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TECHNOLOGICAL DISPARITIES IN EU–UKRAINE TRADE

The conclusion of the Deep and Comprehensive Free Trade Agreement (DCFTA) between Ukraine and the EU both created additional opportunities for Ukrainian exports in terms of simplified access to European markets and liberalization of customs tariffs, and provoked new risks caused by the pronounced asymmetry of economic development between the partners. One of the most threatening manifestations of economic asymmetry is the significant differences in the level of technological complexity of export and import flows between Ukraine and the EU. Therefore, the research aim is to analyze technological imbalances in trade between Ukraine and the EU under the DCFTA.

Based on the results of the assessment of the technological complexity of Ukraine's exports and imports in trade with the EU under the DCFTA and the depth of technological imbalances in trade relations based on the calculation of the technological pressure indicator proposed by the authors, the hypothesis that there is a negative trend in the dynamics of technological complexity of Ukraine's exports and imports in preferential trade with the EU is confirmed. The results are shown that reducing customs barriers and expanding market access for technologically sophisticated goods simultaneously increase

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ТЕХНОЛОГІЧНІ ДИСПРОПОРЦІЇ ТОРГІВЛІ ЄС ТА УКРАЇНИ

Укладання Угоди про поглиблену та все-охоплюючу зону вільної торгівлі (ПВЗВТ) між Україною та ЄС створило додаткові можливості для вітчизняного експорту в частині спрощеного доступу на європейські ринки і лібералізації митних тарифів, а також спровокувало нові ризики, зумовлені вираженою асиметрією економічного розвитку партнерів. Одним з найзагрозливіших проявів економічної асиметрії є суттєві відмінності в рівні технологічної складності експортно-імпортних потоків між Україною та ЄС. Відтак, метою статті є аналіз технологічних диспропорцій у торгівлі України та ЄС у рамках ПВЗВТ. За результатами оцінки технологічної складності експорту та імпорту України в торгівлі з ЄС у контексті з ПВЗВТ, а також глибини технологічних диспропорцій у торговельних відносинах на основі розрахунку запропонованого авторами показника технологічного тиску підтверджено гіпотезу про існування негативного тренду в динаміці технологічної складності продукції експорту та імпорту України в преференційній торгівлі з ЄС. Для досягнення поставленої мети використано методи аналізу та синтезу, метод нормалізації, індексний метод. Отримані результати показують, що зниження митних бар'єрів і розширення доступу до ринків для технологічно складних



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pressure on less developed sectors of Ukraine's economy, which does not always contribute to their development. In such circumstances, protectionist measures such as temporary import restrictions or support for domestic producers may be justified to protect economically vulnerable sectors. This allows gradually increasing the technological complexity of products and adapting domestic producers to the conditions of fierce competition, which will help reduce technological pressure in the long run. The authors consider prospects for further research in substantiating objective criteria for selecting economic sectors that require additional support and gradual increase in competitiveness in the context of deepening Ukrainian-European trade integration.

Keywords: preferential trade, trade relations, DCFTA, economic asymmetry, technological disparities, Product Complexity Index, technological pressure.

JEL Classification: F13, F15, O33.

товарів одночасно підвищують тиск на менш розвинуті сектори економіки України, що не завжди сприяє їх розвитку. У таких умовах протекціоністські заходи, такі як тимчасові обмеження на імпорт або підтримка національних виробників, можуть бути обґрунтованими для захисту економічно вразливих секторів. Це дасть можливість поступово збільшувати технологічну складність продукції та адаптувати національних виробників до умов посиленої конкуренції, що сприятиме зменшенню технологічного тиску в довгостроковій перспективі. Автори бачать перспективи подальших досліджень у визначенні об'єктивних критеріїв для вибору секторів економіки, які потребують додаткової підтримки та поступового підвищення конкурентоспроможності в умовах поглиблення українсько-європейської торговельної інтеграції.

Ключові слова: преференційна торгівля, торговельні відносини, ПВЗВТ, економічна асиметрія, технологічні диспропорції, індекс складності продукції, технологічний тиск.

Introduction

The Deep and Comprehensive Free Trade Area (DCFTA), which is part of the Association Agreement between Ukraine and the European Union, entered into force in January 2016. This document opened up new opportunities for economic cooperation and contributed to the deepening of trade relations between the parties. The main goal of the DCFTA is to ensure the free movement of goods and services through the gradual liberalization of customs tariffs, which stimulates the economic integration of Ukraine with the EU. One of the important aspects that highlights the effects of the DCFTA is the technological complexity of export and import flows between Ukraine and the EU. The technological complexity of products is an indicator that reflects the level of innovation, knowledge-intensiveness and added value embodied in products. High-tech products have higher added value and are more competitive in the global market. Therefore, assessing the technological complexity of exports and imports allows us to better understand the level of technological development of a country, its dependence on imports of high-tech goods, and the potential for further modernization of the economy.

Empirically substantiated conclusions on the positive impact of technological specialization of exports on the economic growth of a country are obtained in the works (Lee, 2011; Zakrajsek & Harrigan, 2006; Hidalgo & Hausmann, 2009; Nepelski & De Prato, 2020). Thus, the results of the analysis of the impact of technologicality of exports on economic development for a statistical sample of 71 countries showed that economies demonstrate higher growth rates if they are oriented towards the export of high-tech products (Lee, 2011). Testing the empirical model of export specialization of countries

confirmed the importance of technological factors for the formation of long-term comparative advantages in the international division of labor (Harrigan & Zakrajsek, 2006). The work (Hidalgo & Hausmann, 2009) identified the technological complexity of products as a critically important factor of economic growth and proved that the complexity of the economy directly correlates with the level of gross national income, which is determined by the complexity of production structures. Based on empirical analysis, researchers (Nepelski & De Prato, 2020) concluded that a country's position in the global technology space determines its profitability and growth rates, and the main driver is the uniqueness of the state's technology portfolio compared to other countries.

The importance of technological specialization of exports for the economic development of the country and its protection from trade dependence in asymmetric bilateral relations is confirmed by the cases of individual countries (Costa et al., 2023; Anzolin & Benassi, 2024; Bernatonyte, 2015; Saboniene, 2013; Hossain et al., 2021). Thus, the analysis results of Brazilian export specialization confirmed its different sectoral composition and structure, which varies in terms of the level of added value and the degree of correlation with trading partners (Costa et al., 2023). The need for transformation from raw material specialization to higher value-added exports for Lithuania is highlighted in the study (Bernatonyte, 2015). Author Saboniene (2013) notes that over time, there have been positive transformations of Lithuanian exports into relatively technological sectors. Scholars have also emphasized the importance of rational industrial policy in developing the technological capacity of exports (Anzolin & Benassi, 2024).

The works of Ukrainian scientists devoted to the issues of Ukraine's foreign trade with the EU consider various aspects of the asymmetry of these bilateral relations (Pyrog et al., 2024; Lyzun et al., 2024; Ischuk et al., 2021; Marunyak et al., 2023). Researchers emphasize the existence of disproportions in the volumes of Ukraine's export-import operations with individual EU countries (Pyrog et al., 2024), which makes the domestic economy more vulnerable to external shocks (Lyzun et al., 2024) and the asymmetry of foreign trade indicators with the EU across regions of Ukraine (Ischuk et al., 2021; Marunyak et al., 2023). However, one of the critical, in our opinion, aspects of the asymmetry of Ukrainian-European trade relations is technological asymmetry as the difference in the level of technological sophistication of goods exported from Ukraine and imported from EU countries. The results of the scientists' research confirm the raw material specialization of Ukrainian commodity exports – both in general (Kalyuzhna & Dashkov, 2023; Lyashok & Taranyuk, 2024; Tur et al., 2024), and in trade with the EU (Kalyuzhna & Dashkov, 2024). The predominance of raw material-type products with a low share of added value prevents the creation of a stable basis for the economic growth of the state (Tur et al., 2024). The imbalance between Ukrainian raw material exports and high-tech European

imports further deepens the asymmetry of bilateral trade with Ukraine's main partner (Lyashok & Taranyuk, 2024). In previous works, the authors of the article, based on the results of the analysis of the degree of technological sophistication of Ukraine's exports, confirmed the trend of its raw material specialization (Kalyuzhna & Dashkov, 2023) and separately emphasized the deepening technological imbalances in Ukrainian-European trade relations (Kalyuzhna & Dashkov, 2024).

The conclusion of preferential trade agreements, in particular free trade zones, should theoretically contribute to the equalization of trade conditions between partners by ensuring mutual access to domestic markets and eliminating/reducing trade barriers. At the same time, preferential trade between partners with a pronounced asymmetric level of economic development, in practice, on the contrary, can lead to a deepening of disparities due to significant differences in the level of technological complexity of export and import products. Therefore, an important scientific and practical task is to confirm the outlined negative effect and develop a toolkit for assessing the depth of such disparities.

The research aim is to determine technological disparities in trade between Ukraine and the EU within the framework of the DCFTA in order to assess the depth of the gap in the technological complexity of export and import products. A hypothesis is put forward regarding the presence of a negative trend in the dynamics of technological complexity of Ukrainian export and import products in trade with the EU within the framework of the DCFTA, which indicates the existence and deepening of technological imbalances in preferential trade between partners with an asymmetric level of economic development.

To achieve the aim, the methods of analysis and synthesis were used (to identify the level of liberalization of preferential trade between Ukraine and the EU in terms of product groups and obligations under customs tariffs), the normalization method (to calculate the normalized index of technological complexity of products in terms of product groups under the customs tariffs of the EU and Ukraine), the index method (to substantiate the indicator of technological pressure in bilateral trade relations and its calculation for trade between Ukraine and the EU within the framework of the DCFTA), abstraction and generalization (to formulate conclusions regarding the risks of deepening technological disparities in preferential trade of economically asymmetric partners). The theoretical and methodological basis is the results of research by scientists on the issues of trade integration, economic asymmetry and technological development. The study is supported by regulatory documentation on trade conditions between Ukraine and the EU within the framework of the DCFTA and the results of the Atlas of Economic Complexity project based on the calculation of the Product Complexity Index (PCI).

To confirm the hypothesis put forward, it is necessary to analyze the technological complexity of products in terms of customs tariffs in accordance with the DCFTA Agreement between Ukraine and the EU

(first section), determine the technological complexity of Ukraine’s exports and imports in trade with the EU (second section), and assess the depth of technological disparities in preferential trade between Ukraine and the EU (third section).

1. Technological complexity of products in terms of customs tariffs under the DCFTA between Ukraine and the EU

The first step in assessing the technological complexity of Ukraine’s exports and imports to the EU is to analyze the agreement on the elimination of customs barriers in accordance with the tariff liberalization schedule set out in the DCFTA. The structure analysis of customs tariffs for different product groups according to the EU schedule and Ukraine’s schedule under the DCFTA demonstrates the differentiation of approaches of both parties to taxation of imported goods and helps to assess the level of protection of certain industries (*Figure 1*).

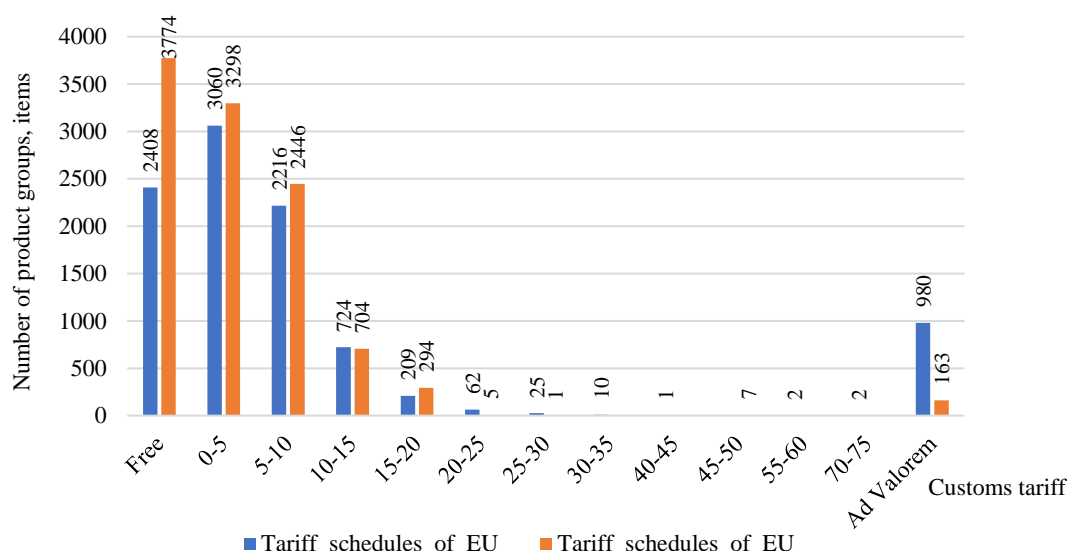


Figure 1. Distribution of product groups by customs tariffs under the DCFTA between Ukraine and the EU

Source: compiled by the authors according to (EU-Ukraine DCFTA, 2016).

As it can be seen from Figure 1, the number of product groups in each tariff rate band indicates the level of market openness and the protective mechanisms that both sides use to support their own industries. Thus, for goods exempted from duties, the number of product groups is 2408 for the EU and 3774 for Ukraine. This indicates that Ukraine provides a larger number of duty-free items for imports from the EU, which contributes to wider access of European goods to the Ukrainian market.

The product groups in terms of tariff value mostly fall within the 0–5% tariff rate range for both the EU (3060 groups) and Ukraine (3298 groups), which in turn also indicates the desire of both sides to

liberalize trade and reduce barriers for a large number of goods. Higher tariff rates (15–75%) apply to a limited number of product groups, mostly for specific goods that require greater protection. The EU, compared to Ukraine, uses significantly more high tariffs in this range (e.g., 15–20% – 209 for the EU vs. 294 for Ukraine, 20–25% – 62 for the EU vs. 5 for Ukraine, 25–30% – 25 for the EU vs. 1 for Ukraine). This may indicate that the EU seeks greater protection of certain sectors from Ukrainian imports. Ukraine demonstrates a more open tariff policy, providing a larger number of product groups with duty-free access and applying fewer ad valorem duties. This is in line with Ukraine’s strategic goal to expand cooperation with the EU and integrate into European economic processes. On the other hand, the EU applies significantly more ad valorem duties and has a larger number of product groups with moderate and high rates, which may be due to the protection of sensitive sectors of the EU economy from competitive imports.

A detailed analysis of customs tariff commitments for individual product groups allows us to assess the depth of liberalization for key sectors of the economy of both parties (*Table 1*).

Table 1

The amount of product groups subject to duty-free regulations under the DCFTA between Ukraine and the EU

Product groups	Obligations under the zero tariff	
	The EU	Ukraine
72 ferrous metals	308	311
84 nuclear reactors, boilers, machinery	177	439
29 organic chemical compounds	164	274
85 electrical machines	119	232
48 paper and cardboard	164	171
73 ferrous metal products	113	194
03 fish and crustaceans	43	260
44 wood and wood products	88	177
90 optical and photographic instruments and apparatus	82	165
27 mineral fuels; oil and products of its distillation	36	90
55 synthetic or artificial	–	121
30 pharmaceutical products	58	61
28 inorganic chemical products	34	68
39 plastics, polymeric materials	31	62
87 means of land transport other than railway	13	78
OTHER TYPES	978	1071

Source: developed by the authors based on data (EU-Ukraine DCFTA, 2016).

A significant number of product groups fall under the zero customs tariff, which indicates the agreement’s focus on creating the most open trading environment and mutual market accessibility. In some categories, Ukraine provides more duty-free items than the EU. The most significant

disproportion of commitments is observed for group 84 nuclear reactors, boilers, machinery, which indicates different market opening strategies for each party. Ukraine also opens its market for ferrous metals, having almost the same number of product lines with the EU. There is also an asymmetry in establishing a duty-free regime for group 29 organic chemical compounds, under which Ukraine provides more benefits, which allows simplifying the import of organic chemicals. The situation is similar for group 85 electrical machines. At the same time, the elimination of duties for group 72 ferrous metals is practically symmetrical, under which the EU provides significant benefits for ferrous metal products, which is important for Ukrainian industry. Thus, the agreement provides for a deep opening of markets on both sides, but with a certain asymmetry in different sectors of the economy. Ukraine often provides more duty-free positions in key industrial categories, while the EU is more cautious about eliminating duties in certain sectors.

Differences in the level of technological complexity of products subject to different customs tariffs were estimated based on the calculation of the normalized product complexity index. Traditionally, the weighted average PCI index (Product Complexity Index) is used to assess the technological complexity of exports and imports, which is determined based on the analysis of the structure of economic activity of countries in the world, in which products of a high level of complexity can be produced by a limited number of countries. On the contrary, the technologically simpler the product (and, accordingly, the lower the PCI value corresponding to it), the greater the number of countries in the world can specialize in its production. The PCI is determined for 1223 types of products according to the Harmonized System for the Description and Coding of Goods HS 1992, i.e. each type of commodity product or service received a certain complexity index. To increase the validity of the results of the comparative analysis of the technological complexity of exports and imports, the authors (Kalyuzhna & Dashkov, 2024) proposed to carry out Z-normalization of the PCI index according to the formula:

$$PCI\ normal = \frac{PCI - PCI(av)}{PCI(\sigma)},$$

where: *PCI normal* – normalized product complexity index;

PCI – product complexity index;

PCI (av) – average value of product complexity index in the sample;

PCI (σ) – standard deviation of product complexity index in the sample.

Standardization allows to eliminate differences in the scales of measurement and to provide the possibility of comparing indices for different product groups. Z-normalization determines how much the PCI value deviates from its average *PCI* value (*av*) in units of standard deviation. As a result of normalization, the data is converted into a standard form, where the average value is 0 and the standard deviation is 1. This allows to compare

indices of different product groups, regardless of their initial scales. Analysis of normalized PCI indices for products subject to different customs tariffs allows to assess the technological complexity of the products subject to these tariffs on both sides of the agreement. An important aspect of this analysis is the comparison of customs obligations and the level of technological complexity for products exported and imported between Ukraine and the EU (Table 2).

Table 2

Standardized PCI index of product groups under customs tariffs according to the DCFTA between Ukraine and the EU

Customs tariffs, %	PCI index	
	ЄС	Україна
No duty	0.023	0.163
0–5	0.476	0.162
10–15	–1.051	–0.914
5–10	–0.014	0.050
15–20	–0.896	–0.858
20–25	–0.898	0.243
25–30	–1.077	–0.980
30–35	–0.856	–
40–45	–0.639	–
45–50	–	–1.613
55–60	–0.723	–
70–75	–0.639	–
Ad Valorem	–0.459	–0.493

Source: compiled by the authors according to (EU-Ukraine DCFTA, 2016).

As the calculation results show, according to the tariff elimination schedule, Ukraine has obligations regarding more technologically complex products for the introduction of a duty-free regime, which gives grounds to argue about the existence of a certain asymmetry in the obligations of the parties: Ukraine opens its market to more technologically intensive products, which can increase competition for domestic producers and stimulate industrial modernization.

2. Technological complexity of Ukraine’s exports and imports in trade with the EU under the DCFTA

Foreign trade between Ukraine and the EU in 2016–2023 demonstrates changes in the structure of exports and imports depending on customs rates, which indicates a change in the level of technological complexity of goods during this period. Analysis of normalized PCI indices for exports and imports of Ukraine at customs tariffs within the framework of the DCFTA for 2016–2023 shows that imports of goods from the EU generally have a higher technological complexity, especially for goods with

no customs duties or with minimal customs rates (*Table 3*). Ukraine’s exports to the EU mostly remain less technologically complex at customs rates, which indicates a significant asymmetry in the structure of trade between the countries. Thus, for groups of goods with a duty-free regime, the gradual increase in PCI for imports from the EU indicates an increase in the technological complexity of imported products. For exports, PCI remains negative, which indicates that goods in this group have a relatively low technological complexity. At customs rates up to 5%, the PCI for imports gradually decreases, which indicates a gradual decrease in the technological complexity of imported goods in this range. For exports, the PCI remains negative. For products with customs rates set within 5–10%, the PCI for imports increased during 2016–2021, but as of 2023 it has significantly deteriorated. The negative dynamics of the PCI is also confirmed for exports in this range of customs rates.

Table 3

Standardized PCI values of Ukraine’s exports and imports in trade with the EU under customs tariffs according to the DCFTA Agreement in 2016–2023

PCI (Exports/Imports)	Customs rate, %	2016	2017	2018	2019	2020	2021	2022	2023
Import PCI	0	0.255	0.273	0.276	0.314	0.320	0.295	0.051	0.099
Export PCI		-0.270	-0.317	-0.304	-0.369	-0.339	-0.314	-0.527	-0.538
Import PCI	0–5	0.258	0.273	0.270	0.249	0.228	0.218	0.041	-0.046
Export PCI		-0.269	-0.261	-0.226	-0.242	-0.225	-0.283	-0.291	-0.262
Import PCI	5–10	0.044	0.069	0.066	0.229	0.216	0.139	0.025	-0.035
Export PCI		-0.368	-0.367	-0.361	-0.298	-0.251	-0.538	-0.642	-0.699
Import PCI	10–15	-0.018	-0.017	-0.017	-0.034	-0.039	-0.034	-0.040	0.051
Export PCI		-0.210	-0.194	-0.154	-0.182	-0.220	-0.107	-0.153	-0.217
Import PCI	15–20	-0.019	-0.019	-0.026	-0.034	-0.039	-0.067	-0.070	-0.057
Export PCI		-0.106	-0.103	-0.072	-0.092	-0.126	-0.119	-0.136	-0.150
Import PCI	20–25	0.000	0.000	0.000	0.000	0.000	0.039	0.031	0.028
Export PCI		-0.009	-0.011	-0.009	-0.009	-0.012	-0.011	-0.010	-0.009
Import PCI	25–30	0.000	0.000	0.000	0.000	0.000	-0.003	-0.004	-0.003
Export PCI		-0.006	-0.007	-0.005	-0.005	-0.007	-0.004	-0.006	-0.006
Import PCI	30–35	-0.006	-0.007	-0.006	-0.005	-0.008	-0.006	-0.007	-0.010
Export PCI		-0.003	-0.002	-0.003	-0.003	-0.003	-0.004	-0.003	-0.003
Import PCI	<i>Ad Valorem</i>	-0.009	-0.010	-0.011	-0.014	-0.017	-0.019	-0.013	-0.018
Export PCI		-0.324	-0.358	-0.345	-0.418	-0.379	-0.322	-0.551	-0.589

Source: calculated by the authors.

In general, imports of goods from the EU to Ukraine showed stable positive or neutral dynamics until 2022 at most customs rates. This indicates that Ukraine imported products of high technological complexity from the EU. After 2022, the trend is negative, i.e. the import structure has changed

towards low-tech products. Complexity indices for products at higher customs rates (from 15%) generally show negative values or are stabilized at a low level, indicating lower technological complexity. Ukraine's exports to the EU at all customs rates are characterized by consistently negative PCI values. This indicates that exported goods have a lower level of technological complexity, which is typical for raw materials or low-tech goods. The deterioration is particularly noticeable in the group of goods with duty-free regime and duty rates within 5–10%, where PCI for exports decreased by 50% and 47%, respectively, compared to 2016. This indicates a deterioration in the technological complexity of goods that Ukraine exports at these customs rates. For goods with other customs rates (10–15% and 15–20%), the trend remains negative, with a deterioration in the complexity indicator by 3% and 30%, respectively.

Thus, the analysis results of the complexity of products under customs tariffs under the DCFTA Agreement illustrate the presence of a pronounced asymmetry in the structure of trade: imports of goods from the EU generally have a higher level of technological complexity, while Ukraine's exports to the EU remain low-tech, with a predominance of exports of raw materials and low-complexity products. There is also a trend towards a decrease in the technological complexity of imports in medium-duty groups and an increase in dependence on imports of high-tech goods, especially for the duty-free group of goods and goods with minimal duties (0–5%).

An in-depth analysis of the complexity of products for Ukraine's imports from the EU under the duty-free regime in 2016–2023 indicates the following trends: high-tech goods occupy a significant share in the import structure, but their share either remains stable or decreases slightly (*Table 4*).

The overall import complexity index throughout the period has a negative trend, indicating a gradual decrease in the technological complexity of goods imported from the EU within the framework of the DCFTA agreement. Thus, the largest group of imported products is mineral fuels, oil and its distillation products, for which the complexity index has a negative value. Since 2018, there has been a gradual decrease in the share of fuel imports in the overall import structure of the country, which had a positive effect on the level of technological sophistication of imports. But in 2022, there is a jump to 24% of the share in the import structure, and the maximum negative value of the complexity index is recorded.

The second group in terms of share in total imports of Ukraine for the period under review is nuclear reactors, boilers, and machinery. The PCI for this group of products remains at a high level throughout the period, indicating a high technological complexity of imported goods. At the same time, the PCI indicator in the structure gradually decreases, indicating a decrease in the share of these products in total imports.

Table 4

Standardized values of Ukraine's imports of duty-free products
in trade with the EU under the DCFTA in 2016-2023

Indicator	2016	2017	2018	2019	2020	2021	2022	2023
27 mineral fuels; oil and products of its distillation								
Share, % (in UAH)	14	15	13	11	9	11	24	20
Weighted average PCI	-0.977	-0.977	-0.977	-0.977	-0.977	-0.977	-0.977	-0.977
PCI in the structure of	-0.141	-0.142	-0.130	-0.106	-0.085	-0.107	-0.234	-0.199
84 nuclear reactors, boilers, machinery								
Share, % (in UAH)	14	14	14	13	13	13	7	8
Weighted average PCI	0.992	0.992	0.992	0.992	0.992	0.992	0.992	0.992
PCI in the structure of	0.141	0.142	0.137	0.131	0.129	0.132	0.071	0.081
87 means of land transport other than railways								
Share, % (in UAH)	8	10	10	13	11	11	11	11
Weighted average PCI	1.116	1.116	1.116	1.116	1.116	1.116	1.116	1.116
PCI in the structure of	0.091	0.112	0.106	0.144	0.123	0.126	0.121	0.126
85 electric machines								
Share, % (in UAH)	7	8	8	9	8	7	6	5
Weighted average PCI	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.783
PCI in the structure of	0.057	0.061	0.066	0.067	0.066	0.055	0.043	0.040
30 pharmaceutical products								
Share, % (in UAH)	7	6	6	6	7	7	5	5
Weighted average PCI	0.786	0.786	0.786	0.786	0.786	0.786	0.786	0.786
PCI in the structure of	0.051	0.048	0.047	0.048	0.058	0.055	0.037	0.037
39 plastics, polymeric materials								
Share, % (in UAH)	7	6	6	5	6	6	5	5
Weighted average PCI	0.798	0.798	0.798	0.798	0.798	0.798	0.798	0.798
PCI in the structure of	0.053	0.050	0.048	0.043	0.045	0.049	0.040	0.038
38 various chemical products								
Share, % (in UAH)	4	4	4	3	3	3	3	2
Weighted average PCI	0.455	0.455	0.455	0.455	0.455	0.455	0.455	0.455
PCI in the structure of	0.019	0.018	0.017	0.015	0.015	0.013	0.011	0.009
48 paper and cardboard								
Share, % (in UAH)	3	3	3	2	3	2	0	2
Weighted average PCI	0.295	0.295	0.295	0.295	0.295	0.295	0.000	0.295
PCI in the structure of	0.010	0.008	0.008	0.007	0.007	0.007	0.000	0.005
Others up to 2%								
Share, % (in UAH)	35	34	36	37	40	39	40	42
Weighted average PCI	-0.072	-0.066	-0.067	-0.097	-0.098	-0.088	-0.095	-0.089
PCI in the structure of	-0.026	-0.023	-0.024	-0.036	-0.039	-0.034	-0.038	-0.037
TOTAL PCI in the structure	0.255	0.273	0.276	0.314	0.320	0.295	0.051	0.099

Source: calculated by the authors.

A general analysis of the dynamics of complexity indices for product groups of Ukraine's imports from the EU for the period 2016–2023 shows several key trends: a gradual decrease in the share of low-tech goods, stability of high-tech groups until 2021 with a peak value in 2020. Since 2022, significant structural changes have occurred in imports, the PCI has decreased sharply, which was accompanied by an increase in the share of

low-tech goods (in particular, mineral fuels) and a reduction in imports of high-tech products (such as equipment, electronics, motor vehicles). Analysis of the structure of Ukraine’s exports to the EU for the period 2016–2023 under the duty-free regime demonstrates negative dynamics of the level of technological complexity of products, exports are mostly based on products with low technological complexity, such as grains, ores, fats and oils (*Table 5*).

Table 5

Standardized PCI values of Ukraine’s exports in trade with the EU by groups of duty-free products under the DCFTA in 2016–2023

Indicator	2016	2017	2018	2019	2020	2021	2022	2023
72 ferrous metals								
Share, % of the total	20	18	18	15	13	20	10	9
Average PCI	0.449	0.449	0.449	0.449	0.449	0.449	0.449	0.449
PCI in the structure of	0.088	0.079	0.079	0.066	0.060	0.091	0.045	0.042
10 cereals								
Share, % of the total	10	10	11	12	9	7	17	20
Average PCI	-1.057	-1.057	-1.057	-1.057	-1.057	-1.057	-1.057	-1.057
PCI in the structure of	-0.100	-0.103	-0.116	-0.131	-0.098	-0.076	-0.177	-0.207
85 electrical vehicles								
Share, % of the total	12	12	12	11	12	10	8	6
Average PCI	0.861	0.861	0.861	0.861	0.861	0.861	0.861	0.861
PCI in the structure of	0.104	0.102	0.104	0.097	0.103	0.083	0.072	0.055
15 fats and oils of animal or vegetable origin								
Share, % of the total	9	8	5	7	10	9	11	13
Average PCI	-0.853	-0.853	-0.853	-0.853	-0.853	-0.853	-0.853	-0.853
PCI in the structure of	-0.074	-0.069	-0.046	-0.062	-0.083	-0.075	-0.094	-0.109
26 ores, slags and ashes								
Share, % of the total	7	9	9	9	8	11	9	7
Average PCI	-1.306	-1.306	-1.306	-1.306	-1.306	-1.306	-1.306	-1.306
PCI in the structure of	-0.095	-0.118	-0.121	-0.115	-0.106	-0.147	-0.112	-0.093
12 seeds and fruits of oilseeds								
Share, % of the total	5	6	6	8	6	6	10	8
Average PCI	-1.430	-1.430	-1.430	-1.430	-1.430	-1.430	-1.430	-1.430
PCI in the structure of	-0.066	-0.092	-0.085	-0.108	-0.091	-0.079	-0.149	-0.119
44 wood and wood products								
Share, % of the total	6	5	5	5	5	5	6	5
Average PCI	-0.959	-0.959	-0.959	-0.959	-0.959	-0.959	-0.959	-0.959
PCI in the structure of	-0.056	-0.046	-0.050	-0.047	-0.052	-0.051	-0.056	-0.051
94 furniture								
Share, % of the total	2	2	3	3	4	3	3	3
Average PCI	0.261	0.261	0.261	0.261	0.261	0.261	0.261	0.261
PCI in the structure of	0.005	0.006	0.007	0.007	0.009	0.009	0.007	0.008

End of Table 5

Indicator	2016	2017	2018	2019	2020	2021	2022	2023
27 mineral fuels; oil and its distillation products								
Share, % of the total	3	3	3	3	2	2	3	1
Average PCI	-0.767	-0.767	-0.767	-0.767	-0.767	-0.767	-0.767	-0.767
PCI in the structure of	-0.020	-0.024	-0.025	-0.026	-0.018	-0.017	-0.025	-0.009
23 residues and waste from the food industry								
Share, % of the total	3	3	3	3	3	2	2	3
Average PCI	-0.829	-0.829	-0.829	-0.829	-0.829	-0.829	-0.829	-0.829
PCI in the structure of	-0.026	-0.023	-0.021	-0.021	-0.021	-0.015	-0.015	-0.028
84 nuclear reactors, boilers, machinery								
Share, % of the total	3	3	2	3	3	2	2	2
Average PCI	0.601	0.601	0.601	0.601	0.601	0.601	0.601	0.601
PCI in the structure of	0.016	0.015	0.015	0.015	0.018	0.014	0.013	0.012
73 ferrous metal products								
Share, % of the total	2	2	2	2	2	2	2	3
Average PCI	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
PCI in the structure of	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Others up to 2%								
Share, % of the total	20	20	20	20	22	20	17	19
Average PCI	-0.233	-0.234	-0.222	-0.223	-0.266	-0.254	-0.208	-0.207
PCI in the structure of	-0.046	-0.046	-0.045	-0.044	-0.059	-0.051	-0.035	-0.040
TOTAL PCI in the structure	-0.269	-0.317	-0.304	-0.369	-0.338	-0.314	-0.526	-0.538

Source: calculated by the authors.

For exports from 2016 to 2023, the largest product group is the ferrous metals group. The PCI for this product group is positive, which allows us to consider this group as technologically complex. The electrical machinery product group has a high PCI index with a twofold decrease in its share in the export structure since the entry into force of the DCFTA Agreement. Grain products have low technological complexity, and their share in the export structure to the EU countries decreases significantly by 2021, which indicates a decrease in the role of this group in exports. A significant increase in the share of grain exports in the overall structure in 2022 and 2023 negatively affected the overall export complexity index. Exports of the animal or vegetable fats and oils product group have positive dynamics, while this product group has a negative complexity index, which negatively affects the overall export complexity index.

Analysis of the dynamics of PCI complexity indices for the main product groups of Ukrainian exports to the EU in the period 2016–2023 demonstrates several key trends: stability or minor fluctuations for groups with high PCI in 2016–2021 and a decline since 2022; raw materials with low technological complexity continue to dominate exports, products with medium complexity

(furniture, ferrous metal products) demonstrate a slight increase in their share in the export structure. In general, Ukraine remains strongly oriented towards the export of raw materials and low-tech goods, which has especially intensified since 2022. The dynamics of the technological complexity indices of products by customs tariff groups illustrates that the weighted average PCI for exports and imports has a negative trend (Figure 2).



Figure 2. Dynamics of Ukraine’s exports and imports in the DCFTA with the EU by customs tariffs in 2016–2023

Source: compiled by the authors.

For groups of goods with a duty-free regime, the complexity index for exports has been gradually decreasing since 2016 with a sharp decline starting from 2022 (study *Figure 2*). For imports, there is an increase in the PCI from 2016 to 2021 with a further significant decline. A similar trend is observed for the group of goods with customs rates up to 5%, for which the complexity index for exports demonstrated some stability in negative values, but significantly decreased from 2022. In general, there is weak progress in the technological complexity of products exported within this rate. For imports in this category, the index has a negative trend, reaching a negative value in 2023.

The group of goods with customs rates from 5 to 10% has an even more pronounced trend of decreasing the technological complexity of export and import products. A sharp decrease in the complexity index for exports starting from 2021 indicates a decrease in the share of technological products in this category. The dynamics of the import complexity index indicates that there is a decline in the technological complexity of imported products in this category at customs rates.

For groups of goods in the category with customs rates from 10 to 15% in exports, the PCI indicator remains negative, but demonstrates some volatility, which indicates the instability of the composition of exported products in this rate group. For imports, the PCI demonstrates stability at a level close to zero with a positive value in 2023, which may indicate a gradual increase in the technological complexity of imported products in the last year of the period under review.

Thus, export trends indicate a consistently low level of technological complexity of products at all customs rates. The worst indicators are recorded in the range of rates of 5–10% and the duty-free regime, which indicates the low competitiveness of Ukrainian exports in these segments. For imports, in all rate groups except 10–15%, a deterioration in the technological complexity of products is observed after 2020. The 10–15% group shows positive dynamics in 2023, indicating a possible increase in imports of products with greater complexity.

3. Technological imbalances in trade relations between Ukraine and the EU under the DCFTA

The analysis of the complexity indices of exports and imports of products by customs tariff groups allows us to proceed to a quantitative assessment of the level of technological disparities in trade relations between Ukraine and the EU within the framework of the DCFTA. For the assessment, we will use the technological pressure indicator (*TP – technological pressure*) proposed in the authors' previous work (Kalyuzhna & Dashkov, 2024), which is calculated as the difference between the values of the weighted average complexity indices of the country's imports and exports:

$$TP = \overline{PCI}(imp) - \overline{PCI}(exp),$$

where: *PCI (imp)* – weighted average import complexity index;
PCI (exp) – weighted average export complexity index.

The weighted average import and export complexity indices are calculated as:

$$\overline{PCI}(imp) = \frac{\sum_{i=1}^n (PCI_i(imp) \times w_i)}{\sum_{i=1}^n w_i},$$

$$\overline{PCI}(exp) = \frac{\sum_{j=1}^m (PCI_j(exp) \times v_j)}{\sum_{j=1}^m v_j},$$

where: $PCI_i(imp)$, $PCI_j(exp)$ – complexity indices of the i imported and j exported goods, respectively;

w_i – share of the i goods in the total import value;

n – total number (nomenclature) of imported goods;

v_j – share of the j goods in the total export value;

m – total number (nomenclature) of exported goods.

The technological pressure indicator reflects technological disparities between trading partners and allows us to assess the level of dependence of a country participating in a trading pair on imports of high-tech goods compared to exports of products of a lower technological level. The results of calculating the indicator make it possible to determine which products a country exports and imports by the level of technological complexity, as well as to find out whether it is an exporter or importer of high-tech goods. This allows us to assess the degree of technological development of the country, its dependence on external sources of advanced technologies and high-tech imports from trading partners. A high value of the technological pressure indicator for a country indicates that imported goods are much more technologically complex than exported ones, which indicates a significant dependence on imports of high-tech products. This, in turn, can limit the country's economic development and pose risks to its economic security. In contrast, a low or negative value of the technological pressure indicator indicates parity in the technological complexity of imported and exported goods, which indicates a country's high technological potential and its strong competitive position in global markets.

The dynamics of the technological pressure indicator of Ukraine's trade relations with the EU countries in terms of customs tariffs under the DCFTA Agreement in 2016–2023 are presented in *Table 6*.

Table 6

Dynamics of technological pressure in Ukraine's trade relations with the EU in terms of customs tariffs under the DCFTA

Group of customs tariffs, %.	2016	2017	2018	2019	2020	2021	2022	2023
0 (No duty)	0.525	0.590	0.579	0.683	0.658	0.610	0.578	0.637
0-5	0.527	0.534	0.496	0.491	0.454	0.502	0.332	0.216
5-10	0.412	0.436	0.427	0.527	0.467	0.677	0.667	0.664
10-15	0.192	0.177	0.137	0.147	0.182	0.073	0.114	0.268

Source: calculated by the authors.

As can be seen from *Table 6*, the highest technological pressure was observed in the group of products with a duty-free regime, which indicates an increase in Ukraine's dependence on imports of technologically complex goods. The increase in technological pressure in this group of products emphasizes that imported goods significantly exceed exported goods in terms of technological complexity.

For the group of products with customs rates up to 5%, the values of the technological pressure indicator fluctuated throughout the period. The highest indicator was recorded in 2017, after which a tendency to decrease in pressure was observed. The value of the technological pressure indicator gradually decreased, which is a positive factor, but in 2022–2023 it fell significantly, reaching a minimum in 2023. Such dynamics cannot be interpreted positively, because the factor of this decline is a significant decline in imports of technologically complex products – that is, the country is losing segments of the economy that attract such imports.

In the group with customs rates from 5 to 10%, the lowest value of the technological pressure indicator was recorded in 2016, after which a trend of increasing technological disparities with some fluctuations was observed. The growth of technological pressure is a negative trend, indicating a deepening technological asymmetry in trade between Ukraine and the EU. High values in 2022–2023 demonstrate the continued dependence on technology imports.

The value of the technological pressure indicator in the group with customs rates from 10 to 15% varied, demonstrating unstable dynamics. The lowest indicator was recorded in 2018, and growth began after 2020. In 2022, the indicator value increased and reached its maximum in 2023. This indicates an increase in dependence on imports, especially in conditions of a decrease in technologically complex exports. The trend for this group indicates a growing imbalance in bilateral trade, especially after 2020. The increase in technological pressure in 2022–2023 indicates a deterioration in the technological structure of exports and increased dependence on imported technologies.

In general, the increase in technological pressure in all product groups indicates that Ukraine is facing a technological deficit, as imported goods have a higher technological complexity than exported ones. This may lead to a decrease in the competitiveness of Ukrainian goods on the world market. It is worth noting that, despite the reduction of tariffs and improved access to EU markets under the DCFTA agreement, there is a reverse trend towards an increase in the technological gap in bilateral preferential trade.

Conclusions

The assessment results of technological disparities in Ukraine's trade with the EU within the DCFTA framework confirm the hypothesis of a negative trend in the dynamics of technological complexity of Ukrainian exports and imports. Technological disparities in preferential trade between Ukraine and the EU, as well as the tendency to their deepening, are obviously due to asymmetric levels of economic and technological development. The opening of the domestic market to more technologically advanced trading

partners leads to significant pressure on domestic producers, who face competition from products with higher added value and innovative potential. Although the opening of the domestic market can provide a certain impetus for the integration of new technologies, this effect is limited. The constant increase in technological pressure leads to the fact that national producers face additional difficulties in maintaining competitiveness, as well as the need to implement modern technological solutions, which requires significant investments and modernization of production.

When analyzing international preferential agreements from the point of view of technological pressure, it is necessary to take into account the need for protectionism of underdeveloped sectors of the economy. Opening markets to more technologically advanced partners may have an ambiguous impact on sectors that are unable to compete at the proper level. Under such conditions, protectionist measures, such as temporary restrictions on imports or support for national producers, may be justified to protect economically vulnerable sectors. This allows for a gradual increase in the technological complexity of products and adaptation of national producers to the conditions of tougher competition, which will contribute to a decrease in technological pressure in the long term.

Therefore, the authors suggest prospects for further research in substantiating objective criteria for selecting sectors of the economy that require additional support and a gradual increase in competitiveness in the context of deepening Ukrainian-European trade integration. For the state, such prioritization is the basis for developing balanced foreign trade strategies that take into account both the need to open markets and introduce new technologies, as well as the need to protect national producers in key but weaker sectors.

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