Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego
Studies of the Industrial Geography Commission of the Polish Geographical Society

38(2) • 2024

ISSN 2080–1653
DOI 10.24917/20801653.382.3

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Modelling the impact of manufacturability and import dependence on the efficiency of the processing industry of Ukraine

Abstract: The article aims to model the processing industry of Ukraine in the direction of increasing its economic efficiency according to the criteria of manufacturability and self-sufficiency (i.e. reducing import dependence). The regularities of the impact of technology and import dependence on the functional efficiency of the economy's industrial sector are revealed. The authors' hypothesis that higher economic efficiency in processing is explained by its greater focus on high-tech processes and production with a greater degree of the processing of raw materials, as well as a lower level of dependence on imported components, has been empirically proven. With the help of correlation-regression analysis, dependence between change in structural parameters (the share of high- and medium-high-tech industries in terms of output and the share of imports for intermediate consumption) and efficiency (the share of GVA in output) is substantiated. Deterministic economic-mathematical models (solved by linear programming) for optimising output and GVA in the processing industry and intermediate consumption were built according to the criteria of increasing manufacturability and reducing import dependence, both towards increasing efficiency. Such intermediate consumption (in terms of imported and domestic components of costs) was modelled, under which the indicator of the share of GVA of Ukraine would correspond to the level in Poland. The optimised data obtained form the basis for strategic planning, as they show what the output (by manufacturability) and intermediate consumption should be to ensure the desired level of economic efficiency of the Ukrainian processing industry.

Keywords: efficiency; gross value added (GVA); import dependence; industry; intermediate consumption; manufacturability; production optimisation

Received: 14 February 2024
Accepted: 28 March 2024

Suggested citation
Ishchuk, S., Sozanskyy, L. (2024). Modelling the impact of manufacturability and import dependence on the efficiency of the processing industry of Ukraine. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [*Studies of the Industrial Geography Commission of the Polish Geographical Society*], *38*(2), 49–68. doi: https://doi.org/ 10.24917/20801653.382.3

Introduction

The processing industry plays a vital role in the innovative and socio-economic development of a country's economy. Therefore, the financial situation of individual business

entities and economic security and prospects for the post-war reconstruction of Ukraine's economy depend on how effectively this sector of the real economy functions and what priorities are set. Unfortunately, due to various reasons, including the oligarchy, the influence of negative geopolitical factors, insufficient consideration of the risks of economic globalisation, most production being from raw materials, and low-tech industry, prevailed before the full-scale war of Russia against Ukraine. The dominant functioning of such industries cannot ensure high economic or social efficiency or the national economy in general. As a result, the irrational nature of the Ukrainian economy from the perspective of efficiency and innovative socio-economic development has led to its critically high import dependence on products of intermediate or final consumption, on capital assets and, above all, on high-tech or medium-high-tech industrial products (Ishchuk, Sozanskyy, Kniaziev, 2023). This high import dependence also caused the excessively high dependence of the Ukrainian economy on world markets for raw materials and finished products, and on exchange rate fluctuations. All this, directly and indirectly, exacerbated social tensions, dissatisfaction with the state, the growth of labour migration and emigration, and the demoralisation of education and science, which limited the prospects for a prosperous and happy future for Ukrainian society.

Post-war reconstruction of the Ukrainian economy, particularly the processing industry, should be based on new criteria and priorities, and the mistakes of the pre-war past should be avoided. Above all, structural transformation towards increasing the importance of industries with higher added value and socio-economic efficiency should ensure the restoration of intersectoral relationships, reduced import dependence, improved technical defence capability, and increased standards of living.

Literature review

Many academic studies are devoted to the problems of the functioning of the Ukrainian industry. At the same time, new opportunities and challenges for the key sectors and their structural transformations under the influence of the economic integration of Ukraine with the EU are considered in Heyets & Ostashko (eds) (2016). In particular, the need to modernise Ukrainian industry and the formation of its industrial policy coordinated with EU goals is emphasised. Elements of Ukraine's joint path to industrial revival within the EU have been identified. The need to activate and expand the domestic market for metal products and the chemical, energy, and woodworking industries was highlighted. It is noted that the emphasis on the domestic market can be the basis for the effective modernisation of Ukrainian industry.

Conclusions about the importance of structural transformations towards 'neo-industrialisation' have been made in a monograph by Vyshnevskyj et al. (2016). In particular, it has been noted that opportunities for extensive growth based on traditional factors (natural and demographic resources, foreign exchange earnings from low-tech exports, and social and labour exploitation) have been practically exhausted in the Ukrainian economy. The dominant national neo-industrial strategy should be the large-scale introduction of innovative technologies that provide tangible effects in terms of such indicators as energy and resource savings, resource efficiency, product quality and environmental safety.

In addition to classical approaches to the structure of industry, its transformation is also considered from the perspective of sustainable development, in particular in the

work by Amosha et al. (2017). According to this approach, the industry structure consists of economic, social and environmental components. A set of indicators is proposed to evaluate each. A key feature of this approach is the consideration of the social and environmental components when assessing the efficiency of structural transformation. In Zbarazsjka (2022), the results of an analysis of compliance with world and European trends in the development of domestic industrial production are presented. The implementation of the sectoral goal of SDG-9 into the national industry, as a set of tasks within the concept of sustainable and inclusive development of production, was studied.

The task of structural and product optimisation is the correct choice for the priorities on which the country's resources should be concentrated, and appropriate state support should be provided (Shynkaruk et al., 2015). When choosing sectoral priorities, the main focus should be restoring the potential for domestic engineering, light industry, diversification and expanding the range of products of both the chemical industry and the mining and metallurgical complex, adapting them to the needs of the domestic market. The basic scenario of the long-term development of Ukraine's industry until 2035 has been given in Okhtenj (2013). The conceptual approach to selecting a system of anticipatory indicators in the development of national industry has been highlighted in Soldak (2022). The range of industrial production and innovative products, according to increasing innovativeness, is presented in Ishchuk, Sozanskyy & Caputa (2023).

Despite the significant contribution of these and other works to the theoretical and practical aspects of solving problematic issues, several topical issues have been left out of academic attention. In particular, proof/refutation of the connection between economic efficiency (the share of GVA in output) and the technological structure of production, import dependence and efficiency by modelling its structure according to import dependence, manufacturability and efficiency criteria. These questions regarding Ukraine are considered here for the first time, and regarding Poland, Germany and Czechia they were the subject of the authors' previous works.

All in all, the scope for the structural transformation of the Ukrainian processing industry is multifaceted and requires a more detailed study in the context of the modern challenges caused by the Russian-Ukrainian war.

Purpose and tasks

The article aims to model the structure of the processing industry in Ukraine towards increasing its economic efficiency according to the criteria of manufacturability, self-sufficiency (i.e. reducing import dependence) and efficiency. Achieving the goal set involves solving several tasks: empirical substantiation of the criteria for the structural transformation of the processing industry; analytical study of relationships between its structure and efficiency; import dependence calculations for processing industrial production; development of deterministic models for optimisation of output, air transport and intermediate consumption; and solutions to these models by the method of linear programming.

The urgent need for the post-war reconstruction of Ukrainian industry on a new basis has actualised the task of applying the key results highlighted in the authors' study (Ishchuk, Sozanskyy, Pukała, 2020).

Methods

The research was conducted in two stages. In the first stage, the following analyses were carried out: trends in the share of GVA in the output (economic efficiency) of the processing industry; the output and GVA of the Ukrainian processing industry based on manufacturability; the structural transformations of Ukrainian industry caused by the large-scale Russian-Ukrainian war. At the same time, key indicators were compared with those for Poland and Germany. The selection of these countries for comparison was due to several similarities in the economy and industry of Ukraine and Poland, in particular, as both have a transition economy. The industries of Ukraine and Poland have similar indicators and problems with economic development: relatively low innovativeness of products, a low share of high- and medium-high-tech industries, significant dependence on the import of intermediate consumption products, an inadequate level of modernisation of the principal production capital, the loss (based on the full production cycle and self-sufficiency) of critical strategic industries (automotive, shipbuilding, agricultural machinery, and other segments of high-tech engineering) the functioning of which would significantly improve socio-economic development. The industries of Ukraine and Poland, in addition to development problems, have common priorities and goals, primarily reducing import dependence, increasing the innovativeness and efficiency of products, and strengthening internal intersectoral ties. Industrial enterprises in Ukraine and Poland cooperate effectively to overcome these challenges. Therefore, their industries have a lot in common, which is an argument for choosing them for comparison. The industry of Germany was chosen as by many indicators, it is a leader in the EU in socio-economic efficiency, innovativeness and industrial technology. Therefore, comparing the studied industries with the leader is argued from the position of targets and goals.

This research was conducted using well-known general academic, economic, and logical methods of economic analysis (correlation, linear programming, comparison, hypothetical-deductive, systematic approach). The application of these methods contributed to the formation and proof of hypotheses, thus modelling the influence of manufacturability and import dependence on the efficiency of Ukraine's processing industry.

In addition, the authors' hypothesis about the existence of a relationship between the share of GVA in the output (economic efficiency) of the processing industry and its structural indicators (shares of products according to technological efficiency in its output), stated in previous work (Ishchuk, Sozanskyy, Pukała, 2020) was verified using correlation analysis, in particular the calculation of the Pearson correlation coefficient, and tested on data from Poland and Germany. Following that, the structure of the processing industry of Ukraine was modelled according to the criteria of economic efficiency and manufacturability towards increasing economic efficiency. For this purpose, experience and the authors' methodological approaches were tested at the level of the processing industry in Poland and Germany and highlighted in Ishchuk, Sozanskyy, Pukała (2020). In particular, "a deterministic economic-mathematical optimisation model (f1) solved by the linear programming method was used." In this study, this model was slightly modified in accordance with the peculiarities of the data from the State Statistics Service of Ukraine (SSSU) on the functioning of the processing industry (in terms of 16 industries, not 17, as reported by Eurostat). The criterion for optimising output remained unchanged – increasing the level of manufacturability, i.e., increasing

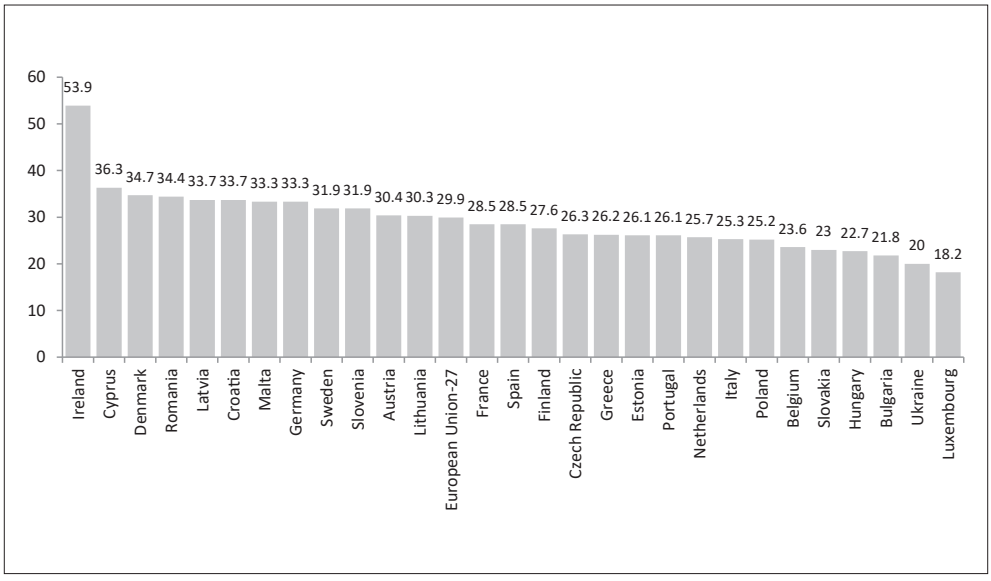
the share of high- and medium-high-tech industries. The target optimisation function was chosen to achieve the level of economic efficiency of the Polish processing industry.

In the second stage of the research, an analysis of the import dependence of the processing industry was carried out using economic and logical analysis methods. With the help of the calculation of the Pearson correlation coefficient, the authors' hypothesis about the existence of a relationship between the economic efficiency of the processing industry and the share of imports in the costs of high- and medium-high-tech industries has been verified. This hypothesis is detailed in the authors' previous work (Ishchuk, Sozanskyy, Pukała, 2020) and tested on industry in Czechia. Modelling of the intermediate consumption of 16 Ukrainian processing industry products (in terms of domestic and imported components) was carried out with the help of improved and supplemented methodological approaches, in particular the optimisation model (f2) from previous studies (Ishchuk, Sozanskyy & Pukała, 2020). The optimisation criteria were chosen to increase economic efficiency and, at the same time, reduce import dependence. Increasing the economic efficiency of Ukraine to the level of Poland was chosen as the target. Data from the "input-output" tables from the State Statistics Service of Ukraine (SSSU) and Eurostat were the key information bases of the research.

The results

Economic efficiency, expressed by the share of GVA in output, is the lowest among the industrialised countries of the EU. Thus, in 2021, the value of this indicator in Ukraine was 1.43 times lower than the average in the EU-27, 1.25 times lower than in Poland, and 1.67 times lower than in Germany (Figure 1).

Figure 1. The share of GVA in the output of the processing industry of Ukraine and EU countries in 2021, in %



Source: authors' calculations based on Eurostat (2023)

The output of the Ukrainian processing industry is highly unsatisfactory (with a steady tendency to deteriorate) in terms of manufacturability. Thus, in 2020, almost half (48.3%) of the output was in low-tech production, while in Poland, it was 38.9% and in Germany, only 22.1% (Table 1).

Table 1. Output of the processing industry of Ukraine, Poland and Germany, in %

Sector	Processing industry	Code classification of economic activities NACE Rev.2	Ukraine		Poland		Germany	
			2013	2020	2013	2020	2013	2020
high-tech	Manufacture of basic pharmaceutical products and pharmaceuticals	C21	1.5	2.3	1.3	1.1	2.6	3.0
	Manufacture of computers, electronic and optical products	C26	0.9	0.8	3.1	3.2	4.1	5.0
	Total		2.4	3.1	4.4	4.3	6.7	8.0
medium-high-tech	Manufacture of chemicals and chemical products	C20	6.0	4.3	5.5	5.0	7.8	7.4
	Manufacture of electrical equipment	C27	2.5	1.9	4.5	6.2	5.8	5.8
	Manufacture of machinery and equipment not elsewhere classified	C28	4.5	3.5	3.7	3.7	13.4	13.5
	Manufacture of motor vehicles, trailers and semi-trailers	C29	1.4	1.4	10.6	10.2	18.8	19.5
	Manufacture of other transport equipment	C30	5.4	2.0	1.8	2.2	2.2	2.6
	Total		19.7	13.1	26.2	27.3	48.0	48.8
moderately-low-tech	Manufacture of coke and refined petroleum products	C19	6.3	4.1	8.7	4.5	4.5	2.1
	Manufacture of rubber and plastic products	C22	2.8	3.3	6.8	7.4	4.3	4.3
	Manufacture of other non-metallic mineral products	C23	4.6	7.4	4.2	4.8	2.5	2.7

moderately-low-tech	Manufacture of basic metals	C24	21.0	16.9	4.0	3.5	5.7	5.0
	Manufacture of fabricated metal products, except machinery and equipment	C25	3.4	3.8	8.0	9.4	7.1	6.9
	Total		38.1	35.5	31.7	29.5	24.0	21.0
low-tech	Manufacture of food products; beverages and tobacco products	C10-12	29.6	35.2	20.6	20.2	10.4	11.2
	Manufacture of textiles, wearing apparel, leather and related products	C13-15	1.4	2.0	2.4	2.3	1.3	1.1
	Manufacture of wood, paper, printing and reproduction	C16-18	5.0	6.3	7.6	7.9	4.7	4.3
	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-33	3.9	4.8	7.3	8.5	5.0	5.5
	Total		39.8	48.3	37.8	38.9	21.3	22.1
Total processing industry			100.0	100.0	100.0	100.0	100.0	100.0

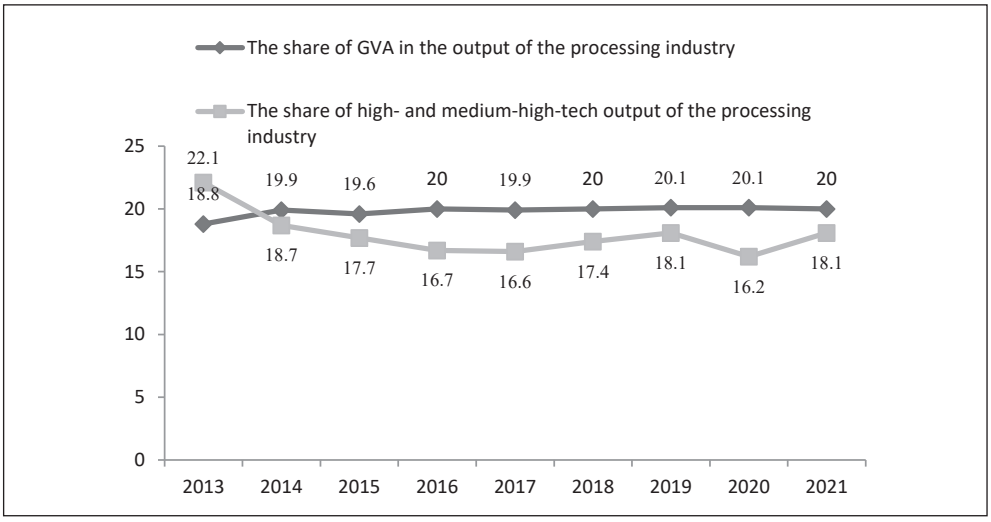
Source: authors' calculations based on SSSU (2023), (Eurostat, 2023)

In countries with a developed market economy, the structural parameters of industry are relatively stable; that is, over a decade, the share of individual industries would change by a maximum of 1–3 percentage points. For example, in Poland and Germany, from 2014 to 2020, the share of medium-high-tech industries increased by 1.1 and 0.8 percentage points, respectively. On the other hand, in Ukraine, it decreased by 6.6 percentage points over the same period. It confirms both the general instability of the Ukrainian processing industry and its negative transformation.

Structural transformation towards growth in the output of high- and medium-high-tech industries is economically justified since their products have higher added value content. In addition (and this is the most important), these products are centres of intersectoral relations and critical producers of technical and technological innovations. In 2020, in Germany, high- and medium-high-tech production accounted for a total of 56.8% (+2.1 percentage points for 2014–2020) of output, in Poland, 31.6% (+1.1 percentage points), while in Ukraine it was only 16.2% (–5.9 percentage points). At the same time, it should be noted that the economic efficiency of Ukrainian machine-building industries (except C28) is greater than that of Polish ones. However, as the authors' research has proved (Ishchuk, Sozanskyy, Kniaziev, 2023), the import dependence of mechanical engineering in Ukraine is critically high.

In the authors' previous works (Ishchuk, Sozanskyy, Pukała, 2020), using the example of Poland and Germany, their hypothesis that there is a high direct correlation between the share of high- and medium-high-tech industries and the share of GVA has been analytically proven (with an increase in one indicator, there is an increase in another). However, this hypothesis was not confirmed for the Ukrainian processing industry (Figure 2). On the contrary, a high inverse relationship was found (as the values of one indicator increase, the values of the other decrease), and the correlation coefficient (r) between them is –0.87. At the same time, a high direct correlation was found between the share of GVA and the share of high-tech products (r=0.81), as well as the share of low-tech products (r=0.65) (Table 2).

Figure 2. Indicators of the efficiency of the processing industry of Ukraine, in %



Source: authors' calculations based on SSSU (2023)

Table 2. Correlation coefficient between the share of GVA and share of production in Ukraine, in %

Sector	Processing industry	Code classification of economic activities NACE Rev.2	Correlation coefficient (r)
high-tech	Manufacture of basic pharmaceutical products and pharmaceuticals	C21	0.83
	Manufacture of computers, electronic and optical products	C26	0.28
	Total		
medium-high-tech	Manufacture of chemicals and chemical products	C20	–0.74
	Manufacture of electrical equipment	C27	–0.52
	Manufacture of machinery and equipment not elsewhere classified	C28	–0.67
	Manufacture of motor vehicles, trailers and semi-trailers	C29	–0.15
	Manufacture of other transport equipment	C30	–0.83
	Total		

moderately-low-tech	Manufacture of coke and refined petroleum products	C19	–0.7
	Manufacture of rubber and plastic products	C22	0.73
	Manufacture of other non-metallic mineral products	C23	0.54
	Manufacture of basic metals	C24	–0.22
	Manufacture of fabricated metal products, except machinery and equipment	C25	0.28
	Total		
low-tech	Manufacture of food products; beverages and tobacco products	C10–12	0.37
	Manufacture of textiles, wearing apparel, leather and related products	C13–15	0.72
	Manufacture of wood, paper, printing and reproduction	C16–18	0.83
	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31–33	0.44
	Total		

Source: authors' calculations based on SSSU (2023)

The functioning of the processing industry in Ukraine in the post-war period should ensure stable and significant budget revenues; competitive wages and new jobs in the industrial sector and the economy in general; filling the domestic market with competitive (in terms of quality and price parameters) products for intermediate and final consumption, in particular, high- and medium-high-tech industries; and ultimately (most importantly) a high technical and technological defence capability. All this can be achieved under the condition that the central place in Ukrainian industry will be occupied by mechanical engineering, chemical and pharmaceutical industries, and production processes will have a high level of technology, innovativeness, focus on national science and the IT sector, and low dependence on the import of intermediate consumption products.

Given the outlined priorities, modelling of output and GVA for the processing industry of Ukraine was carried out towards increasing its economic efficiency (the share of GVA in output) to the level of the Polish indicator (25.2%), according to the modified formula (f.1) (Ishchuk, Sozanskyy, Pukała, 2020).

The actual (according to the latest available data) output is volatile and irrational, particularly from the standpoint of economic efficiency. It is evident that during the period of the war and post-war reconstruction, its instability in general will increase even more, due to the dependence on logistics, the situation on world markets for raw materials, the speed of financial and investment flows into the national economy, the restoration of production capacities, the formation of a new industrial policy and many other factors.

According to the results of the calculations, the share of GVA will reach a similar indicator level to Poland (25.2%), provided that the share of high-tech industries increases by 0.6 percentage points and the share of medium-high-tech by 2.8 (Table 3). At the same time, the share of high-tech industries should increase by 0.7 percentage points, and the share of medium-high-tech industries should increase by 4.3. It is also necessary to emphasise that the achievement of the goal set implies a significant increase in the share of GVA in the output of all products of the processing industry of Ukraine.

Table 3. GVA and the output of the processing industry of Ukraine, in %

Sector	Processing industry	Code classification of economic activities NACE Rev.2	Actual indicators (2021)			Optimised indicators		
			Structure of gross added value	Structure of output	Share of gross added value in output	Structure of gross added value	Structure of output	Share of gross added value in output
high-tech	Manufacture of basic pharmaceutical products and pharmaceuticals	C21	3.3	2.2	30.0	4.0	2.7	37.9
	Manufacture of computers, electronic and optical products	C26	1.4	1.0	29.8	2.0	1.2	42.7
	Total		4.7	3.2	x	6.0	3.8	x
medium-high-tech	Manufacture of chemicals and chemical products	C20	2.3	4.4	10.4	3.0	5.2	14.5
	Manufacture of electrical equipment	C27	3.2	2.2	28.3	4.0	2.7	37.4
	Manufacture of machinery and equipment not elsewhere classified	C28	6.0	4.0	30.4	7.2	4.7	39.0
	Manufacture of motor vehicles, trailers and semi-trailers	C29	1.5	1.3	23.5	2.0	1.5	33.0
	Manufacture of other transport equipment	C30	5.1	3.0	33.8	6.2	3.6	43.0
	Total		18.1	14.9	x	22.4	17.7	x
moderately-low-tech	Manufacture of coke and refined petroleum products	C19	2.9	4.8	4.8	2.8	5.5	12.8
	Manufacture of rubber and plastic products	C22	2.3	3.2	3.2	2.2	3.8	14.9
	Manufacture of other non-metallic mineral products	C23	5.2	6.5	6.5	5.0	7.4	17.0

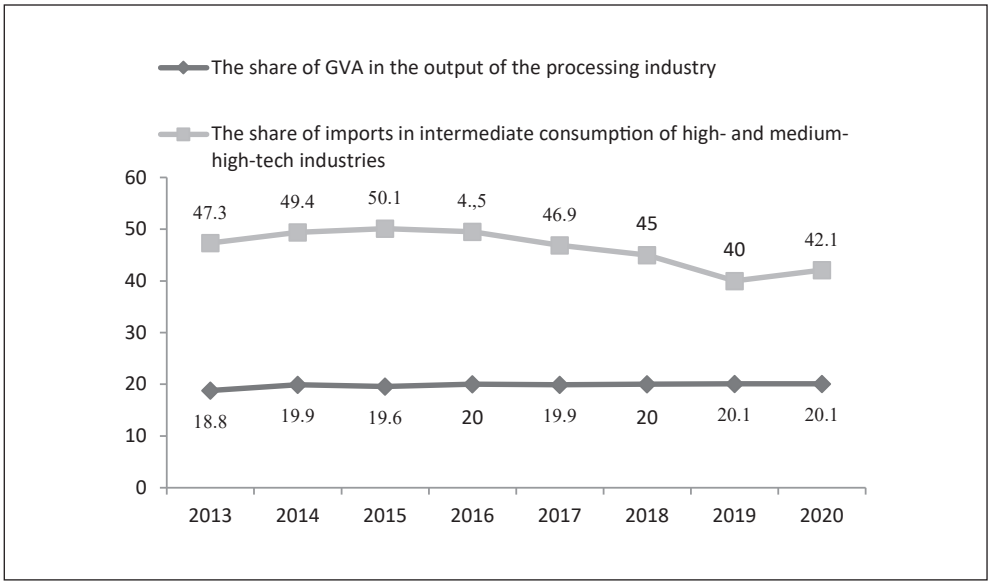
moderately-low-tech	Manufacture of basic metals	C24	13.6	19.1	19.1	12.7	18.0	17.8
	Manufacture of fabricated metal products, except machinery and equipment	C25	4.5	4.0	4.0	4.3	4.8	22.8
	Total		28.5	37.6	x	27.1	39.5	x
low-tech	Manufacture of food products; beverages and tobacco products	C10–12	27.6	30.9	17.9	24.3	23.4	26.2
	Manufacture of textiles, wearing apparel, leather and related products	C13–15	5.0	2.1	48.4	4.8	2.5	48.7
	Manufacture of wood, paper, printing and reproduction	C16–18	6.9	6.2	22.2	6.6	7.1	23.4
	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31–33	9.2	5.1	36.1	8.7	5.9	37.2
	Total		48.7	44.3	x	44.5	38.9	x
Total processing industry			100.0	100.0	20.0	100.0	100.0	25.2

Source: authors' calculations based on SSSU (2023)

According to the results of the author's previous research (Ishchuk, Sozanskyy, Pukała, 2020), an increase in the share of high- and medium-high-tech products can contribute to a significant increase in economic efficiency in general, but the named products must be highly efficient. However, not all EU countries have high efficiency for these products; in particular, this applies to Czechia, Slovenia, Slovakia and Hungary. One of the main reasons for the low efficiency of high- and medium-high-tech industries is their high level of import dependence. In particular, based on the example of Czechia, the authors' hypothesis was analytically proven that the lower the value of the share of imports in the intermediate consumption of high- and medium-high-tech industries, the higher the share of GVA in the output of the processing industry (Ishchuk, Sozanskyy, Pukała, 2020). In other words, there is a high inverse correlation between import dependence (expressed as the share of imports in the costs of these industries) and economic efficiency (the share of GVA in output).

For the processing industry of Ukraine, the hypothesis was confirmed, although not fully (Figure 3). The calculated correlation coefficient between the share of GVA in output and the share of imports in the intermediate consumption of high- and medium-high-tech industries for 2013–2020 was (–0.34), which is evidence for the presence of an inverse average relationship between the indicators studied. This can be explained by the fact that during the analysed period, the share of medium-high-tech industries significantly and sharply decreased (see Table 2) due to the influence of primarily non-economic factors.

Figure 3. Indicators of efficiency and import dependence for high- and medium-high-tech industries in Ukraine, in %



Source: authors' calculations based on SSSU (2023)

Given the presence of specific features in the functioning of the Ukrainian processing industry, the modelling of its structural parameters towards optimisation, according to the criteria of reducing import dependence and increasing economic efficiency, should be based on the results of a detailed analysis:

- the actual level of import dependence of the processing industry in terms of production;
- the correlation between the share of imports in production costs and the share of GVA in the output.

As evidenced by the results of the author's calculations, during the years 2014–2020, the share of imports generally decreased by 13.0 percentage points (or by 35%), which is certainly a positive trend (Table 4). A decrease in import dependence took place in 12 industries, especially in the production of chemicals and chemical products (by 41%). However, despite that, in 2020, in the vast majority (10 out of 16), the share of imports in costs exceeded 30%. The most profound problem was the significant increase in the import dependence of machine-building industries (belonging to medium-high-tech industries), out of which the largest (by 45%) is the production of 'other vehicles' (C30). In 2013, the share of imports (27.5%) was one of the lowest, compared to other products. As already mentioned, the production of 'other vehicles' is one of the strategic segments of mechanical engineering as, among other things, it manufactures products for the defence industry (weapons and equipment). Accordingly, the deepening of import dependence means a weakening of the economy and the national security of Ukraine, especially in the face of Russia's full-scale war.

In the authors' previous studies, based on the example of machine-building, it was analytically proven that the share of imports in their total costs is smaller than, in particular, the machine-building products of intermediate consumption which are used in their production (Ishchuk, Sozanskyy, 2022), (Ishchuk, Sozanskyy, Kniaziev, 2023). Further research revealed that such a feature is also characteristic of one of the primary segments of the Ukrainian processing industry, the manufacturing of food products, beverages and tobacco products (C10–12), which are low-tech. Thus, in 2020, import dependence was generally relatively low, only 13.5% (compared to 19% in 2013), but at the same time, the share of imports in the food industry consumed by C10–12 was 44.1% (against 17.5%). It follows from this that the problem of reducing import dependence is relevant for all four technological groups, but above all, in high- and medium-high-tech.

The results of the study of the relationship between the economic efficiency of the Ukrainian processing industry and import dependence revealed the following pattern: with a decrease in the share of imports in the costs of each of the four technological production groups there is an increase in the share of GVA in general, and vice versa. It is confirmed by high or very high negative values for the correlation coefficient R for high-tech and low- and medium-low-tech industries. At the same time, for medium-high-tech industries, such a relationship was inverse but low. The obtained results are an analytical justification for the fact that one of the criteria for optimising the processing industry of Ukraine towards increasing its economic efficiency should be a decrease in the import dependence of all industries, but above all, medium-high-tech (chemical and machine-building), which play a key role in ensuring economic and technological self-sufficiency. The target optimisation was chosen to increase the value of the share of GVA by 5.1 percentage points, i.e. to the desired level of 25.2% (Poland's indicator in 2021).

The results of the modelling carried out according to the formula ($\phi 2$) given in [8] showed that an optimised structure of intermediate consumption was built (Table 5).

Table 4. Interrelationships between import dependence and economic efficiency in the processing industry of Ukraine

Sector	Processing industry	Code classification of economic activities NACE Rev.2	Indicator	2013	2014	2015	2016	2017	2018	2019	2020	R
high-tech	Manufacture of basic pharmaceutical products and pharmaceuticals	C21	X	23.4	30.3	30.5	30.5	30.2	30.5	30	30.7	–0.59
			Y	46.4	48.7	41.9	39.8	36.5	34.2	28.9	36.4	
	Manufacture of basic pharmaceutical products and pharmaceuticals	C26	X	28.7	28.4	29.2	29.4	29.4	29.9	29.8	25.3	–0.82
			Y	55.5	51.5	46.0	42.3	40.0	40.9	40.0	41.0	
	Total		X	25.3	29.7	30.2	30.2	29.9	30.3	29.9	29.3	–0.68
	Y		49.5	49.7	43.0	40.6	37.6	36.3	32.3	37.7		
medium-high-tech	Manufacture of chemicals and chemical products	C20	X	10.5	10.9	10.9	11.2	11.3	11.6	10.4	10.9	–0.71
			Y	59.4	53.6	55.3	47.3	51.5	48.8	38.8	34.5	
	Manufacture of electrical equipment	C27	X	28.9	29.0	29.2	29.4	29.3	29.1	28.3	27.9	0.61
			Y	40.9	45.1	47.5	50.1	46.4	43.8	44.8	46.4	
	Manufacture of machinery and equipment not elsewhere classified	C28	X	31.0	31.2	31.2	31.4	31.2	31.2	30.4	29.9	0.76
			Y	44.3	49.3	48.4	55.7	51.1	54.0	50.6	49.5	
	Manufacture of motor vehicles, trailers and semi-trailers	C29	X	22.8	23	23	23.9	23.3	24.6	23.5	21.9	-0.30
			Y	60.1	66.9	63.4	64.1	56.7	43.9	41.0	58.2	
	Manufacture of other transport equipment	C30	X	41.3	41.2	41.1	41.6	41.4	34.2	33.8	34.3	0.55
			Y	27.5	30.7	35.2	48.0	35.1	35.8	32.4	40.1	
	Total		X	26.7	25.1	23.4	25.0	26.0	25.0	24.2	23.3	–0.19
	Y		47.0	49.3	51.3	51.3	48.7	46.6	41.6	43.1		

moderately-low-tech	Manufacture of coke and refined petroleum products	C19	X	10.0	11.5	12.0	12.4	12.3	12.2	12.1	11.6	0.05
			Y	45.8	50.3	56.2	48.6	57.8	48.0	43.7	45.6	
	Manufacture of rubber and plastic products	C22	X	17.8	14.5	14.7	14.7	14.6	14.7	14.4	13.1	–0.77
			Y	70.0	62.6	59.7	62.5	62.9	62.9	58.5	54.6	
	Manufacture of other non-metallic mineral products	C23	X	19.3	16.5	16.6	16.8	16.3	16.4	15.9	16.0	–0.42
			Y	22.1	23.0	25.2	23.0	20.6	20.4	14.6	11.1	
	Manufacture of basic metals	C24	X	8.9	14.7	14.7	14.9	14.8	15.0	14.4	15.2	–0.70
			Y	30.7	29.8	29.1	24.1	25	23.2	22.4	17.9	
	Manufacture of fabricated metal products, except machinery and equipment	C25	X	20.9	21.9	22	22.4	22.2	22.3	22.0	19.4	0.48
			Y	23.4	27.4	35.1	34.1	32.5	29.5	28.3	28.2	
	Total Y		X	12.1	14.9	15.1	15.4	15.3	15.4	15.2	15.2	–0.56
			34.4	34.4	35.5	31.5	33.0	30.0	27.5	24.4		
low-tech	Manufacture of food products; beverages and tobacco products	C10-12	X	17.2	18.7	18.3	18.4	18.1	18.1	18	19.1	–0.27
			Y	18.0	19.0	17.0	18.6	18.0	18.6	15.5	13.5	
	Manufacture of textiles, wearing apparel, leather and related products	C13-15	X	54.9	54.6	50.8	50.3	50.0	48.6	48.4	47.9	–0.50
			Y	35.5	36.7	31.1	32.0	32.5	31.9	30.8	32.1	
	Manufacture of wood, paper, printing and reproduction	C16-18	X	21.4	22.9	22.3	22.0	21.7	21.7	22.2	21.0	–0.76
			Y	30.6	29.5	27.5	26.4	25.9	25.4	23.0	22.9	
	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-33	X	35.1	36.2	36.5	35.5	36.1	36.3	36.1	35.7	–0.18
			Y	25.3	27.3	25.9	27.3	26.0	25.8	22.4	21.8	
	Total Y		X	20.8	22.0	21.5	21.6	21.6	21.8	22.1	22.2	–0.36
			26.3	27.4	24.3	26.3	25.4	26.3	21.7	19.4		
Total processing industry Y 37.8			X	18.8	19.9	19.6	20.0	19.9	20.0	20.1	20.1	–0.75
			34.6	33.5	32.2	32.1	31.1	27.4	24.7			

X is the share of gross added value (GVA) in the output; Y is the share of imports in costs; R is the correlation coefficient between the share of GVA in output and the share of imports in production costs

Source: authors' calculations based on SSSU (2023)

Table 5. Optimised structure of intermediate consumption of the processing industry of Ukraine, in %

Sector	Processing industry	Code classification of economic activities NACE Rev.2	Actual indicators			Optimised indicators		
			Share of gross added value in output	Domestic component of intermediate consumption (expenditure)	Import component of intermediate consumption (expenditure)	Share of gross added value in output	Domestic component of intermediate consumption (expenditure)	Import component of intermediate consumption (expenditure)
high-tech	Manufacture of basic pharmaceutical products and pharmaceuticals	C21	30.7	62.6	37.4	32.7	68.2	31.8
	Manufacture of computers. electronic and optical products	C26	25.3	58.0	42.0	30.1	63.5	36.5
	Total		29.3	61.4	38.6	32.1	67.0	33.0
medium-high-tech	Manufacture of chemicals and chemical products	C20	10.9	64.8	35.2	15.1	69.2	30.8
	Manufacture of electrical equipment	C27	27.9	52.9	47.1	34.3	58.5	41.5
	Manufacture of machinery and equipment not elsewhere classified	C28	29.9	49.7	50.3	33.9	55.0	45.0
	Manufacture of motor vehicles. trailers and semi-trailers	C29	21.9	37.6	62.4	27.8	43.1	56.9
	Manufacture of other transport equipment	C30	34.3	58.9	41.1	40.9	64.3	35.7
	Total		23.3	55.8	44.2	28.8	60.7	39.3

moderately-low-tech	Manufacture of coke and refined petroleum products	C19	11.6	54.4	45.6	12.9	60.0	40.0
	Manufacture of rubber and plastic products	C22	13.1	44.3	55.7	14.6	49.5	50.5
	Manufacture of other non-metallic mineral products	C23	16.0	88.2	11.8	19.0	90.1	9.9
	Manufacture of basic metals	C24	15.2	81.7	18.3	26.0	82.0	18.0
	Manufacture of fabricated metal products. except for machinery and equipment	C25	19.4	71.0	29.0	21.1	75.9	24.1
	Total		15.2	75.1	24.9	21.1	76.7	23.3
low-tech	Manufacture of food products; beverages and tobacco products	C10–12	19.1	83.6	16.4	23.2	86.8	13.2
	Manufacture of textiles. wearing apparel. leather and related products	C13–15	47.9	51.0	49.0	51.5	56.3	43.7
	Manufacture of wood. paper. printing and reproduction	C16–18	21.0	69.0	31.0	25.1	73.7	26.3
	Manufacture of furniture; jewellery. musical instruments. toys; repair and installation of machinery and equipment	C31–33	35.7	70.8	29.2	40.9	75.8	24.2
	Total		22.2	79.7	20.3	26.5	83.3	16.7
Total processing industry			20.1	74.5	25.5	25.2	77.8	22.2

Source: authors' calculations based on SSSU (2023)

The obtained optimised data show what the level of intermediate consumption (in terms of imported and domestic components of costs) of each of the 16 sectors should be in order to ensure an increase in the share of GVA in their output in order to ultimately achieve the desired level of economic efficiency.

CONCLUSIONS

The study of the interrelationships between the processing industry's economic efficiency and its technological structure (in terms of 16 sectors) has produced important scientific and practical results.

It was established that the authors' hypothesis (tested in previous studies using the example of Poland and Germany) has not been confirmed that there is a high direct correlation between the share of GVA and the share of high- and medium-high-tech industries. On the contrary, in the Ukrainian processing industry during 2013–2020, these indicators had a high but inverse correlation. Such a paradoxical situation is because in Ukraine, during the studied period, under the influence of non-economic factors there was a significant decrease in the share of medium-high-tech industries, with a simultaneous decrease in the share of GVA. Accordingly, the critical influence on efficiency was mainly exerted by low- and medium-tech industries, particularly the food industry and metallurgy. In addition, the authors proved the instability of output in Ukraine in the direction of a decrease in technological level (a sharp decrease in the shares of chemical and machine-building industries). Based on the received analytical information and using the results of previous studies, output and GVA were modelled, under which efficiency will correspond to the indicator for Poland.

Further studies have proved that the authors' hypothesis (substantiated in previous studies using the example of Czechia) that there is a high inverse correlation between the share of imports in the intermediate consumption of high- and medium-high-tech products and the share of GVA was confirmed in Ukraine, but only partially. In the Ukrainian processing industry, there was an inverse but average relationship between these indicators from 2013 to 2020. According to the results of a detailed correlation analysis between import dependence and economic efficiency, several negative features were revealed, particularly the deepening of the import dependence of primary and strategic segments, increasing the volume of production based on raw materials. This has become an additional justification for the need to optimise according to the criterion of reducing the import dependence of all industries, but, above all, in medium-high-tech. Based on this criterion, using the authors' methodological toolkit and the experience of previous work, such a structure of intermediate consumption (in terms of imported and domestic components of costs) was modelled, for which the indicator of the share of GVA in output would correspond to the level in Poland.

The main results of the research, in particular, substantiated hypotheses and analytical conclusions, contribute to theoretical approaches to solving the problems of industrial development in countries with a transition economy. In addition, when modelling results, deterministic models and methodological approaches are practical means for forecasting and planning socio-economic efficiency, product innovation and import dependence. In optimising the processing industry, a methodical approach to modelling structural parameters and industrial efficiency can be helpful in an applied and informational toolkit for use in strategies for the economic development of the Ukrainian industry.

Further research in this direction will aim to develop models for optimising the structure of Ukrainian industry, with the criteria of increasing the innovativeness of industrial production and ensuring socio-economic development.

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