

STRUCTURAL CHANGES IN THE EXPORT OF MECHANICAL ENGINEERING OF UKRAINE UNDER THE IMPACT OF FOREIGN ECONOMIC POLICY TRANSFORMATION

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Abstract. The *objective* of this article is to evaluate the structural changes that have occurred in the export of mechanical engineering from Ukraine. These changes have been influenced by significant transformations in the country's foreign economic policy, which have been primarily caused by a shift in the country's foreign policy as a result of military aggression from Russia, which has been a leading foreign trade partner for a considerable period of time. *Methodology.* The study is based on the authors' previous works, which are devoted to the study of the features of the export-oriented development of the country and the industry. In particular, the studies examine the strengthening of the innovative component in the export potential and the formation of mechanisms and strategies for ensuring the development of exports on a high-tech basis. The methodological basis of this work was also formed by the scientific studies of leading Ukrainian and foreign researchers devoted to the development of the export of mechanical engineering, problems and prospects of the industry in the implementation of foreign economic activity. In order to calculate structural changes in exports, a generalised methodology has been developed based on the systematisation of scientific papers that outline different approaches to assessing structural changes and disproportions. The main content of the proposed methodology is to form a system of indicators that allow for a comprehensive assessment of structural changes in the exports of a particular industry. To calculate and test the methodology, open statistical data on exports of mechanical engineering products were used. *Results.* The research findings indicated that, despite the pivotal role of the mechanical engineering sector in the national economy, the sector's performance in Ukraine has exhibited a discernible negative trajectory in terms of overall production and sales volumes, export volumes, and the patterns of expansion observed in export operations. In Ukraine, the contribution of mechanical engineering to the national economy is 8%, whereas in industrialised countries, this figure ranges between 30 and 50%. The long-term orientation of mechanical engineering enterprises towards the conventional Russian market has not provided the impetus for the innovative development of such enterprises. Objective changes in Ukraine's foreign economic policy related to Russia's military invasion have created a field of uncertainty for mechanical engineering companies. The search for partners in new foreign markets was rather slow and not always effective. All this led to structural changes in the export of mechanical engineering products. Calculations have shown the existence of imbalances in the structure of exports of mechanical engineering products. In particular, for a long time there was a predominance of heavy engineering products. Conversely, the calculations demonstrated that products with competitive advantages in foreign markets account for a relatively minor proportion of exports. This provides a rationale for a shift in strategy with regard to the expansion of exports in the mechanical engineering sector, with a focus on the increased export of competitive high-tech products. *Practical implications.* A complex of indicators was employed to calculate the structural changes in the export of mechanical engineering. This enabled the identification of those priority groups of mechanical engineering products with the greatest export potential. *Value / Originality.* The developed methodological approach, which integrates a set of indicators for the analysis of structural changes in exports, provides a foundation for the

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formulation of management decisions and the development of export strategies for the advancement of mechanical engineering enterprises within the context of an export-oriented economic model.

Keywords: structural changes, export, mechanical engineering, foreign economic policy, transformation.

JEL Classification: F13, L62, L63, O12, O24

1. Introduction

The transformations that occurred in Ukraine's foreign economic policy over the past two decades have, at times, exhibited a polar character, which has had a considerable impact on the formation of the country's economic potential, its renewal and development based on an export-oriented economic development model. The export-oriented model defined in regulatory acts was frequently merely formal and not fully implemented. The industries that could form the basis of such a model underwent corresponding structural changes in production and export.

In the context of the formation of post-industrial society in Ukraine, the development of export activities of industrial enterprises necessitates alterations to conventional mechanisms of enterprise subsystems, with due consideration given to the disorder of economic development, erratic and poorly predicted changes in the external environment (Dunska and Zhaldak, 2021).

A comparative analysis of the experiences of different countries reveals that those that have adopted an export-oriented economic development model have primarily focused on high-tech exports, which have provided tangible competitive advantages in the global market. However, an analysis of the statistical data reveals that in 2021, the structure of Ukraine's GDP was dominated by the wholesale and retail trade sector, which accounted for 13.6% of the total GDP. The second largest contributor to GDP was the agriculture, forestry and fishing sector, which accounted for 10.89% of the total GDP. The processing industry, on the other hand, accounted for only 10.28% of the total GDP, ranking third in terms of GDP contribution. The structure of the national economy is thus reflected in the structure of the country's exports. In 2021, the largest share of exports in the overall structure was comprised of ferrous metals (20.5%), grain crops (18.1%), fats and oils of animal or vegetable origin (10.3%), and engineering products constituted only the fourth largest export category, accounting for 8% of Ukraine's total exports.

The year 2022 commenced with a series of perilous and crisis-inducing external factors, most notably the onset of a comprehensive military conflict. This resulted in active hostilities, particularly in regions with substantial export potential, encompassing not only the processing industry but also a diverse range of other economic activities. Concurrently, augmented reliance on partner countries constrained

the provision of support for trade operations. Consequently, in 2022, the primary sector of Ukraine's GDP remained dominated by wholesale and retail trade, with a combined contribution of 641.7 billion UAH and 12.36%, respectively. Nevertheless, the agricultural and processing industries suffered a decline in their respective positions due to the military actions that took place on Ukrainian territory. The resulting losses amounted to 426.8 billion UAH, representing 8.22% of the agricultural sector, and 393.3 billion UAH, or 7.58% of the processing industry. In terms of the country's export structure, the primary commodity was cereals, accounting for 20.6% of exports. This was followed by fats and oils of animal or vegetable origin (13.5%), ferrous metals (10.3%), and engineering products (8.8%).

In the absence of consideration of the year 2022 and the deformation of the country's economic structure due to military actions, it can be observed that during the last decade the structure of Ukraine's GDP and exports remained almost unchanged. It is notable that the leaders of exports are still not high-tech industries, but raw materials exports. As evidenced by statistical data, the proportion of enterprises integrating new technologies into their production processes is on the decline. In 2019, this figure stood at 13.8%, a figure that falls below the average for EU countries, which stands at 51%. Moreover, the proportion of innovative products in the total product volume is a mere 1.3% (based on 2019 data).

In this context, it is worthwhile to consider the potential of the mechanical engineering industry, which has historically been a cornerstone of the Ukrainian economy. This sector has the capacity to serve as a foundation for an export-oriented economic model, given its production of a diverse range of high-tech products for industrial and final consumption, including for export.

The objective of the presented research is to elucidate the substantial transformations that have shaped the export landscape of the mechanical engineering industry and to assess the structural shifts that have occurred in response to alterations in foreign economic policy through the utilisation of a set of calculated indicators. The objective will be met by pursuing a series of research tasks, including: an examination of the dynamics of key indicators within the mechanical engineering industry of Ukraine, both in aggregate and in terms of specific product groups; a comparison with leading global markets; an identification of the most notable shifts in

foreign economic policy; the establishment of a methodological foundation for assessing structural shifts in mechanical engineering exports; and the implementation of diagnostics of structural changes based on the aforementioned methodology.

The general export orientation of the economy has a positive impact on the level of competition, the introduction of innovations and the growth of innovative activity. In the context of the international division of labour, Ukraine has established itself as a participant in accordance with the available natural and geographical features and socio-economic conditions. Nevertheless, at the current stage of economic development, these factors are gradually acquiring decisive importance. These were supplanted by a range of scientific and technological factors that domestic enterprises are unable to ignore. The aforementioned transformations reinforce the necessity to examine the substance of export-oriented enterprise development (Dunska and Bondar, 2020).

2. Analysis of Mechanical Engineering in the Structure of the Ukrainian Economy

The field of mechanical engineering is a highly sophisticated and diverse sector of industry. Its growth and advancement are contingent upon the cutting-edge discoveries of science and the ingenuity of innovation. In addition to developing finished products for the end consumer, mechanical engineers also create the means of production that facilitate technological processes in other industrial sectors.

It can be stated that the mechanical engineering complex forms the basis of the country's economy and its defence potential. This is due to the fact that mechanical engineering enterprises ensure the processes of automation, technical armament and mechanisation of the national economy.

In order to evaluate the role of mechanical engineering in the Ukrainian economy, it is necessary to consider the data provided by the State Statistics Service of Ukraine. This data indicates that in 2021, a total of 1,956,320 enterprises were operational within the Ukrainian economy. Of these, 610 were classified as large, 17,502 were medium-sized, and 35,772 were small. In comparison to preceding years, a consistent trajectory towards an expansion in the number of large enterprises and a modest decline in the aggregate size of medium and small enterprises can be discerned. Nevertheless, in 2021, the level of enterprises operating in Ukraine was still below that observed in 2013. Following this, a consistent downward trend in the total number of operating enterprises was noted over several years.

In the year 2021, a total of 7,505 enterprises were engaged in the mechanical engineering industry. Of these, 22 were classified as large-scale operations,

686 were identified as medium-sized enterprises, and the remaining enterprises were categorised as small-scale. Consequently, the proportion of large and medium-sized enterprises within the mechanical engineering sector is 3.61% and 3.92%, respectively.

The geographical distribution of mechanical engineering enterprises is illustrated in Figure 1. As illustrated in Figure 1, mechanical engineering enterprises are dispersed throughout the country. However, the highest concentration is observed in regions that are under temporary occupation or significantly affected by shelling due to their proximity to areas of hostilities.

The dynamics of sales volumes of industrial products in Ukraine in general and in the mechanical engineering sector in particular is shown in Figure 2.

The data presented clearly demonstrate that the proportion of mechanical engineering products within the total volume of industrial products sold in Ukraine is relatively low (at a level of 5-8%) and that, over a certain period of time, there has been a tendency for this figure to decrease. In contrast to Ukraine, the proportion of products from mechanical engineering enterprises in the total volume of product sales in industrialised countries is at least 30-50%.

Fluctuations in mechanical engineering exports are shown in Table 1 and Figure 3.

Mechanical engineering represents a pivotal sector within the industrial landscape, playing a pivotal role in ensuring the sustained advancement of technical capabilities. This industry is distinguished by its high added value, which is why considerable attention is devoted to the advancement of engineering enterprises in the economies of technologically advanced countries. A statistical analysis revealed that in economically developed countries, mechanical engineering serves as the foundation for industrial advancement, facilitating the technical re-equipment of the entire production process on a 10-year cycle. Consequently, the proportion of mechanical engineering in the overall production structure of Germany is 53.6%, in comparison to Japan at 51.5% and China at 35.2%. The global leaders in the mechanical engineering industry are China, Germany, the USA, and Japan, which are also in the top five for the majority of other mechanical engineering branches (Bondar, 2018).

Chinese companies are the predominant exporters of approximately half of the world's engineering products, while they have collectively occupied almost a quarter of the relevant markets over the past ten years. A comparative analysis of Ukraine's engineering product export performance vis-à-vis the world's leading exporters (China, the USA and Germany) is presented in Figure 4.

The share of Ukrainian exports of machinery in the structure of global exports of these products is insignificant. In the export of nuclear reactors and

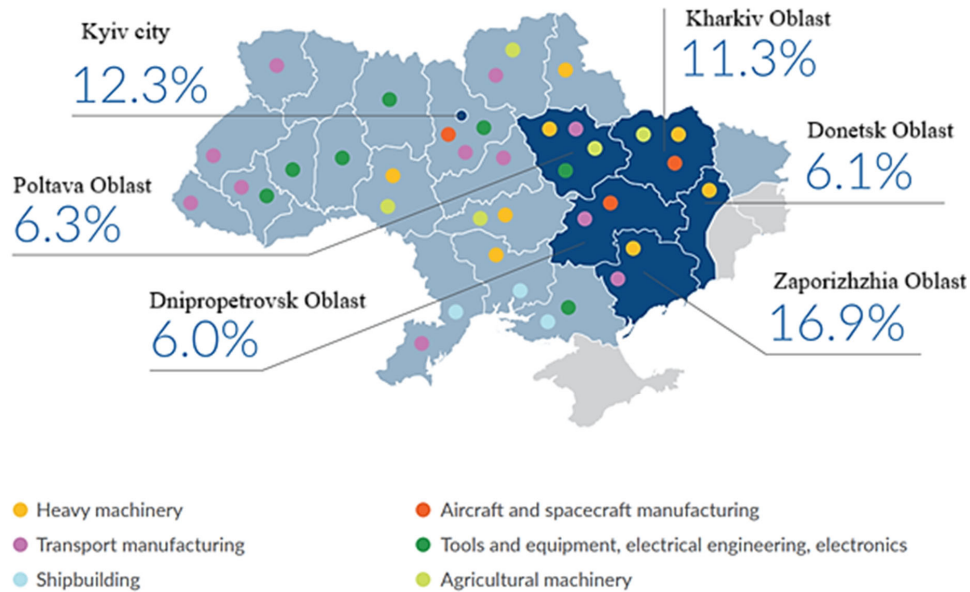


Figure 1. Breakdown of sales of mechanical engineering products by oblast of Ukraine, %
 Source: Ministry of Economy of Ukraine, 2020

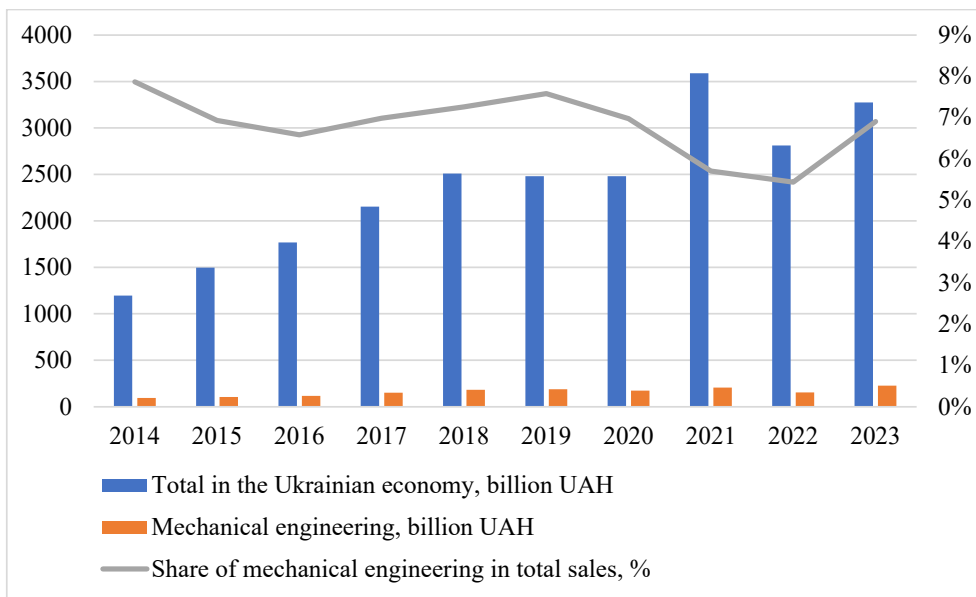


Figure 2. Volume of mechanical engineering products sold
 Source: compiled by the authors using data from the State Statistics Service of Ukraine

boilers, the share of Ukrainian goods has remained at 0.1% over the past 10 years, reaching 0.2% in 2012-2013, in electrical equipment – 0.1%, in aircraft – remained at 0.1% until 2015, after which it declined significantly, in vessels – 0.1%, falling from the level of 0.2% after 2012. In the field of land transport equipment, the proportion of exports from Ukraine is approaching zero. In the field of railway locomotives, until 2013, Ukraine was among the top five exporters globally, but currently exports have fallen to 0.3% in 2022, having risen to a level of 1.4-1.2% in 2019-2020.

In comparison to the global leaders in the field, the mechanical engineering sector in Ukraine has been one of the industries to experience a period of decline over the past few years. Notwithstanding the decline in export activity, the range of products remains sufficiently extensive to ensure that there are industries whose products continue to enjoy significant demand abroad.

Over the past few years, there has been a sharp decline in both mechanical engineering production and exports.

Table 1

Production dynamics of the mechanical engineering industry of Ukraine

Year	Sales volume of mechanical engineering products					From it the volume of exported products	
	million UAH	in % to the total sales volume	among them enterprises			million UAH	in % to the total sales volume of mechanical engineering products for the year
			large	middle	small		
2011	150112,9	3,761%	61,183%	34,114%	4,703%	94779,1	63,1%
2012	164236,6	3,907%	59,160%	35,608%	5,233%	106139,2	64,6%
2013	130730,4	3,228%	52,932%	39,776%	7,292%	84789,7	64,9%
2014	113141,9	2,713%	43,003%	49,154%	7,843%	87495,4	77,3%
2015	128497,2	2,491%	36,768%	52,684%	10,549%	104308,8	81,2%
2016	150027,8	2,405%	30,494%	57,518%	11,988%	110806,8	73,9%
2017	183446,6	2,380%	26,876%	60,425%	12,699%	134364,8	73,2%
2018	218212,5	2,370%	32,066%	54,283%	13,651%	14877,4	6,8%
2019	233412,5	2,421%	40,223%	47,995%	11,782%	142818,6	61,2%
2020	215145,4	2,141%	29,422%	56,712%	13,866%	145685,8	67,7%
2021	256710,1	1,885%	29,393%	55,117%	15,490%	169114,8	65,9%

Source: compiled by the authors using data from the State Statistics Service of Ukraine

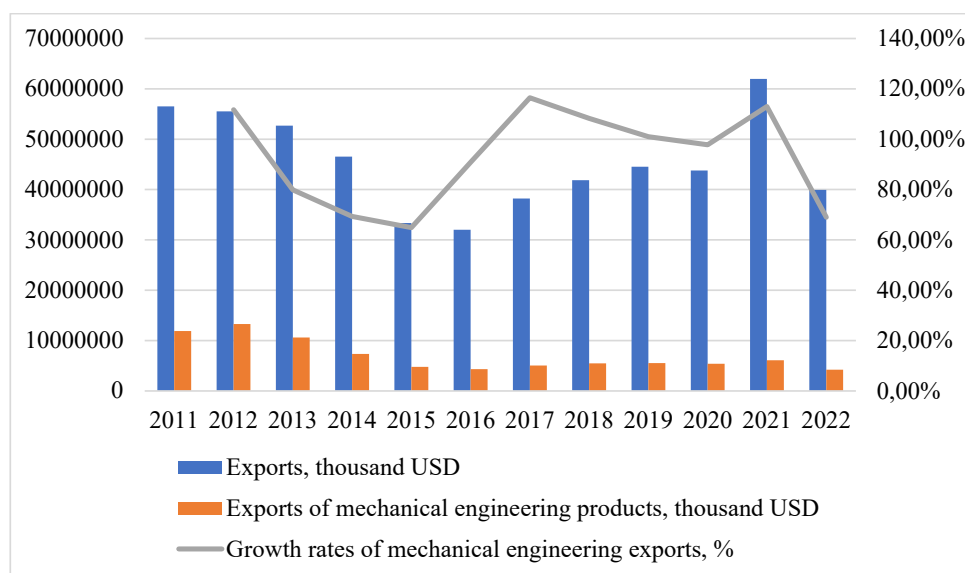


Figure 3. Share of mechanical engineering products in Ukraine's exports

Source: compiled by the authors using data from the State Statistics Service of Ukraine

3. Transformational Changes in the Exports of the Mechanical Engineering Sector of the Ukrainian Economy

In this context, it is important to investigate which factors harm mechanical engineering enterprises, deepening crises.

From the perspective of integrating the Ukrainian economy into the European and global economic landscape, the most pivotal factor is globalisation. Some researchers (e.g., Wang X, Meng W, Wang C, Huang B, Li Y, 2022) have concluded that the exports of developing and non-EU countries are more affected by reverse globalization than those of developed countries and EU countries. The phenomenon of reverse globalisation exerts a considerable inhibitory influence on export trade.

The majority of research in this field has concentrated on identifying the factors that have a detrimental impact on the general state of domestic engineering. The most significant factors, as identified by scientists (Kudria, 2014; Danylyshyn, 2013; Moroz, Karachyna and Balzan, 2015), are as follows:

- Inefficient use of resource potential;
- structural disproportions in the economy of Ukraine;
- high energy intensity of production;
- morally and physically outdated production facilities;
- the imperfection of the domestic financial services market, which makes it difficult for enterprises to obtain the necessary funds for technical re-equipment;
- the gap between research institutions and real industry enterprises in terms of implementing advanced technologies and know-how.

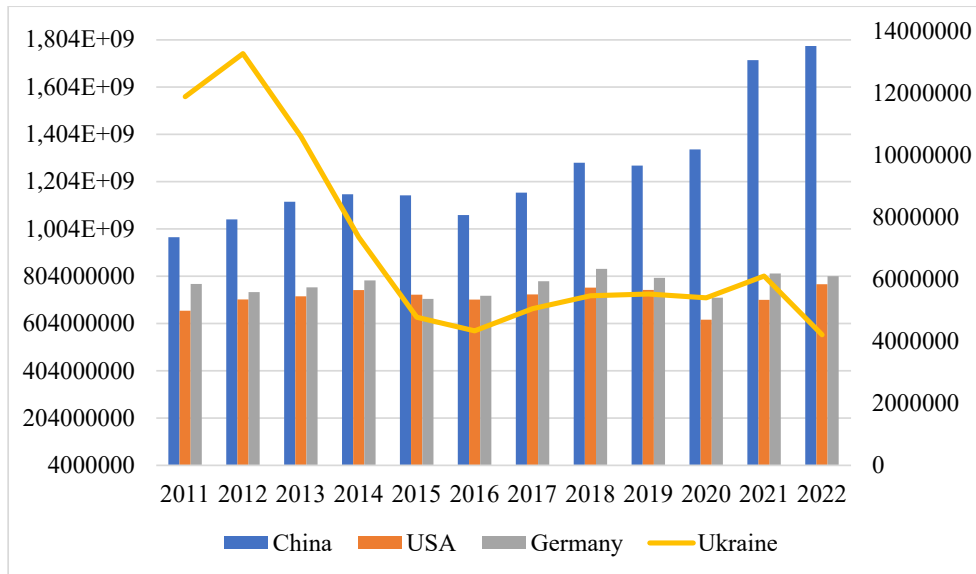


Figure 4. Comparison of total exports of mechanical engineering products of the top 3 exporting countries and Ukraine (Ukraine on the auxiliary axis)

Source: compiled by the authors

In the work (Lukianenko, 2024), it is observed that the adverse developments in the field of mechanical engineering in Ukraine can be attributed to the impact of the ongoing state of war, which serves to exacerbate the prevailing economic crisis and accentuate the existing disparities in the advancement of this industry within Ukraine.

In alignment with the perspectives espoused by the aforementioned researchers, this study posits that the most pivotal shifts in foreign economic policy, which exacerbate the adverse factors enumerated above and precipitate structural transformations within the industry, are the deterioration of relations with Russia in 2014 and the comprehensive armed conflict of 2024.

Prior to 2014, Ukrainian mechanical engineering enterprises had concentrated their efforts on the Russian market. However, following the annexation of Crimea and the commencement of military operations in the Donetsk and Luhansk oblasts, these enterprises were compelled to make a pivotal decision to reorient their focus towards new foreign markets.

In addition, since 2013, there has been a trend for mechanical engineering enterprises to specialise not only in the production of engineering products, but also in military products. The re-profiling of production led to the creation of new equipment that had not been produced in Ukraine before: passenger cars, diesel and electric train cars, electric locomotives, continuous casting machines, some types of pumps, valves, compressors, etc.

Since 2014, there has been a notable reduction in the export of specific categories of engineering products. The underlying causes of this decline can be attributed to three key factors: the disruption

of traditional trade relations between Ukrainian enterprises and their Russian counterparts, the impact of military actions in eastern Ukraine on the operational capacity of certain mechanical engineering enterprises, and the prevailing political instability in the country. At that time, the reorientation of enterprises to European markets was gradual, which can be attributed to the low competitiveness of their products.

Similarly, the growth rate of exports of engineering products has increased by more than 100% since 2017. The global crisis in the processing industry, and in Ukraine in particular, has also affected the development of exports, with the growth rate of exports of the mechanical engineering complex reaching -2.19% in 2020, a consequence of the impact of the pandemic.

Exports of electrical machinery and equipment, where the main importing countries remained unchanged and exports declined by an average of 10%, were the least affected by the hostilities in Ukraine.

The export of nuclear reactors and boilers, in addition to electrical products, represents the primary source of foreign currency in the domestic engineering sector. Their contribution to the total export of Ukrainian products is 2.67% and 5.79% in 2022, 4.8% and 7.11% in 2021, respectively. In comparison to the figures for 2011, the export of railway locomotives has decreased considerably (from representing 8.62% of Ukraine's total exports to 0.33% in 2022 and 0.65% in 2021). Table 2 and Figure 5 illustrate the structure of exports of domestic mechanical engineering products over the past 10 years.

The dynamics of exports to the main partner countries is shown in Figure 6.

Table 2

Structure of Ukrainian exports of mechanical engineering products

Year	Total exports from Ukraine, million USD	Export of engineering products, million USD	% of mechanical engineering products in the total export structure of Ukraine	Export structure of mechanical engineering						
				nuclear reactors, boilers, machines	electric machines	railway locomotives	land transport, excluding rail transport	air transport	vessels	optical and photographic instruments and equipment
2011	68394,2	11892	17,39	30	26,8	32	5,3	2,7	0,8	2,3
2012	68809,8	13284	19,31	28,6	24,3	30,9	4,4	7	2,6	2,2
2013	63312	10612	16,76	36,2	29,5	23,2	3,5	3	1,8	2,8
2014	53901,7	7358,7	13,65	40,5	36,4	11,4	4	3,3	1,3	3,1
2015	38127,1	4776	12,53	41,1	41,4	4,4	3,7	4	2,1	3,3
2016	36361,7	4336,9	11,93	36	47,9	5,5	3,1	1,8	2,5	3,3
2017	43234,7	5051,3	11,68	34,2	50,5	4,3	2,6	0,6	4,8	2,9
2018	47335	5469,6	11,56	31,5	53,6	4,6	2,5	1,1	4	2,7
2019	50054,6	5524,9	11,04	30,6	50,2	9,9	2,5	1,3	2,3	3,2
2020	49191,8	5403,8	10,99	35,4	47,6	7,7	2,1	1,5	2,6	3
2021	68072,3	6105,2	8,97	34,7	51,4	4,7	2,7	7,1	2,5	2,8
2022	44148,8	4214	9,55	27,9	60,7	3,5	3,2	0,6	1,5	2,8

Source: compiled by the authors using data from the State Statistics Service of Ukraine

The geography of the countries that import Ukrainian mechanical engineering products is undergoing a gradual transformation. In 2021, Hungary was the primary importer of domestic engineering products, with an estimated value of 997.3 million USD. The majority of exports are electrical products, with a value of 961 million USD. Since 2019, Hungary has been the primary importer of mechanical engineering products, having overtaken exports to the Russian Federation, which remained at a high level even after 2014. In recent years, exports to Germany, Poland and the USA have demonstrated a consistent upward trajectory, reaching levels comparable to those observed in 2012.

In recent years, the principal importing countries have remained consistent across the majority of sub-branches within the mechanical engineering sector. In the field of nuclear reactors, boilers and their parts, the leading exporters are Russia, China and Germany. There has been a slight decline in exports to Belarus. In the field of electric machines, the leading exporters are Hungary, Germany, Poland, and the Czech Republic. With regard to the field of railway locomotives, the main exporting countries are Belarus and Russia. In addition, there has been a diversification of sales to the European and USA markets. Before the full-scale invasion, most of Ukraine's land transport (except for railways) was exported to Russia, Poland, and Belarus, and exports to European countries (Poland, Germany, and the Czech Republic) are growing. In the field of aircraft, there has been a certain reorientation from the markets of Kazakhstan and Pakistan to the markets of India, the United States, and the United Arab Emirates.

In 2021, the Netherlands became the leader in the shipbuilding industry, but a high share of exports was directed to Russia and Norway. It is difficult to identify certain trends in this group of goods, as the main market players and their needs change every year.

4. Calculation of Indices of Structural Changes in Ukrainian Exports of Mechanical Engineering Products

The aforementioned systematization of data on the export of mechanical engineering products constituted the foundation for a more comprehensive investigation into structural alterations in exports, employing a set of calculated indicators. The aforementioned indicators comprise the quadratic coefficient of "absolute" structural shifts, the Salai index, the Gatev index, the Ryabtsev index, and indices of the comparative advantages of the various branches of the mechanical engineering sector (Figure 7).

The quadratic coefficient of "absolute" structural shifts illustrates the percentage dynamics of the deviation of the specific weight of structural elements from one another in a given population over a specified period. The scale of measurement of structural shifts according to this coefficient is divided as follows: minor structural shifts are those of less than 2%, significant structural shifts are those of between 2 and 10%, and large structural shifts are those of more than 10% (Kolomytseva, 2011; Romanova, 2018). The coefficient is calculated according to Formula 1 (Romanova, 2018):

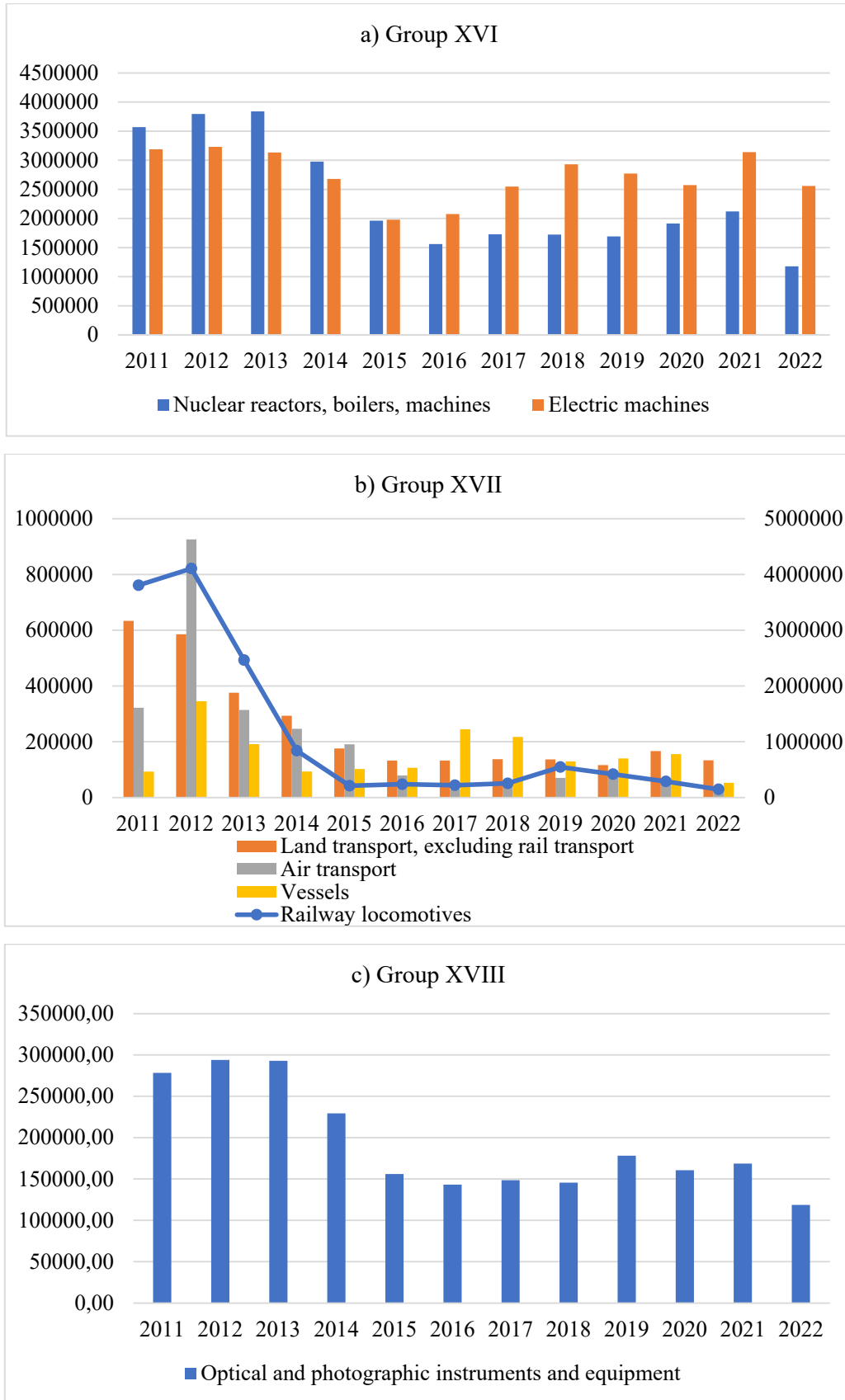


Figure 5. Dynamics of exports of mechanical engineering products in Ukraine, thousand USD
 Source: compiled by the authors

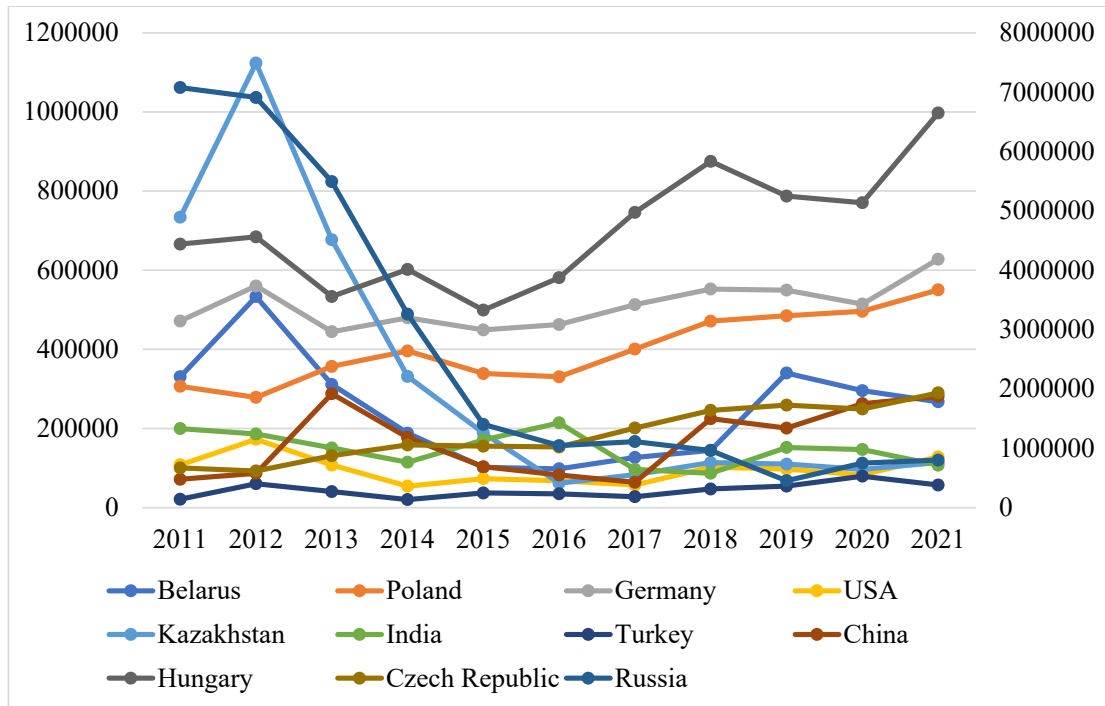


Figure 6. Major importing countries of Ukraine's mechanical engineering products, thousand USD (with Russia on the auxiliary axis)

Source: compiled by the authors

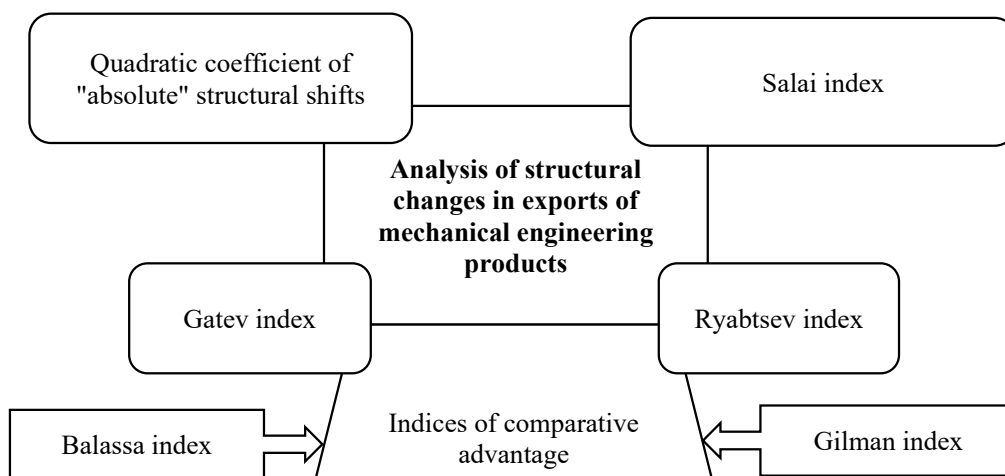


Figure 7. Indicators for assessing structural changes in exports of mechanical engineering products

Source: developed by the authors

$$K_{kv,A} = \sqrt{\frac{\sum (d_{ij} - d_{ij-1})^2}{n}} \quad (1)$$

where $K_{kv,A}$ is the quadratic coefficient of "absolute" structural changes;

d_{ij} is the share of the i -th element of the structure in the j -th period;

d_{ij-1} is the share of the i -th element of the structure in the period preceding the j -th;

n is the number of gradations in structures.

In order to ascertain the materiality of structural alterations, the Gatev integral coefficient is calculated. This enables the materiality of structural discrepancies to be evaluated in a relative manner, taking into account the intensity of modifications in specific structural elements and changes in their relative importance within the general population under investigation (Romanova, 2018). The calculation is made according to Formula 2:

$$K_{Gatev} = \sqrt{\frac{\sum (d_1 - d_0)^2}{\sum d_1^2 + \sum d_0^2}} \quad (2)$$

where K_{Gatev} is the integral coefficient of Gatev;

d_0 is the specific weight (share) of the structural element in the aggregate in the base period;

d_1 is the specific weight (share) of a structural element in the aggregate in the current period.

In contrast to the Gatev index, the Salai index considers not only the magnitude of structural shifts but also the number of indicators, thereby enhancing the precision of its values. As the Salai index, in addition to measuring the intensity of structural shifts, also accounts for the number of indicators, resulting in more accurate values, slightly different outcomes were observed. However, the discrepancy between these values is also insignificant, as seen in the Gatev index (Orlov, 2022). The coefficient is calculated according to Formula 3:

$$K_{Salai} = \sqrt{\frac{\sum (d_1 - d_0)^2}{(d_1 + d_0)^2 n}} \quad (3)$$

where K_{Salai} is a generalised indicator of structural changes Salai;

d_0 is the specific weight (share) of the structural element in the aggregate in the base period;

d_1 is the specific weight (share) of a structural element in the aggregate in the current period;

n is the number of gradations in structures.

The Ryabtsev index is defined as the actual difference between the values of two structures with their maximum permissible value. This allows for the analysis of deviations from the normalised development of the structure (Orlov, 2022). Calculated by Formula 4:

$$K_{Ryabtsev} = \sqrt{\frac{\sum (d_1 - d_0)^2}{\sum (d_1 + d_0)^2}} \quad (4)$$

where $K_{Ryabtsev}$ is the Ryabtsev Index;

d_0 is the specific weight (share) of the structural element in the aggregate in the base period;

d_1 is the specific weight (share) of a structural element in the aggregate in the current period.

To compare the structure of exports of machine building products by Ukrainian enterprises, the above indicators were calculated for the period from 2011 to 2022. The results of the calculations are shown in Table 3.

The quadratic coefficient of absolute structural shifts demonstrates the percentage dynamics of the deviation of the specific weight of structural elements from one another within a given population. A value of less than 2% indicates the presence of minor structural shifts, while a range of 2% to 10% denotes significant structural shifts, and a value exceeding 10% signifies major structural shifts (Romanova, 2018). The calculations demonstrate that during the period under study, only in 2016-2018 and 2020-2021 were structural shifts in the export of mechanical engineering insignificant. The range of changes in the quadratic coefficient of absolute structural shifts is also illustrated in Figure 8.

In order to interpret the Ryabtsev index, a scale has been developed for assessing the degree of significance of structural differences (Popova, Koval, 2017). The aforementioned scale indicates that the structure of mechanical engineering exhibited a notable degree of divergence in the 2019-2020 period, whereas in all other years, this divergence was either significant or very significant. This finding is corroborated by the correlation between the scale's observations and the values of the quadratic coefficient of absolute structural shifts.

It can be observed that there is a positive correlation between the values of the Gatev and Ryabtsev indexes and the degree of homogeneity in the structure of exports. A comparison of the dynamics of the indicators of structural shifts (Figure 9) reveals that the export structure of domestic engineering is disproportionate once more. This is explained

Table 3

Dynamics of structural changes in exports of mechanical engineering products of Ukraine for the period from 2011 to 2022

	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Quadratic coefficient of absolute structural change	2,13%	4,82%	5,42%	3,29%	3,24%	1,63%	1,61%	2,48%	2,22%	1,88%	4,41%
Gatev index	0,056	0,128	0,143	0,087	0,086	0,043	0,043	0,066	0,059	0,050	0,117
Salai index	0,266	0,194	0,156	0,198	0,158	0,239	0,130	0,174	0,073	0,122	0,183
Ryabtsev index	0,704	0,514	0,414	0,524	0,417	0,633	0,345	0,460	0,194	0,322	0,485

Source: calculated by the authors

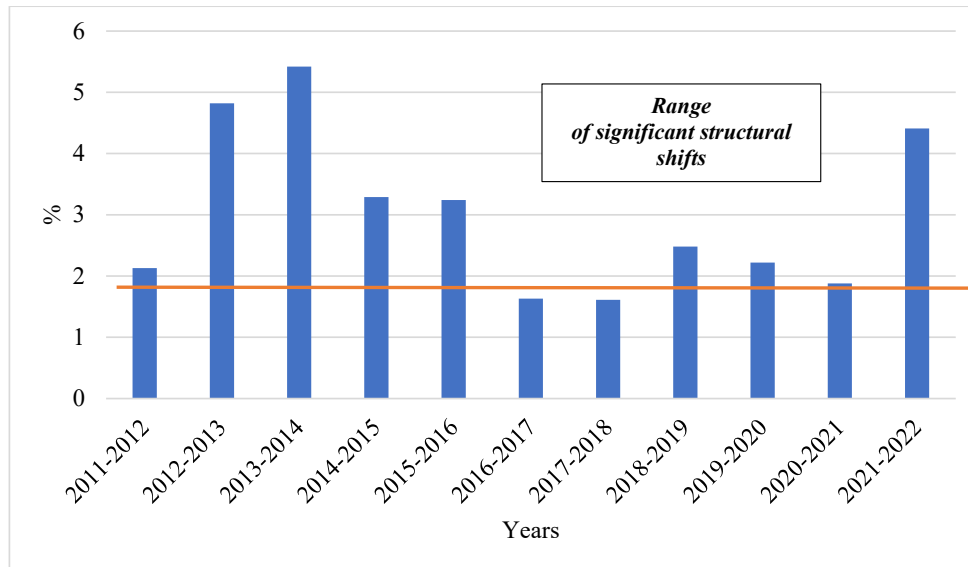


Figure 8. Range of changes in the quadratic coefficient of absolute structural changes
 Source: compiled by the authors

by the fact that the export value of groups 84 and 85 is many times higher than that of all other groups. The gradual increase in indicators observed since 2022 is a consequence of the significant reduction in the export of heavy engineering. This indicates a partial levelling of the structure.

In order to examine the competitive advantages of all branches of mechanical engineering on the international market, the index of comparative advantages (Balassa index) was calculated in accordance with Formula 5 (Orlov, 2018).

$$RCA_i = \frac{X_{ij} / X_{rj}}{X_{iw} / X_{rw}} \quad (5)$$

where X_{ij} is the total export volume of a country's commodity group;

X_{rj} – the country's total exports;

X_{iw} is the total volume of exports of the commodity group by all countries of the world;

X_{rw} is the total volume of world exports.

The index indicates that a country has a comparative advantage in the export of a product or product group if its share of the world export of that product exceeds the country's total export share in the world export. A country is said to have a comparative advantage in the export of goods if the value of the relevant indicator exceeds 1, and is said to have a strong

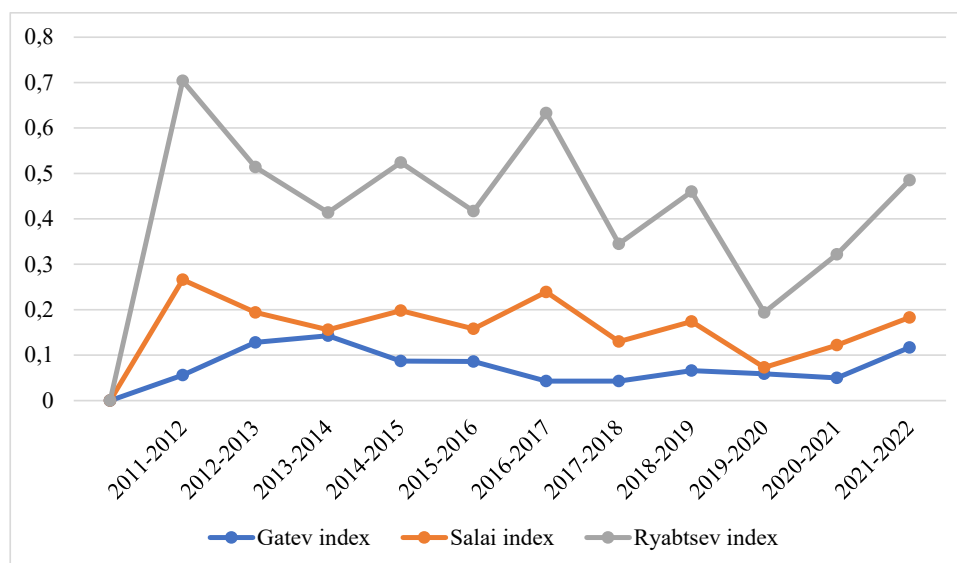


Figure 9. Dynamics of the values of indicators characterising structural changes in the export of mechanical engineering products of Ukraine in 2011-2022
 Source: compiled by the authors

comparative advantage if the value of the indicator exceeds 5. The Balassa index value for Ukrainian engineering products on the global market is presented in Table 4 and Figure 10.

The calculations demonstrate that Ukraine has comparative advantages in the export of railway locomotives and their parts. However, prior to 2015, Ukraine exhibited robust competitive advantages within this category. Nevertheless, this indicator has since exhibited a gradual decline. The lowest figures for the year 2022 are observed in the fields of land transport and aircraft.

An indicator of the adequacy of the index of comparative advantage of exports is the Gilman index (Formula 6):

$$1 - \frac{X_{ij}}{X_{iw}} > \frac{X_{ij}}{X_{rj}} \left(1 - \frac{X_{rj}}{X_{rw}} \right) \quad (6)$$

Should this inequality be fulfilled, the Balassa index will undergo a change determined by the rate of change in the country's export volumes.

For all product groups, the calculated values of the Gilman index meet the inequality condition (formula 6), as shown in Table 5.

The first place in the exports of nuclear reactors and boilers is occupied by engines, mainly turbojets, which generate the bulk of revenue. Exports peaked in 2012-2013. The sharp decline in exports of this type of product was due to the Russian Federation (where it was used for military purposes) and the suspension of shipments to Iran. But in 2015, producers entered the Indian market.

Sales of pumps are in second place. China and Uzbekistan are the leading importing countries. These products have been on the market for a long time, so competition is particularly strong here. Sales to the EU countries remain stable, which is

Table 4

Index of comparative advantages of mechanical engineering product groups in Ukraine for 2011-2022

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nuclear reactors, boilers, machines	0,459	0,492	0,553	0,489	0,440	0,365	0,340	0,309	0,286	0,325	0,277	0,254
Electric machines	0,397	0,399	0,409	0,399	0,370	0,398	0,410	0,435	0,384	0,329	0,300	0,389
Railway locomotives	23,578	24,767	18,324	6,823	2,369	3,202	2,374	2,503	5,190	4,278	1,698	1,602
Land transport, excluding rail transport	0,132	0,120	0,083	0,073	0,057	0,043	0,037	0,037	0,034	0,032	0,036	0,045
Air transport	0,338	0,857	0,296	0,265	0,249	0,103	0,036	0,074	0,078	0,133	0,094	0,059
Vessels	0,129	0,578	0,400	0,223	0,292	0,338	0,728	0,672	0,402	0,470	0,413	0,237
Optical and photographic instruments and equipment	0,139	0,142	0,156	0,140	0,124	0,117	0,104	0,097	0,109	0,097	0,080	0,099

Source: calculated by the authors

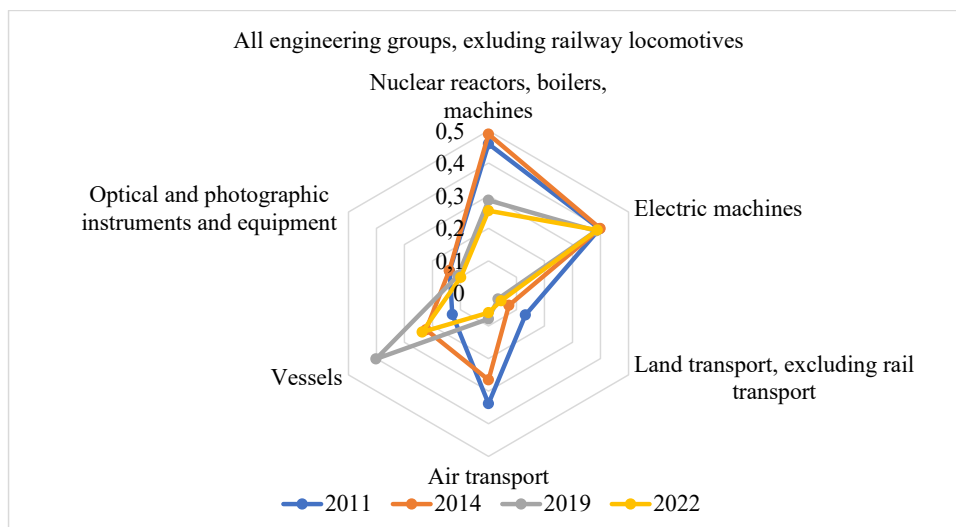


Figure 10. Graphical representation of the index of comparative advantage of mechanical engineering groups in 2011-2022

Source: compiled by the authors

Table 5

Gilman index by product groups of mechanical engineering in Ukraine in 2011-2022

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nuclear reactors, boilers, machines	37,54	32,17	25,75	29,63	27,50	25,08	23,32	19,46	18,13	16,51	18,17	19,20
Electric machines	17,28	21,73	19,16	18,09	16,18	17,00	17,53	19,29	20,15	20,24	21,34	21,49
Railway locomotives	300,37	235,79	116,43	90,64	186,07	196,29	152,15	180,27	63,15	24,20	15,26	16,43
Land transport, excluding rail transport	331,12	409,92	425,43	367,58	345,11	326,84	275,06	217,59	184,41	169,09	117,92	108,33
Air transport	1663,55	1030,51	601,80	715,16	777,11	1493,94	461,55	200,35	219,33	202,31	74,37	213,06
Vessels	842,91	438,40	351,71	386,81	217,97	177,07	342,09	373,99	578,25	331,98	199,72	739,59
Optical and photographic instruments and equipment	372,77	404,84	307,12	281,70	325,84	291,82	254,34	244,89	235,54	216,74	234,91	246,62

Source: calculated by the authors

not enough to offset the negative impact of the loss of a part of the Russian market.

Bearing exports are in third place. Here, the situation has not changed relatively, as the role of Russian companies is not that significant.

The export of electrical products is based on the export of automotive wire. Companies in this sector account for about 50% of export revenues for all electrical products. Most of the products are exported to Europe, so the dynamics are more stable than in other industries with low growth rates, and a significant number of exporting companies are European branches of large concerns. Sales of electrical products are growing from year to year, but account for a small share of the total.

It is also noteworthy that the export of mechanical engineering products for agricultural purposes has constituted a long-standing specialisation of Ukrainian enterprises. Historically, the enterprises of this industry were associated with buyers from the CIS countries. However, following the economic crisis of 2014-2015, they were able to reorient themselves towards the markets of Europe and Asia, which led to the recovery of the industry. In Ukraine, some enterprises are capable of not only satisfying the existing domestic and foreign demand but also of introducing advanced technologies into production and manufacturing high-tech products.

From the outset, the export of transformer equipment was concentrated on the markets of the Russian Federation and Kazakhstan. In this market, the principal competitors to domestic products are Russian goods. Furthermore, there has been an increase in Chinese and Korean manufacturers, who have been observed to employ dumping methods in order to gain a foothold in the market.

The delivery of radio equipment is experiencing a gradual increase, particularly in developing countries. The majority of the aforementioned goods are

exported to Myanmar, Egypt, and Ethiopia, which has experienced a decline in its position. The export of these goods to the Russian Federation has reached zero. There is also a negligible quantity of radio equipment exported to Europe.

Railway locomotives and freight vessels, which are traditional exports of Ukrainian machine building, are also selling worse and worse. Sales of railway wagons targeting the markets of Kazakhstan and the Russian Federation, which have suspended the modernisation of their transport fleets due to the crisis, have fallen particularly. In 2015, there was a major crisis in railcar sales; in 2016, sales almost doubled, but they are still 20 times less than in 2012, when exports peaked.

In other instances, Ukrainian enterprises engage in the production of goods destined for the European market, such as automotive cables. Similarly, the introduction of new high-tech products to the European market by emerging enterprises, including telephones, heaters, and various household electrical appliances, represents another avenue for Ukrainian enterprise. However, in the second case, the specific weight of sales is insufficient to effect a change in the negative market situation.

In addition to the competitive advantages that Ukrainian mechanical engineering enterprises currently enjoy in individual foreign markets, it is essential that they develop strategies for integration into global value chains. By entering a value chain, economies can industrialise and export high-technology goods without the necessity of developing a comprehensive range of industrial capabilities (Pauline Lectard, 2023).

6. Conclusions

The results of the conducted research demonstrate that the indicators of the export of mechanical engineering products are significantly influenced by

transformations in the country's foreign economic policy. Over the past decade, the most significant transformations in foreign economic policy were the result of a shift in approach prompted by Russia's assertive and unfriendly actions. Despite this, Russia remained an important foreign trade partner, even after 2014. It was only following a full-scale invasion that trade relations between Ukraine and Russia were entirely severed. In light of the pertinent developments in the country's foreign economic policy that emerged at the outset of 2014, it is imperative for mechanical engineering enterprises to respond with greater alacrity to such alterations.

Nevertheless, the calculations of structural changes in the export of mechanical engineering products demonstrated that the enterprises have not yet fully adapted to the alteration of foreign economic policy (and the transformation of foreign economic policy has been ongoing for a decade). In particular, the reorientation of enterprises towards new foreign markets required an innovative update of the technological component, which would contribute to an increase in competitive advantage in the global context. Nevertheless, one of the most significant challenges facing mechanical engineering enterprises in Ukraine is the discrepancy between the material and technical bases of Ukrainian enterprises and those of their foreign counterparts. This diminishes their competitive advantage, and it is evident that the competitiveness of exported products is adversely affected by this. Furthermore, there are challenges associated with the ability of these enterprises to adapt to the constant changes in the global market, which in turn necessitates the fulfilment of new requirements.

The analysis of structural changes in the export of mechanical engineering using a set of indicators revealed significant disproportions in the export structure. Consequently, the largest proportion of exports was accounted for by products of heavy engineering, specifically the groups "Nuclear reactors,

boilers, machines" and "Electrical machines". The aforementioned imbalances were rectified in 2022 due to the cessation of the supply of products belonging to the specified groups to the Russian market. However, it is crucial to highlight that the levelling of disparities is a consequence of the enhanced competitiveness of mechanical engineering products originating from Ukrainian enterprises. This is a phenomenon that can only occur as a result of the reinforcement of the innovative component within the framework of export growth strategies.

The export-oriented development of mechanical engineering enterprises in Ukraine should be based on existing advantages and the creation of new opportunities in the context of modern trends in the mechanical engineering industry worldwide. The prevailing trends in global mechanical engineering can be identified as an increase in scientific technologies and the expansion of electronic mechanical engineering, which is based on robotic processes.

The mechanical engineering of developed countries is distinguished by a comprehensive production structure, a notable contribution to precision mechanical engineering, superior quality and competitive pricing, and a strong export orientation. The proportion of mechanical engineering products in the total value of exports in Japan is 60%, while in the USA, Germany, Sweden, and Canada it is in excess of 40%. The mechanical engineering of developed countries is characterised by the prevalence of the following types of production: machine tool construction, transport engineering, equipment production, electrical engineering, instrument construction, rocket engineering, and aircraft construction.

In order to comply with global trends, it is necessary to reorient the management mechanisms of mechanical engineering enterprises in order to increase the level of competitiveness of mechanical engineering products. This, in turn, forms the basis for ensuring export-oriented development.

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