MODELLING OF DEMAND SHOCK IMPACT IN FOOD SECTOR ON SECTORAL DEVELOPMENT: CASE OF LATVIA

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Abstract. In order to promptly model the cross-sectoral impact of the market crisis (macro-level impact in the narrow sense) that primarily has a direct impact on agriculture and food production, but due to the cross-sectoral linkages, the full impact also includes the impact on other sectors and the overall impact on the economy (macro level in the broadest sense), the input-output modelling tool is used. Two scenarios have been modelled: the effect of external shocks on the demand for products from the agricultural and food production sectors. Latvian farmers, producers and consumers are mostly price takers, therefore the changes in the global price level largely determine the price level in the domestic market. The modelling of the first scenario which involves a decline of food industry exports by 40%, assuming that household consumption remains at its previous level and is not initially affected and replaced by cheaper imported food industry goods, results in the net final consumption expenditures on food products decrease by 30.1%, resulting in a 25.1% drop in food industry output, also affecting the output of agriculture (-8.3%) and fishing (-10.9%). The impact on other sectors is relatively minor. The total net final consumption declined by 1.8%, but the domestic output -2.5%. Modelling the second shock scenario with two sub-scenarios the product market is experiencing a shock and export demand is declining by 50%. Modelling results show that agriculture itself has the most significant impact due to a decrease in the net final consumption expenditure by 44.2%, while agricultural output by 28.1%. The food production output declined by 0.8%, the total output – by 1.9%, and the total value-added – by 1.4%. The use of the input-output approach is directly linked to the available data on agricultural subsectors and their linkage with all other sectors of the economy.

Keywords: food sector, input-output modelling, demand shocks, cross-sectoral impact.

Introduction

There is growing scientific evidence on demand shock assessment and modelling applying various modelling approaches, micro or macro impact, sectoral disaggregation, impact specifics, regional development, descriptive and/or predictive application etc., especially caused by the demand to assess and examine the impact of the COVID-19 pandemic impact in the EU countries [1-4], large scale external shocks on international trade [5], economic resilience to shocks in global production networks [6], AI technologies in supply-chain reliance [7]. Crucial metals and food products are at the centre of many studies due to their impact on all economic agents and the scale of potential economic, social, political and other consequences [8]. However, far too little scientific attention has been paid to the major external demand shocks and their impact on the agriculture and food industry in Latvia or even in the EU.

The aim of this study is to model the impact of extreme external demand shocks in agriculture and food industry markets on the economic activity in Latvia (both in disaggregated and aggregated perspectives) by taking into account cross-sectoral linkages.

The input-output approach that takes into account cross-sectoral linkages is applied to various fields and combined with other methods and approaches, as in estimating the carbon footprint in the EU [9], and the Baltic countries [10]. Scientific evidence argues that economic performance is differently affecting regions estimated by the input-output approach, as rural areas are affected differently (less affected) than urban in Greece [11]. Environmentally extended input–output models have been applied for modelling climate change and decarbonisation in Europe [12]. The study applying the regional input-output model argues that agriculture is an important driver of growth in regions [13]. The input-output approach is widely used to assess the importance of critical materials and metals in the country's economy, such as copper in France [14]. Modified and extended input-output models and models with incorporated input-output intersectoral linkages are also used for large-scale shocks and disaster impact assessment [15].

The input-output approach has also been applied in Latvia, for example, in assessing the impact of transportation on sustainable development [16] and the impact of education [17] on the national economy.

Materials and methods

The main data sources for the study are the data and modelling obtained within the research project "Assessment of the impact of the Russian military invasion of Ukraine on the agricultural and food sectors and the development of methodology for assessing the impact of market crises on production costs and revenues of the agri-food sectors" (No. 23-00-S0INZ03-000010; 2023) [18]. In addition, additional modelling was performed by applying just-released the latest data in 2020 [19].

The classic input-output demand side model is applied. The economy is disaggregated according to NACE classification into 64 economic activities and corresponding CPA products. The research is based on symmetric input-output tables that technically are developed either in *product-by-product* or *industry-by-industry* approach at minimum every 5 years according to Eurostat guidelines [20]. *Product-by-product* approach is applied in Latvia. The computations are based on the latest available set of tables for 2015 at the project timeline and 2020 (released by CSB of Latvia in late December of 2023) [19].

The main focus of the research is paid to the food sector and agricultural production – respectively, C10-12 Food industry and A01 Agriculture. The classic input-output linkage is applied [14]:

$$X_i = \left(I - A_{ij}\right)^{-1} * Y_i, \quad (1)$$

where X_i – i-th industry's output, thsd. EUR,
$(I - A_{ij})^{-1}$ – indirect input coefficients (Leontief inverse),
I – identity matrix;
A_{ij} – direct input coefficients of product i in product j production (technological matrix),
Y_i – net final demand of industry's i products, thsd. EUR.

The net final demand vector (per product i) is computed as the sum of households' final consumption expenditure, government expenditure, fixed capital formations (investments), exports, and minus imports. Demand side shocks included in scenario assumptions are modelled to affect one or several elements of final demand.

The general modelling assumption is that the demand side shocks do not change the technologies applied by economic activities (direct input coefficients are held constant). Value added is computed on the basis of the individual value-added coefficients, which are constant as the whole technological matrix is held constant, and the just computed output per product i.

Technological matrix A_{ij} elements are whether domestically produced (A^d_{ij}) or imported (A^m_{ij}) as :

$$A_{ij} = A^d_{ij} + A^m_{ij}. \quad (2)$$

The research applies A_{ij} matrix and the equation (see Formula (1)), due to available information and modelling limitations.

The classic input-output modelling approach involves modelling the impact of demand-side shocks, modelled individual demand shocks (as given product exports decrease by 40% due to external shocks in major markets) or multiple effect (final demand for products by elements exports, domestic private consumption) results in industrial output and added value. As a result, it is possible to model both the direct impact on the food industry and the full impact, including indirect effects on many other economic activities and the overall impact on the economy, and the model applies the bottom-up approach.

Two modelling scenarios are developed and modelled to reveal the potential impact. The 1st modelling scenario assumes the export of the food industry (C10-C12 according to NACE) decreased by 40% as a result of major external shocks and impacts, assumptions are made about the other elements of final consumption; assuming that the private consumption by households remains at the previous level and is not initially affected and replaced by low-priced imported food industry products.

The 2nd shock modelling scenario has two sub-scenarios if the market of agricultural products experiences a shock and export demand decreases by 50%. In the case of this scenario, two variants are modelled, firstly (scenario 2.1), that only the export markets of agricultural products are affected, but domestic final consumption remains at the current level in the short term. Secondly (scenario 2.2), if all final consumers of agricultural products have access to the world's lower-priced products, thus reducing domestic final consumption demand for the same amount.

Results and discussion

The modelling results of the 1st scenario confirm that the net final consumption expenditure on food industry products decreases by 30.1%, and the output of the food industry decreases by 25.1%, also affecting agriculture – output decreases by 8.3%, fisheries: -10.9%. The modelled impact on other economic activities is relatively small. However, net final consumption decreases by 1.8%, while total domestic output decreases by 2.5%. The calculated change in total added value is equivalent to the change in net final consumption (macroeconomic equilibrium condition). The results of the major modelled impact on the industrial output in the 1st scenario (see Table 1).

Table 1

Major affected industries in the 1st scenario modelling results

NACE code	Economic activity	Impact on output (% change from baseline under shock)
C10_12	Food industry	-25.1%
C17	Paper production	-21.4%
C22	Production of rubber and plastic products	-17.7%
A03	Fisheries	-10.9%
A01	Agriculture	-8.3%

Source: the authors' calculations

As for industrial output, the value added and final demand values are in sectoral disaggregation (64 elements), the absolute values are aggregated (bottom-up approach), obtaining sectoral absolute values and relative impact computed for major sectors according to NACE letter-level disaggregation (see Table 2).

Table 2

Modelled impact on the added value of sectors in the 1st scenario

NACE code	Sector	Impact (% change from baseline under shock)
A	Agriculture	-5.1%
BE	Industry	-6.4%
F	Construction	-0.1%
G_I	Trade, transport, accommodation	-1.4%
J	Information and communication services	-0.5%
K	Financial and insurance activities	-0.8%
L	Operations with real estate	-0.3%
M_N	Professional, scientific services and administrative services	-1.6%
OQ	State administration, education, health	0.0%
RS	Art and other services	0.0%
Total		**-1.8%**

Source: the authors' calculations

The modelling results of scenario 2.1. confirm that the most significant impact is on agriculture itself, as net final consumption expenses decrease by 44.2% and agricultural output by 28.1%. Since agriculture consumes a relatively large amount of its own production and imported goods and services, in general, other sectors are affected relatively by a smaller amount than in the case of a food industry shock scenario (the 1st scenario). The output of the food industry decreases by only 0.8%, but in general, the output of the entire economy decreases by 1.9%, due to the decrease in demand for manufacturing goods (such as chemical industry products, paper, fuel, etc.) consumed in agriculture. Total added value decreases by 1.4%.

The modelling results of scenario 2.2 claim that agricultural output decreases by 31.9% (because only part of agricultural production is final consumer products, mostly intermediate goods), similar to the previous agricultural scenario (scenario 2.1), the manufacturing industry has a greater impact on many economic activities, accordingly it reduces the demand for the products of other sectors, as a result the total impact results into output decreases by 2.2%. The total value added declines by 1.6% (see Table 3). Similarly, using the calculated values of the added value of sub-sectors, it is possible to sum

up the indicators of industries and sectors, as well as changes in the view of higher-level aggregation in both sub-scenarios.

Table 3

Modelled impact on the added value of sectors in the 2nd scenario

NACE code	Sector	Impact (% change from baseline under shock)	
		Scenario 2.1	Scenario 2.2
A	Agriculture	-15.7%	-17.7%
B_E	Industry	-2.1%	-2.4%
F	Construction	-0.1%	-0.1%
GI	Trade, transport, accommodation	-1.0%	-1.2%
J	Information and communication services	-0.4%	-0.5%
K	Financial and insurance activities	-0.8%	-0.9%
L	Operations with real estate	-0.3%	-0.4%
M_N	Professional, scientific services and administrative services	-1.1%	-1.2%
O_Q	State administration, education, health	0.0%	0.0%
RS	Art and other services	0.0%	0.0%
Total		**-1.4%**	**-1.6%**

Source: the authors' calculations

It is worth stressing that volume, price side, real side and quantity modelling is possible in more advanced and extended input-output models. At present, due to the availability of existing data, volume modelling is selected, with the possibility of supplementing with quantity and price modelling solutions, which is possible only in conditions of broader data availability.

In conclusion, additionally, the researched external shock scenarios were also modelled by an updated modelling instrument that is built on a symmetric input-output data set of 2020, published in late December 2023, which was after the project timeline. The scenario assumptions are unchanged.

The modelling results using this updated data set of 2020 are presented in Table 4 (suffix _U represents the applied data set of 2020 for intersectoral linkages). The findings claim that in five years intersectoral linkages have changed and scenario 2.2_U has relatively smaller impact (-1.4%) compared to scenario 2.1_U (-1.7%).

Table 4

Modelled impact on the added value of sectors using the updated database

NACE code	Sector	Impact (% change from baseline under shock)		
		Scenario 1_U	Scenario 2.1_U	Scenario 2.2_U
A	Agriculture	-7.7%	-21.0%	-17.5%
B_E	Industry	-7.5%	-2.1%	-1.8%
F	Construction	-0.2%	-0.1%	-0.1%
G_I	Trade, transport, accommodation	-1.6%	-0.9%	-0.7%
J	Information and communication services	-0.6%	-0.4%	-0.4%
K	Financial and insurance activities	-1.4%	-1.7%	-1.4%
L	Operations with real estate	-0.3%	-0.2%	-0.2%
M_N	Professional, scientific services and administrative services	-1.9%	-1.1%	-1.0%
O_Q	State administration, education, health	0.0%	0.0%	0.0%
R_U	Art and other services	-0.1%	0.0%	0.0%
Total		**-2.2%**	**-1.7%**	**-1.4%**

Source: the authors' calculations

It is detected that both the food industry and agriculture have experienced both technological changes and changes in the final demand structure. Hence, the same modelling scenario assumptions result in diverse results. The most significant finding is related to scenario 2.2. If the data on 2020 are used, then the relative impact to the total value added is smaller (-1.4%) than in scenario 2.1 (-1.7%). One of the core factors is linked to a significantly larger export orientation in agriculture and a higher share of imported agriculture products in final demand.

This study set out to examine the macro impact of large-scale demand shock taking into account cross-sectoral linkages, and the results are valuable for wide audiences, including policymakers, business managers and stakeholders operating in the examined economic activities. The food demand shocks might be caused by trade dependencies [5; 21] and also domestic shocks (as by drastic changes in diets and food consumption [22]). Other studies examine agriculture, food processing, distribution and food service providers in the country and their regional allocation [23], which are heavily dependent on imported fossil energy concerning technological intermediate inputs [24]. A limitation of this study is that the direct input coefficients are applied. Further studies must disaggregate and apply domestic and import direct technological matrices to disclose the impact on imported products as import dependency is high and, for some products even growing in past decades, highlighting the supply-chain resilience and disruptions risks. This study has indirectly raised important questions about the scale and nature of dependency on export markets and reliance on imported products in intermediate consumption in many industries. And these questions still remain to be answered. Further research needs to examine more closely the technological shifts and dynamics in cross-sectoral linkages over time.

Conclusions

1. The major external shock of a decline of 40% in food industry exports mainly affects the food industry (decline by 25.1%), also agriculture (-8.3%) and fishing (-10.9%); however, the impact on other sectors is relatively minor. The domestic output declines by 2.5%; the total value-added declines by 1.8%, and similar results (-2.2%) are obtained with the updated database for 2020.
2. Modelling results argue that major external shock abroad in agriculture markets (exports decline by 50%) results in the most significant impact on agriculture itself, resulting in the value-added decline of 1.4%, and correspondingly similar results (-1.7%) are obtained with the updated database.
3. The use of the input-output approach is directly linked to the available data on agricultural subsectors and cross-sectoral linkage with all other sectors of the economy.
4. External demand shocks regarding limited products, such as the food industry and agricultural products, are resulting in a notable impact on the overall economic activity.
5. Updated modelling results on the latest data set indicate that there is a significantly larger export orientation in agriculture and a higher share of imported agriculture products in final demand.
6. Major external demand shocks must be modelled to be equipped with a targeted and well-balanced policy action plan if applicable.

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Author contributions

Conceptualization, A.A.-E., A.A; methodology and validation, A.A.-E.; investigation and data curation, A.A.; writing-original draft preparation, writing-review and editing, A.A.-E., A.A.; project administration, A.A. Authors have read and agreed to the published version of the manuscript.

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