, while later being extended by Jackson (2003) with environmental aspects included. The analyses allow identifying the main forces behind the observed changes between two selected years for variables such as output, energy and labor inputs, emissions and income. Based on structural decompositions Hudcovsky et.al. (2017) analyse the determinants of employment growth in Vyšehrad countries. Chang and Laar (2016) combine structural decomposition analysis with the linkage analysis. Structural decompositions are predominantly used in energy consumption and emissions studies.

Miller and Blair (1985) describe the Structural Decomposition Analysis as standard input-output method that allow for the division of changes in output, employment, income, or other variables into a number of components, such as intermediate consumption (technological) variation or final demand variation. The selection of variables depends on the research objective. However, the application of the method is possible only when there are complete data pertaining on each sector enclosed in the input-output framework. There are three factors that might contribute to the in final demand. First, it is the total amount of the aggregate expenditures of households, general government, gross fixed capital formation, changes in inventories and exports. The second is the distribution of the expenditures among these categories. Finally, it is the product mix within each of these categories which depends on changes in supply and demand structure.

Structural Decomposition Analysis (SDA) has been used by National Statistics offices in various countries as a tool to break down the observed changes in physical variables, mainly energy consumption and emissions in their physical and economic determinants. The results of the analysis are included in the annual publications of National Environmental Accounts.

2 Materials and methods

The data for the analysis are retrieved from World Input-Output Database (WIOD, 2021) by extracting input-output tables and wage data from socio-economic accounts for 2010 and 2014 comprising 54 industry sectors. The latest available information is on 2014. The detailed description of database is provided by Timmer et al. (2015). The latest available information on input-output tables in OECD database is on 2015. However, the tables here cover only 33 industry sectors. Moreover, the agriculture is merged with forestry in a single industry thus making analysis of agrifood sector impossible.

The linkages among industries can be analyzed with Leontief model, also called Open Static Leontief model (Leontief, 1986). The model is called static because of assumption of a fixed structure of the output by industries. The basic equation of the model for economy with n industries computes the total output necessary to satisfy an exogenously given final demand:

$$X = LY, \tag{1}$$

where:
$X = (x_1 \dots x_n)$ - vector of industry output,
L - Leontief Inverse Matrix,
$Y = (y_1 \dots y_n)$- vector of final demand.

The objective of structural decomposition analysis is disentangling an aggregate change over the given period of time into a number of effects or factors. The main problem of the approach is lack of a unique solution. Setting the starting year of a period as a base assumes Laspeyres perspective, whereas end year as a base assumes Paasche perspective (Siegel, 1941). These two are called „polar decompositions". In their seminal article by Dietzenbacher and Los (1988), they prove that the number of possible decompositions equals to factorial of number of factors involved.

There are three requirements to decompositions. The decomposition must not contain residual or interaction terms (completeness), it should deal with zero values (zero value robustness), and it should yield the same result with opposite sign when period is reversed (time reversal). None of possible single decompositions satisfy the requirement of time reversal. A pair of two decompositions with „forward" and reversed period is called „mirror pairs". So number of pairs equals one half of the factorial of number of factors involved. An average of any „mirror pair" satisfies the time reversal requirement. The same is true for the average of all possible decompositions. As proven by Dietzenbacher and Los (1988), the difference between the average of two polar decompositions and the average of all decompositions is not significant. The average of two special cases is called also polar decomposition. In a polar form, right side of a factor contains weights for the same year and left side of the factor contains weights for the other year.

As a comparison of variables for two different periods of time is necessary, the periods herein are denoted using the subscripts 0 (first period) and 1(last period).

A decomposition of equation (1) (changes in output over the period) is given by:

$$\Delta X = \Delta L Y + L \Delta Y, \tag{2}$$

where:
$\Delta X = X_1 - X_0$ - vector of difference between output in final and starting years,
$\Delta Y = Y_1 - Y_0$ - vector of difference between final demand in final and starting years,
$\Delta L = L_1 - L_0$ - matrix of difference between Leontief inverse matrices in final and starting years.

There are two factors enclosed in equation (2). The first term at the right hand side of equation shows the changes in output due to changes in intermediate input structure (input-output coefficient effect).The second term shows the changes in output due to changes in final demand (final demand effect). The change in the Leontief inverse matrix can be weighted with final demand in the first year, and the change in final demand can be weighted with the Leontief inverse matrix in the second year:

$$\Delta X = X_1 - X_0 = L_1 Y_1 - L_0 Y_0 = \Delta L Y_0 + L_1 \Delta Y. \tag{3}$$

Another way to express the change in final demand is weighting the change in the Leontief inverse matrix can be weighted with final demand in the second year, and the change in final demand can be weighted with the Leontief inverse matrix in the first year:

$$\Delta X = X_1 - X_0 = L_1 Y_1 - L_0 Y_0 = \Delta L Y_1 + L_0 \Delta Y. \tag{4}$$

These two equations are the only two complete decompositions in polar forms for two variables, as they do not contain interaction term $\Delta L \Delta Y$. Adding the equations (3) and (4) yield:

$$2\Delta X = \Delta L Y_0 + L_1 \Delta y + \Delta L Y_1 + L_0 \Delta Y = \Delta L (Y_0 + Y_1) + (L_1 + L_0)\Delta Y, \quad (5)$$

or:

$$\Delta X = 1/2\, \Delta L(Y_0 + Y_1) + 1/2\,(L_1 + L_0)\Delta Y \quad (6)$$

So the changes in the output are decomposed in two effects from changes in technical coefficients (intermediate demand) and from changes in final demand. Similarly, decomposition for the changes in employment could be done. Depending upon the input variable of interest, the input-output model could be modified by adding intensities or ratios of this particular input necessary for producing a unit of output. Based on assumptions of fixed proportions between labour requirements and total output by industries, direct labor coefficients (labor requirements necessary for one unit of output) can be expressed as:

$$r_j = \frac{e_j}{x_j}, j = 1, \ldots, n. \quad (7)$$

where:
r_j- direct labor coefficient for industry j,
e_j - employment in industry j,
x_j - output in industry j.

The importance of these direct labor coefficients is determined by their usefulness in assessment of sectoral economic efficiency. As stated by Fischer and Schornberg (2007), sectoral efficiency can be defined as the degree to which outputs are generated in terms of inputs, and productivity is its measurable indicator. Direct labour coefficients can be considered the "reversed" labour productivity. Then the model can be augmented by the effects of final demand on total employment in the whole economy:

$$E = RLY, \quad (8)$$

where:
$E = (e_1, \ldots, e_n)$ - vector of employment in industries,
R- square matrix whose diagonal elements equal direct labor coefficients,
L - Leontief Inverse matrix,
$Y = (y_1, \ldots, y_n)$- vector of final demand.

In the case of employment, the number of factors (effects) is 3. The two polar decompositions for of the employment in equation (8) are:

$$\Delta E = \Delta R L_1 Y_1 + R_0 \Delta L Y_1 + R_0 L_0 \Delta Y, \quad (9)$$

$$\Delta E = \Delta R L_0 Y_0 + R_1 \Delta L Y_0 + R_1 L_1 \Delta Y. \quad (10)$$

So, the decomposition of the employment on the basis of the average of the polar decompositions is:

$$\Delta E = 1/2(\Delta R L_1 Y_1 + \Delta R L_0 Y_0) + 1/2(R_0 \Delta L Y_1 + R_1 \Delta L Y_0) + 1/2(R_0 L_0 \Delta Y + R_1 L_1 \Delta Y) \quad (11)$$

The change in employment is decomposed in three effects. The first term at the right hand side of equation (11) is the direct employment coefficients effect, which reflects the changes in employment per unit of output for each sector of economy. The second term is the input-output coefficient effect due to changes in the intermediate input structure and the third term measures the effect of changes in final demand. Following the same procedure, decomposition of the income in three effects is done, using the data on wages in each industry sector. In their decompositions, Lábaj and Puškárová (2018) derive cross-industry wage inequalities directly from the input-output tables and analyse the final inequality variations through the changes in the inputs.

3 Results and Discussion

Structural decompositions are calculated for changes in output, employment and income between 2010 and 2014. The results of the decompositions are shown in Table 1.

Table 1. The results of the structural decompositions for output, employment and income (percentage changes, 2010-2014).

Variable / sector	Total	Intensity effect	Intermediate consumption effect	Final demand effect
Output				
Agriculture	37.9		4.3	33.6
Fisheries	15.3		1.4	13.9
Food processing	11.5		-29.0	40.5
Employment				
Agriculture	-10.5	-21.7	0.6	10.6
Fisheries	29.5	15.0	-0.6	15.1
Food processing	-9.5	-11.6	-2.2	4.3
Income				
Agriculture	-14.3	-26.9	0.7	11.9
Fisheries	39.0	24.4	-0.6	15.2
Food processing	20.5	4.7	-16.7	32.5

Source: WIOD (2021), author's calculations

In agriculture (crop and animal production, hunting and related service activities) and fisheries (fishing and aquaculture), the effect of the intermediate consumption on output growth is small, while the largest share comes from final demand. In food processing (manufacture of food products, beverages and tobacco products), the effect from other sectors' consumption is even negative and final demand effect exceeds the total increase. Note that for output there is no intensity as it always is constant at 1 (one unit of output is needed to produce one unit of output).

Absolute and relative changes in output, employment, income, relative changes in intensities, absolute changes in final demand along with the estimated effects in three sectors are shown in Table 2.

Table 2. Changes in variables and estimated effects in agriculture, fisheries and food processing, 2010-2014

Variable / sector	Agriculture	Fisheries	Food processing
Output			
Total, %	37.9	15.3	11.5
Changes in intermediate consumption, MUS$	178.4	5.5	-37.6
Changes in intermediate consumption, %	33.4	34.3	-9.3
Changes in final demand, MUS$	706.0	2.9	113.8
Changes in final demand, %	42.6	5.1	6.1
Intermediate consumption effect, %	4.3	1.4	-29.0
Final demand effect, %	33.6	13.9	40.5
Employment			
Total, %	-10.5	29.5	-9.5
Changes in employment intensity, %	-35.1	12.4	-18.8
Intensity effect, %	-21.7	15.0	-11.6
Intermediate consumption effect, %	0.6	-0.6	-2.2
Final demand effect, %	10.6	15.1	4.3
Income			
Total, %	-14.3	39.0	20.5
Changes in income intensity, %	-37.9	20.6	8.1
Intensity effect, %	-26.9	24.4	4.7
Intermediate consumption effect, %	0.7	-0.6	-16.7
Final demand effect, %	11.9	15.2	32.5

Source: WIOD (2021), author's calculations

In agriculture, the effect on output from final demand at 33.6% significantly exceeds the intermediate consumption effect at 4.3%. The share of the intermediate consumption in use of total growth in output in monetary terms is about 20%. This illustrates how the use of simple comparisons instead of decompositions might lead to biased estimations and erroneous conclusions. For employment, negative changes in employment intensity (productivity growth) more than compensate the employment growth effect from final demand while the intermediate consumption effect is rather negligible. The situation with the effects on income is similar. However, the results for income have to be treated cautiously, as income is measured by total wages paid in agricultural sector where 96% out of total number of farms are represented by family farms. As pointed by Parlinska and Parlinska (2015), family farmers are often part-time, they engage in multiple and diversified activities. Moreover, wages in the sector vary extensively on year, from being almost the sole source to being only a minor component.

Breakdown of the intermediate demand and final demand in agriculture is mapped on Figure 1.

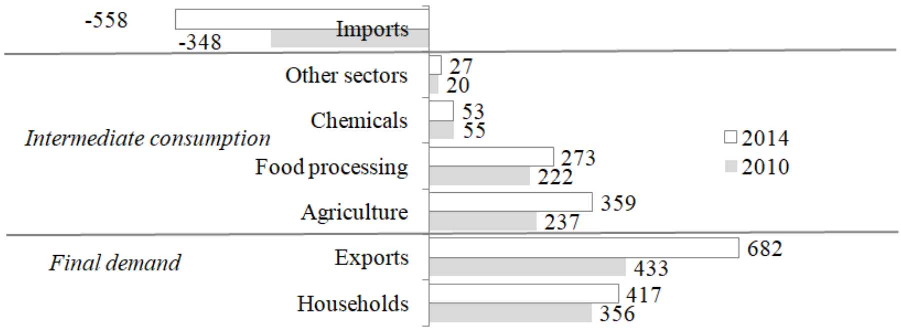

Figure 1. Structure of the intermediate demand and final demand in agriculture, MUS$, 2010, 2014

Source: WIOD (2021), author's calculations

Both major constituents of changes in final demand, exports and household consumption, have grown.

Fisheries are relatively small sector in terms of total output. Here, changes in output occur mainly due to increased final demand. Increase in labor force almost by one third is evenly divided by intensity (decline in labor productivity) and final demand. Again, the effect from changes in intermediate consumption is negligible albeit in absolute terms the share of intermediate consumption exceeds the share of final demand almost twice. The marked growth in income is caused mainly by intensity effect and final demand effect.

Breakdown of the intermediate demand and final demand in fisheries is mapped on Figure 2.

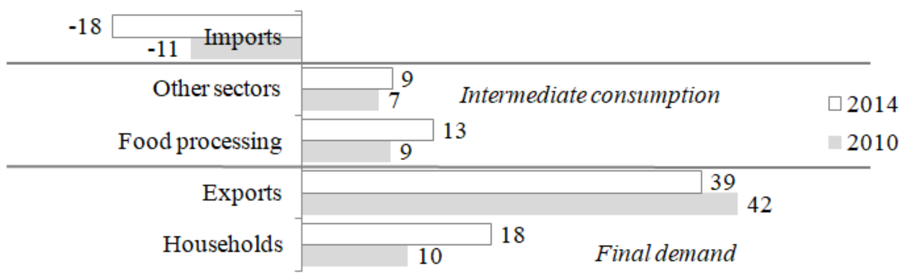

Figure 2. Structure of the intermediate demand and final demand in fisheries, MUS$, 2010, 2014

Source: WIOD (2021), author's calculations

Here, the changes in final demand are important, as the effects from intermediate demand on all three variables are not significant. While exports have somewhat declined, household consumption of fish products has almost doubled in monetary terms.

In food processing, about 6% increase in final demand yields more than 40% of the effect on output growth while intermediate demand effect is negative as other sectors purchase less food. Almost 10% decline in employment is caused mainly by negative changes in intensity (productivity growth), more than compensating the positive effect form final demand. Positive income intensity effect means that reduced workforce earns more per unit of output and this combined with the significant final demand effect more than compensate negative effect from other sectors' demand.

Similar results for Chinese economy are reported by Doan and Trinh (2019) where the increase in final demand, including both domestic demand and exports, is the main driver of employment growth which offsets the decline in employment caused by enhanced labour productivity. Breakdown of the intermediate demand and final demand in food processing is mapped on Figure 3.

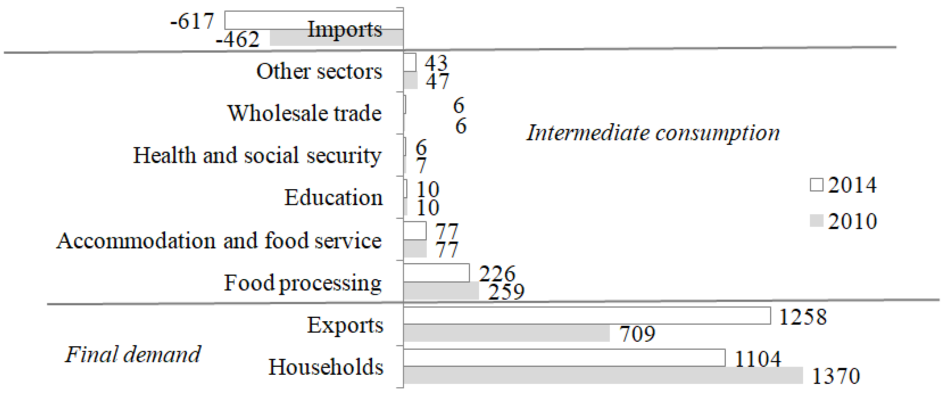

Figure 3. Structure of the intermediate demand and final demand in food processing, MUS$, 2010, 2014

Source: WIOD (2021), author's calculations

Changes in final demand for processed products are the main force behind the changes in all three variables. The significant increase in exports, in turn, is the main contributor to growth in final demand as household consumption has markedly declined. Simultaneous growth in imports and exports point towards the increase of the exports in products processed from imported agricultural commodities. The purchases of processed foods from other sectors largely remain unchanged.

4 Conclusions

Structural decompositions have to be considered a useful tool for estimation of causality for effects of changes of intensities, intermediate consumption and final demand on output, employment and income in agrifood sector. The results obtained by structural decompositions differ from simple derivations based on absolute variable values.

The effects from changes in intermediate consumption on variables are not significant. This might reflect the relative stability in technical coefficients (major technological breakthroughs have not happened).

The changes in final demand have to be considered the major factor affecting changes in output, employment and income in agrifood sector. Changes in exports and household consumption are equally important.

Simultaneous growth in unprocessed agricultural commodities and decline in processed foods in household consumption might reflect the general situation in economics with less disposable household income for food purchases.

The increased labour productivity in agriculture is the major factor affecting the decline in agricultural workforce. Nevertheless, this is countered by opposite effects of changes in final demand, namely, exports. Thus, steady agricultural exports have to be considered the main factor preventing further decline in agricultural employment.

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