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Composite Index of the World Economy Technological Core Development: Methodological Framework

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ABSTRACT

The aim of the study is to develop and test approaches to constructing a composite index of the world economy's technological core development, represented by the United States of America (USA), the European Union (EU), and China. The research applies general scientific, economic, and econometric methods. **The methodological framework** is based on principal component analysis, which enables the integration of key indicators of global hypercompetition and the strategic autonomy of national economies. The index incorporates parameters reflecting the state and dynamics of the economy, infrastructure, and technological development. **The results** assess the degree of self-sufficiency of technological cores in terms of access to critical resources and their dependence on certain goods and export markets. Empirical testing of the composite index demonstrates that in the 21st century, China has significantly narrowed the gap with the EU and the USA, most notably in advanced technologies and access to strategic resources. The EU and the USA hold roughly comparable positions as technological cores; however, since the 2008–2009 global financial crisis, the EU's global competitiveness has been declining, reflected in its growing dependence on imports of knowledge-intensive information and communication technologies and research and development services. **Conclusion**. The proposed composite index clarifies theoretical approaches to the formation of a polycentric world economy, highlights the strengthened positions of new economic and technological centres, and provides a practical tool for assessing the maturity of technological cores.

Keywords: technological core; composite index; European Union; USA; China; global competitiveness; strategic autonomy

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Композитный индекс сформированности технологических ядер мирового хозяйства: методика построения

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АННОТАЦИЯ

Целью исследования является разработка и апробация подходов к построению интегрального индекса сформированности технологических ядер мирового хозяйства. В качестве технологических ядер рассматриваются Соединенные Штаты Америки (США), Европейский союз (ЕС) и Китайская Народная Республика (КНР). В исследовании применяются общенаучные, экономические и экономико-математические методы. **Методологическая основа** построения индекса базируется на методе главных компонент, позволяющем

интегрировать ключевые параметры глобальной гиперконкуренции и стратегической автономии национальных экономик. В состав индекса включены показатели состояния и динамики развития экономики, инфраструктуры и технологического уровня. **Полученные результаты** позволяют оценить степень самодостаточности технологических ядер с точки зрения доступа к критическим ресурсам, а также их зависимость от отдельных товаров и рынков сбыта. Апробация интегрального индекса показала, что в XXI в. Китай существенно приблизился к ЕС и США, особенно в сфере развития передовых технологий и обеспечения доступа к критическим ресурсам. ЕС и США занимают сопоставимые позиции как технологические ядра мирового хозяйства, однако после кризиса 2008–2009 гг. глобальная конкурентоспособность ЕС снижается, что выражается в росте зависимости от импорта наукоемких услуг в секторах информационно-коммуникационных технологий и научно-исследовательских и опытно-конструкторских работ. **Выводы**. Разработанный интегральный индекс уточняет теоретические подходы к формированию полицентричного мирохозяйственного порядка, выявляет укрепление позиций новых центров экономической и технологической силы и служит практическим инструментом для оценки зрелости технологических ядер.
Ключевые слова: технологическое ядро; интегральный индекс; Евросоюз; США; Китай; глобальная конкурентоспособность; стратегическая автономия

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1. Introduction

Domestic and foreign researchers observe an emerging tendency towards strengthening global hypercompetition processes, which is manifested in the rivalry of countries and integration blocs for access to advanced technologies and sales markets [1]. The world's leading economies are striving to ensure accelerated development of knowledge-intensive sectors of national production that create high domestic added value [2]. Equally important is the task of ensuring an advanced competitive advantage for national economies in terms of integration into the most profitable segments of global value chains [3].

Concurrently, the world economy is witnessing a steadily increasing 'neo-capitalistic neo-protectionism' [4, 5]. Contrary to a 'classical' trade protectionism characterised by prohibitive tariffs and other customs formalities, the new one hinges on alternative restriction measures towards mobility of goods, services, and production factors [6]. 'Core' economies exhibit a great interest in fostering vitally significant sectors of the national economy, relying heavily on restrictive barriers to intercountry interindustry trade in services, as well as intellectual properties (hereinafter — IP) and foreign direct investments (hereinafter — FDI). In recent years, FDI screening, or testing for threats to national economic interests, has increasingly been used in relation to such critical sectors [7]. Modern forms of protectionism represent increasingly less transparent methods and mechanisms for restricting international economic cooperation. The frequency and amplitude of crisis shocks in the global economy have increased significantly, which has made it necessary to take measures in order to ensure the strategic autonomy of the resource sector and manufacturing industry [8]. Giunta et al. [9] suggest that ensuring the sustainable functioning of national economies today requires government agencies to implement a set of measures to support the regionalisation of production chains, localisation of the extraction and processing of critical raw materials, as well as diversification of foreign economic relations.

The transformation of the structure of the technological cores of the world economy is described in the concept of 'wandering internationalised reproductive cores' by E.G. Kochetov [10], by which the author understands mobile production centres of the world economy, carrying out their economic activities on a global scale and forming a geo-economic picture of the world.

The technological core of the global economy at the present stage is defined as a country or integration association capable of maintaining a competitive advantage in the economy and technology, as well as supporting strategic autonomy in relation to third major production and technological centres [11, 12]. Technological cores determine long-term technological trends in the development of the global economy and establish standards and principles for intercountry economic interaction [13]. Technological cores, therefore, receive the bulk of global income in the form of technological rent, strengthening their dominance over developing economies [14].[1]

The scientific literature extensively studies the evolution of technological cores of the world economy from an evolutionary perspective. J. Arrighi convincingly demonstrated the movement of reproductive cores from Genoa and Holland to the modern United States of America (USA) and China. The evolution of long cycles of capital accumulation can be observed in the USA and China [15]. The "wandering" of reproductive nuclei is also characterised in the category of a spatio-temporal shift" by D. Harvey [16], driven primarily by activity of transnational enterprises [17]. Before the turn of the XXI century, the two key technological cores of the world were the United States and the European Union (EU). In recent decades, however, there has been a confident strengthening of China's position in the global economy [18].

Yet it is worth admitting that in the academic domain, there is no consensus regarding the evolution of technological cores and methodological approaches that determine the degree of their formation. As a scientific hypothesis, the authors of this article attempt to prove that the formation of a polycentric world order presupposes going beyond the dual system of global technological cores and the transition to a triple system of relations between the USA, the EU and China. This article develops theoretical approaches to constructing an integral index of the formation of technological cores of the modern world economy, which allows for their assessment and monitoring based on key parameters: global competitiveness and strategic autonomy.

2. Literature review

The current stage of formation and development of the technological cores of the world economy is unfolding in the context of increasing global geoeconomic fragmentation. One of its factors is recognised as the crisis of the globalisation model that existed before the global financial crisis of 2008–2009.[2] The United States and the European Union, as the technological cores of the global economy, have de facto ceased to view China only as an "assembly factory," as the People's Republic of China (PRC) has moved toward rapid expansion in the high-tech markets of Western countries [19]. Experts note the rapid convergence of the technological potential of China and the United States, especially after 2016 [20]. Growing instability in the global markets at the turn of the century is also claimed to be a significant factor in the recent fragmentation. A series of disruptions in transport and logistics chains, political and macroeconomic shocks in the global economy caused by the COVID-19 pandemic have predetermined the course towards strengthening the self-sufficiency of national economies, reducing dependence on external markets for production resources, capital and final sales [21].

The process of autonomisation (separation) of economic blocks in the global economic system, as an expression of its geoeconomic fragmentation, is reflected in the concept of "strategic autonomy" of technological cores [22]. In terms of implementing this concept, the practice of the European Union, which is actively applying measures at the supranational level to achieve technological and resource sovereignty, is particularly characteristic [23, 24]. It is underscored that the world economy's technological cores accumulate their intellectual, research, and financial potential [25]. According to Glazyev, the concentration of global production and innovation resources around technological forces third countries to pay "intellectual rent" and follow the economic strategies of technological cores. However, the disposition of technological cores in the world economic landscape is not static. Meanwhile, at the end of the 20th and the beginning of the 21st century, three key cores were identified in the literature — the European Union, the USA, and Japan; today, researchers define the EU, the USA, and China as technological cores. The latter has demonstrated unprecedented growth of the national economy in recent decades [26], which is particularly notable in the aftermath of the country's accession to the World Trade Organisation (WTO) in 2001, ensuring a large influx of FDI into the country's productive sectors [27].

Since the beginning of the 21st century, a number of quantitative indicators and indices have appeared in the research field, reflecting the development of processes of global hypercompetition, the formation of production and cooperation ties

[1] Organisation for Economic Co-operation and Development (OECD). The Geopolitics of Innovation. Paris: OECD Publishing; 2020. URL: https://www.oecd.org/innovation/geopolitics-of-innovation.pdf

[2] Rodrik D. Globalization's wrong turn. Foreign Affairs. 2019;98(4):26–33.

between countries in the process of globalisation of the world economy.

Examples include the World Economic Forum's Global Competitiveness Index, which assesses the level of development of a country's institutions, infrastructure, financial sector, and other areas of the economy and society. Hidalgo and Hausmann [28] have proposed the Economic Complexity Index, measuring the level of a country's technological development. One of the areas of scientific research in the field of strategic autonomy has become the development of complex methods for assessing the strategic significance of certain resources (technologies) [29]. It should be noted that existing indices do not fully reflect the processes and degree of formation of technological cores in the world economy in the context of geoeconomic fragmentation and increased protectionism.

In our opinion, there is a gap between the conceptual understanding of the logic for the development of technological cores in the modern world economic system and the need for a quantitative assessment of their formation using economic and mathematical methods [30]. Already elaborated indices do not fully allow for studying the nature of global hypercompetition amidst geoeconomic fragmentation and expanding protectionist policies. This determines the growing demand to develop theoretical and practical approaches to constructing integral indices of the degree of formation of technological cores in the modern global economy.

3. Methodology

3.1. Main stages of research

The transformation of the nature and development of the world economy's technological cores prescribes the need to upgrade existing methods of their assessment. The composite index method is one of the most preferable quantitative approaches, considering a wide range of economic and other aspects that are critical for technological cores.

In the present research, the authors attempt to develop a novel composite index that reflects the degree of sophistication of the main world economy's technological cores.

During the initial stage, a set of standards that the index must meet has been specified. First, the index needs to contain the main information that is present in the underlying indicators of global competitiveness and strategic autonomy. Second, the absolute values of the index have to be normalised so that they are comparable between different technological cores. Last but not least, it is required that the index be decomposable into subindices accounting for its specific structural components.

The second stage of research implied the selection of the most effective tools for the index compilation. The literature has a large body of composite indices that measure innovation activity, economic development, etc. They are broadly based on various multidimensional statistical techniques, including weighted linear aggregation, entropy weighting, scaling, factor analysis, and principal component analysis (PCA) [31]. The latter one is of particular analytical relevance since it enables representation of a set of initial parameters in the form of several artificial variables that provide the main 'information' of a sample [32]. In addition, it alleviates redundancy and multicollinearity and reveals the latent structure of observations. Practically, PCA is utilised in the creation of the Global Innovation Index (GII), Sustainable Development Index (SDI), Digital Economy and Society Index (DESI), as well as indices compiled by the United Nations (UN) and World Bank.

Hence, the PCA method has been chosen as a primary quantitative tool for the creation of the novel index. Specifically, the values of the index are comprised of the first principal component that, to a great extent, recreates the dynamics of underlying parameters.

In order to bring indicators having different units of measurement to a single scale, we apply the data normalisation procedure according to formula (1).

$$x_{i,j,norm} = \frac{x_{i,j} - \overline{x_j}}{\sigma_j}, \tag{1}$$

where $x_{i,j,norm}$ is the normalised value of an observation, *i* represents a specific observation (a country or an integration union in a given period of time), *j* is the initial variable, $\overline{x_j}$ represents the mean of *j* among all observations, σ_j and represents the standard deviation of *j* among all observations.

To comprehensively analyse the process of polycentric world order formation on the basis of three technological cores, a set of composite indices for each structural subblock is calculated (*Fig. 1*).

In the third stage of research, a set of basic parameters for each aggregated structural subblock of

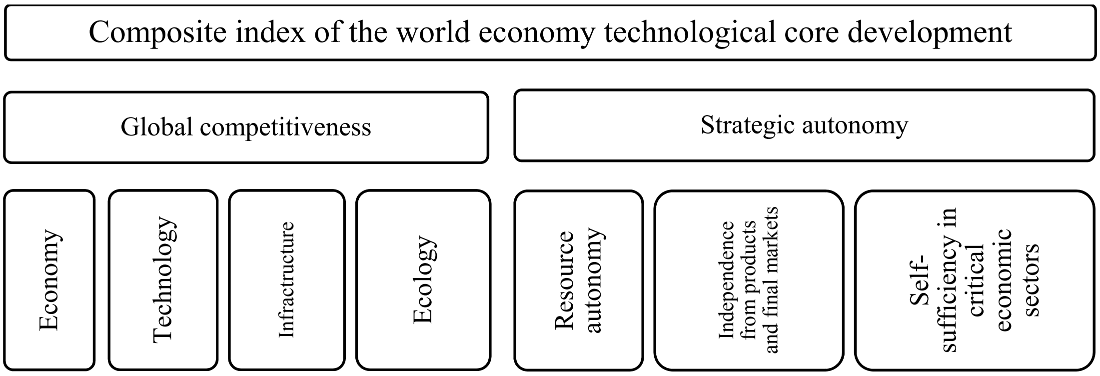

Fig. 1. **Structural subblocks of the Composite index of the world economy technological core development**

Source: Authors' elaboration.

the composite index (namely, global competitiveness and strategic autonomy) has been selected (*Table 1*). Importantly, all these indicators can be quantified and unambiguously interpreted.

Finally, during the fourth stage of research, the methodology presented above has been applied to the USA, the EU, and China for the period 2000–2023.

3.2. Baseline parameters of the "Global competitiveness" block

Today, the largest technological cores of the world economy find themselves involved in global hypercompetition for access to the key modern technologies, as well as to global final markets. Achieving success in such competition requires concerted actions to gain superior competitive advantages [33]. A commonly shared perspective is that broadly established economic development indicators (i.e., GDP, export volume, etc.) fail to uncover the whole nature of global hypercompetition.

The transition towards a new technological layout prioritises assessments of a country's innovation capacity and its investments into knowledge-intensive economic sectors. Maintaining critical infrastructure is crucial for ensuring technological leadership and sovereignty, which serves as a foundation for long-term international competitiveness. Finally, the nature of modern global hypercompetition dictates the necessity of responsible utilisation of natural resources and promotion of renewable sources of energy. To recap, in the present paper, the measurement of the positioning of world economy technological cores in global hypercompetition synthesises quantitative metrics representing certain aspects of economy, technology, infrastructure, and ecology.

Economy

The 'Economy' subblock comprises indicators of a country's position in the world economy and its macroeconomic performance. The share of world GDP is a critical measure of an economy's contribution to the global value added. The share in world exports accounts for a country's orientation to the global market, as well as its integration into inter-country economic relations. Thus, the share of world imports allows for assessing a country's potential as a final market for finished and intermediate products.

The share in world services exports or imports characterises a country's engagement in intercountry trade in intangibles as one of the most promising spheres of international economic cooperation [34]. In the present article, a share of the world's total inward and outward FDI stock is studied. The FDI stock represents a country's degree of control over priority sectors of other economies. Increasing values of the terms of trade index suggest that foreign trade becomes more profitable for a given country. By assessing gross fixed capital formation, one can judge the technological core's determination for the long-term investments in the production base.

To assess the overall macroeconomic performance of an economy and the efficiency of cooperation between certain economic sectors and agents, the authors estimate the rate of inflation and the level of unemployment. An advanced economy must demonstrate superior labour productivity that reflects how well the labour force performs different activities. Another indicator is the resource rent; the growth of the indicator suggests a decline in manufacturing and deterioration of the technological capacity of an economy [35]. Finally, the 'Economy' subblock includes the Human

Table 1
Parameters of global competitiveness and strategic autonomy of technological cores of the world economy

Subblock	Parameter	Unit of measurement	Source of data
Global competitiveness			
Economy	Share in world gross domestic product (GDP)	%	United Nations Conference on Trade and Development (UNCTAD)
	Share in world exports/imports of goods	%	UNCTAD
	Share in world exports/imports of services	%	World Bank
	Share in world total inward FDI stocks	%	UNCTAD
	Terms of trade	index	World Bank
	Economic complexity	index	Observatory of Economic Complexity
	Gross fixed capital formation	% of GDP	UNCTAD
	Rate of inflation (yearly est.)	index	UNCTAD
	Level of unemployment (average yearly est.)	%	World Bank
	Resource rent	% of GDP	World Bank
	Labour productivity	Per worker GDP, index, 2020 = 100	World Bank
	Human development index	index	United Nations Development Program (UNDP)
Technology	Research and development (R&D) expenditures	% of GDP	World Bank
	Share of high-end products in manufacturing exports	%	UNCTAD
	Share of Information and communication technologies (ICT) and computer services in services exports	%	UNCTAD
	Patents in 'green' and digital technologies	abs. number	Organization for Economic Cooperation and Development (OECD)
	Persons employed in R&D sector	per million of population	World Bank
	Publications in scientific journals	abs. number	World Bank
Infrastructure	ICT infrastructure advancement	index, from 0 to 100	UNCTAD
	Transport infrastructure advancement	index, from 0 to 100	UNCTAD
	Port container throughput	TEU	World Bank

Table 1 (continued)

Subblock	Parameter	Unit of measurement	Source of data
Ecology	CO2 emissions	Index, 2000 = 100	OECD
	Share of renewables in total energy consumption	%	OECD
	Energy intensity	tons per capita	OECD
Strategic autonomy			
Self-sufficiency in critical economic sectors	Share of domestic R&D in total R&D expenditures	%	OECD
	Share of domestic ICT in total ICT expenditures	%	OECD
Independence from products and final markets	Theil index for product structure of exports/imports	index	UNCTAD
	Theil index for geographical structure of exports/imports	index	UNCTAD
Resource autonomy	Arable land	% of total territory	World Bank
	Energy availability	index	UNCTAD
	Natural resources availability	index	UNCTAD

Source: Authors' elaboration: UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (accessed on 10.03.2025); OECD Data Explorer. URL: https://www.oecd.org/en/data/datasets/oecd-DE.html (accessed on 11.03.2025); World Bank Open Data. URL: https://data.worldbank.org/ (accessed on 11.03.2025); The Observatory of Economic Complexity. URL: https://oec.world/en (accessed on 15.03.2025); United Nations Development Program. URL: https://www.undp.org/ (accessed on 20.03.2025).

Development Index as an aggregate metric of the effectiveness of an economy and institutions in terms of quality of life [36].

Technology

The 'Technology' subblock covers metrics of a country's orientation towards high-end industries [37]. The share of world R&D expenditures indicates an amount of national income directed to investments in growing higher technology sectors. Share of high-technology products in total exports measures a country's competitiveness in the international knowledge-intensive product markets [38]. The share of ICT and computer services in total service exports represents a country's position in the global value chains' segments of intangible production with the greatest value-added. Considering the growing importance of 'green' and digital technologies as drivers of the world economy, it appears critical to account for the patent performance of countries as their superior competitive edge.

Infrastructure

The 'Infrastructure' subblock comprises indicators characterising the advancement of infrastructure and maintenance [39]. Specifically, indices of ICT and transport infrastructure capacity proposed by UNCTAD[3] are assessed in the paper. The former index represents accessibility and integrity of communication systems and cybersecurity. The latter index estimates transport connectivity and coverage, as well as airport performance. To account for a country's ability to act

[3] United Nations Conference on Trade and Development. Productive Capacities Index: 2nd generation. Enhanced statistical and methodological approach with results. Geneva: UNCTAD; 2023. (UNCTAD/ALDC/2023/2). DOI: 10.18356/9789213587171

as a marine transport hub, in this paper, we study the port throughput indicator calculated as the volume of standardised twenty-foot containers handled in the port per unit of time.

Ecology

The 'Ecology' subblock is the final component of the 'Global competitiveness' block. First, we analyse CO_2 emissions as an index with the year 2000 as the base level. It appears that in the modern geoeconomics reality, large technological cores of the world economy ought to accommodate low energy-intensive and eco-friendly production technologies, as well as to curtail harmful impact on the biosphere by implementing targeted industrial policies. In addition, the paper assesses another indicator of the effectiveness of national ecological policies: the share of renewables in total energy consumption. Presumably, advanced economies outperform other countries in incentivising businesses and individuals to austere energy consumption so as to contain a negative ecological footprint.

3.3. Baseline parameters of the "Strategic autonomy" block

A distinctive feature of contemporary technological cores' formation is the promotion of strategic autonomy, which implies achieving high self-sufficiency of the national economy and mitigating the risks of foreign economic ties' disruptions. Strategic autonomy is the top priority for large technological cores amidst increasing turbulence in global commodity markets, as well as growing demand for energy sources. Apart from securing continuous access to energy, another central goal for the main global production centres is to maintain food security.

Today, the existing model of international trade and production manifests itself in the form of a dense network of inter-country collaboration, where breaking certain linkages risks evoking a series of cascade shocks impacting other countries and regions. The above problem motivates the necessity to diversify trade and economic ties and to lower dependence on specific markets. Attaining sustained development of a technological core is unfeasible without securing self-sufficiency in critical economic sectors (such as R&D and information and communication technologies (ICT)). Thus, reaching strategic autonomy hinges on multiple parameters. Here in the paper, to assess strategic autonomy, we apply a set of indicators presented below.

Resource autonomy

Resource autonomy is hereby defined as a country's possession of energy and natural resources critical to the sustained functioning of an industry. Hence, the 'Resource autonomy' subblock comprises the share of arable land with respect to an overall country's territory, as well as UNCTAD energy and natural resources availability indices that are designed to represent self-sufficiency in both positions. Particularly, the natural resources availability index measures the volume of domestic raw materials per unit of industrial value-added.

Independence from products and final markets

In the paper, dependency is understood as a situation when a country's exports (imports) are largely comprised of a relatively small number of goods (services) or when it is restricted to a certain number of geographical partners. To quantify such dependency, we apply the Theil concentration index, formula (2), which growing values indicate deepening dependency [40].

$$T = \frac{1}{n \times m} \sum_{k=1}^{n} \sum_{j=1}^{m} \left(\left(\frac{X_{jk}}{\mu} \right) \ln \left(\frac{X_{jk}}{\mu} \right) \right),$$

$$\mu = \frac{1}{n \times m} \sum_{k=1}^{n} \sum_{j=1}^{m} X_{jk},$$

$$x_k = \sum_{j=1}^{m} X_{k,j} \times \left[\sum_{k=1}^{n} \sum_{j=1}^{m} X_{jk} \right]^{-1},$$

$$x_{k,j} = X_{k,j} \times \left[\sum_{j=1}^{m} X_{k,j} \right]^{-1},$$

$$T_p = \left(\sum_{k=1}^{n} x_k \times \ln x_k \right) + \ln n,$$

$$T_m = \left(\sum_{k=1}^{n} x_k \times \sum_{j=1}^{m} x_{k,j} \ln \left(x_{k,j} \times m \right) \right), \quad (2)$$

$$T = T_p + T_m,$$

where n is the total set of available (potential) products for exports (imports), m represents an overall number of available (potential) geographical partners in exports (imports), $X_{k,j}$ is the value of exports (imports) of product *k* respectively to partner *j*, x_k stands for a share of product *k* in total exports (imports), $x_{k,j}$ is a share of partner *j* in exports (imports) of product *k*, M represents the average value of exports (imports) (for all products and geographical partners), T is the overall Theil concentration index, T_p is the product Their concentration index, T_m is the geographical partners (per a single product) Theil concentration index.

Self-sufficiency in critical economic sectors

This subblock estimates the share of domestic content of total R&D and ICT services consumed in the country. In our assumption, such a metric indicates the extent to which national companies are capable of satisfying the demand of technology-domestic intensive industries for funding new research and innovations, as well as ensuring smooth communication and coordination of interfirm transactions. Considering higher global risks related to cybersecurity and counterfeiting of intellectual properties, it is essential for leading technological cores of the world economy to curtail dependency on foreign suppliers of critical services.

3.4. Building the composite index

The proposed approaches to calculating the composite index are based on principal component analysis, which is a multidimensional statistical tool designed to move from a large number of initial features to a small number of new artificial variables reflecting the basic "information" about the initial features. In other words, the algorithm allows one to combine individual indicators into a single composite index. In this case, according to the methodology, the assignment of weights to individual components of the index is performed automatically. The most weight is given to indicators with the largest variation among the observations in the sample (i.e., those that carry the most "information"). Due to this, there is no need to assign weights based on expert opinion, which makes the composite indicator less subjective and allows for a more accurate description of the general trend. The composite indices themselves become normalised; the level of deviation from the average value, represented by zero, characterises differences between the level of development of technological cores.

The reduction of indicators with different units of measurement to a single scale, as mentioned earlier, is carried out by the method of data normalization, formula (1).

Thus, as a result of combining all the initial indices, a composite index of the world economy's technological core development is formed. The partial composite indexes for each block and subblock are calculated in a similar way (two indexes for blocks and seven indexes for subblocks in total). Due to this, it is possible to ensure a comparison of the cores for each of the constituent components of the composite index.

4. Results

4.1. Global competitiveness

Economy

The resulting index of the 'Economy' subblock is presented in *Fig. 2*. According to the estimated values, it is the European Union that maintains the greatest global competitiveness in the economy throughout the XXI century. Nonetheless, the position of China has notably improved over the last two decades, while the gap between China and the USA has become even less than that between the USA and the EU. Based on the methodology applied, one can infer that the most significant positive factors behind economic competitiveness are high economic complexity and active outward FDI activity of a technological core.

Analysing the economic complexity index, one can infer several main takeaways. *Table 2* suggests that among all three studied technological cores, the EU, with Germany as a leading economy, has the most complex structure of production and exports. In 2023, the index value for the EU amounted to 2.1, whereas for China and the USA it was 1.3 and 1.6, respectively. Despite steadily lagging behind the EU and the USA, China demonstrates superior growth of economic complexity: the index increased by more than 110% over 2000–2023. Another important indicator that China constantly outstrips the EU and the USA in is gross fixed capital formation (*Table 3*). China invests a large 41.3% of its GDP in fixed capital; the EU and the USA invest 22.2% and 21.4%, respectively. It is important to highlight that the EU and USA show no changes in the index throughout the studied period. On the

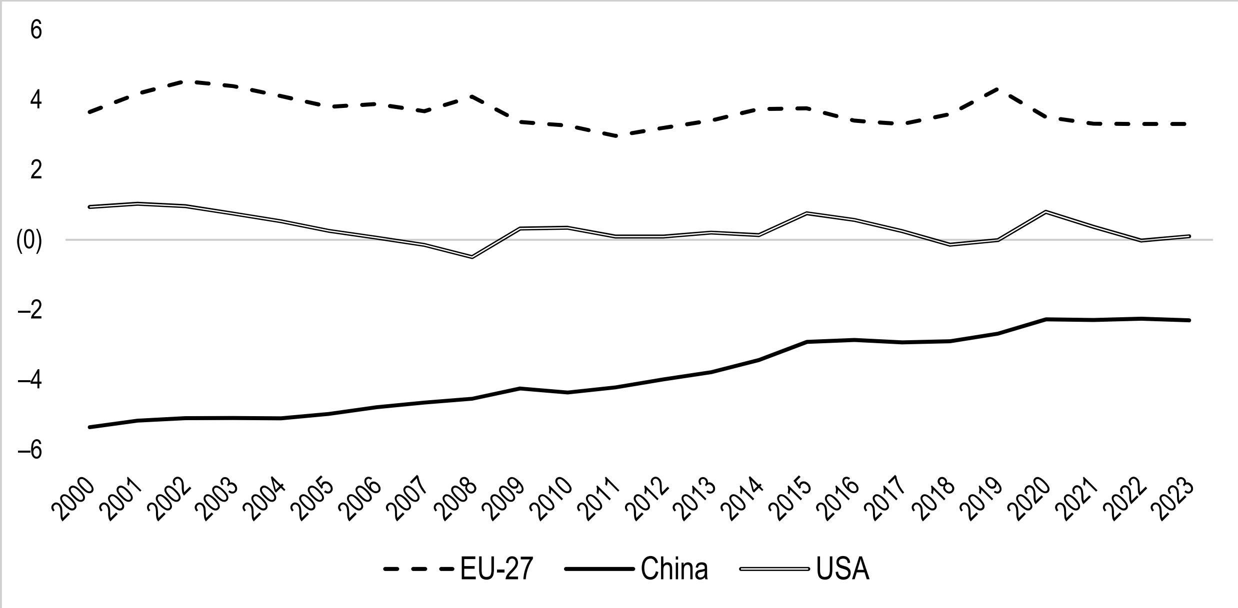

Fig. 2. **Composite index of the 'Economy' subblock of the 'Global competitiveness' block**

Source: authors' elaboration.

Table 2

Economic complexity index for the EU-27, China and the USA, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	2.30	2.15	2.03	2.24	2.11	2.01
China	0.62	0.74	0.96	1.13	1.22	1.33
USA	1.81	1.68	1.70	1.78	1.69	1.64

Source: authors' elaboration on The Observatory of Economic Complexity database. URL: https://oec.world/en (retrieved on 15.03.2025).

contrary, gross fixed capital formation in China has increased by 8 p.p., which can be considered a substantial success that lays the pathway for future competitiveness of the Chinese economy.

To conclude, a trend towards equalisation of the three technological cores' positions in the world economy with respect to global economic competitiveness is observable. Since the beginning of the XXI century, China has manifested substantial progress in almost every aspect of the world's economic relations.

Technology

Specific features of contemporary polycentric world formation can be viewed in *Fig. 3.* To begin with, one should note that, contrary to the economy, the Chinese gap with the EU and the USA in the technological sphere is diminishing rather slowly. According to our estimations, it was only in 2021 that China managed to achieve the technological power that the EU demonstrated in 2004. The USA is a standalone leader among technological cores in terms of global technological competitiveness. However, the EU's gap with the USA is by no means critical. The study revealed that modern technological competitiveness hinges primarily on funding innovations, publishing activity, as well as hiring new researchers.

The values presented in *Table 4* suggest the USA is the leading technological core in funding innovations: the share of R&D expenditures in GDP was equal to 3.7% in 2023.

To compare, the EU spent only 2.3% of GDP on funding innovations in the same period. The dynamics of the indicator in China are admirable. In 2000, the share of R&D expenditures in GDP totalled a meagre 0.9%, but up to 2014 it reached 2.0%, and in 2023 its value exceeded 2.5%, thus

Table 3
Gross fixed capital formation, % of GDP, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	22.83	21.98	20.65	20.17	22.03	22.19
China	33.43	39.43	43.93	42.09	42.49	41.34
USA	23.15	22.93	18.31	20.65	21.59	21.39

Source: authors' elaboration on the United Nations Development Programme database. URL: https://www.undp.org/ (retrieved on 20.03.2025).

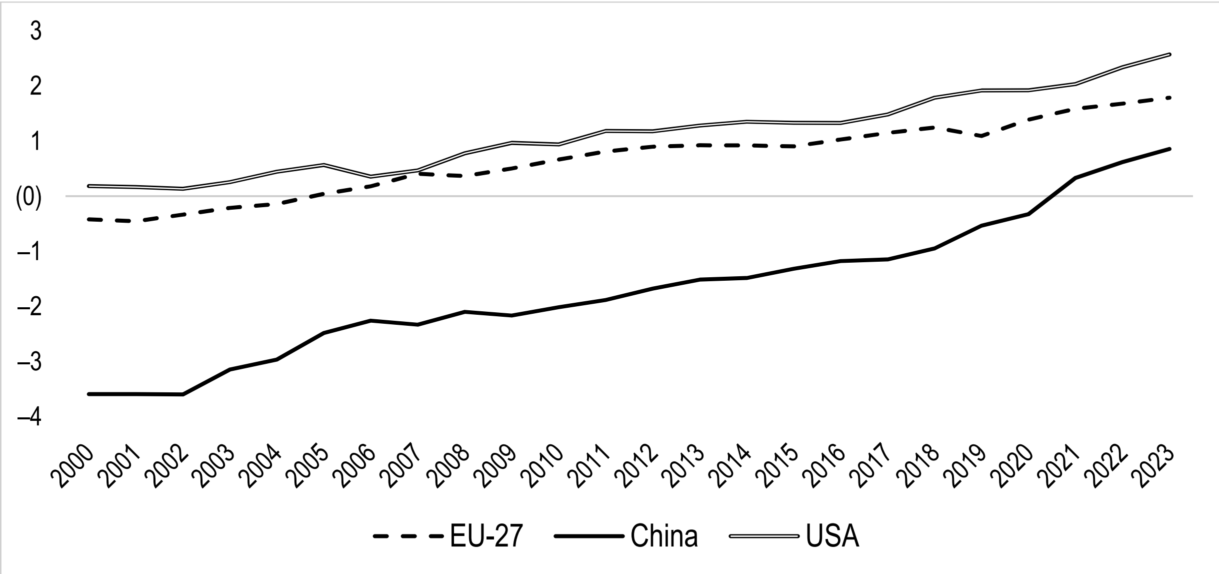

Fig. 3. **Composite index of the 'Technology' subblock of the 'Global competitiveness' block**

Source: Authors' elaboration.

outstripping the level of the EU. Hence, China unambiguously bets on technological growth as a basis of its strategic autonomy in the world economy.

Infrastructure

Securing domestic infrastructure is of top priority for long-term national competitiveness. First and foremost, it refers to maintaining the performance of seaports, improving ICT technical potential, and upgrading logistic infrastructure.

As can be seen in *Fig. 4*, the USA maintains leadership among the three analysed technological cores in this domain. The European Union continuously lags behind the 'American core' with co-directional dynamics of the index. Chinese lagging behind the USA and the EU appears more evident and constant. The country barely manages to sustain a stable trajectory of ICT and logistics infrastructure development.

The USA is leagues ahead of other technological cores in transport infrastructure advancement, as suggested in *Table 5*. In 2023, the respective indices for the USA totalled 50.4, whereas for the EU it was only 48.6 and for China, even more modest, 38.1. Notably, over the course of the first decades of the XXI century, the American transport infrastructure development has been generally high, a trend supported by the index values steadily exceeding 60. Over the period of 2000–2011, China successfully upgraded its transport infrastructure — a respective index increased from 28.0 to 38.1 points. However, in the following years, no dynamics were observed.

Ecology

Figure 5 suggests that since the turn of the XXI century, both the EU and the USA have progressed in the transition to a 'green' economy, in spite of the fact that the USA moderately ceded their leading position to the EU after 2010. China, on the other hand, significantly lags behind the other major technological centres of the world economy regarding ecological aspects. The convergence between respective values of the index

Table 4
R&D expenditures, % of GDP, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	1.76	1.78	1.97	2.12	2.30	2.32
China	0.89	1.31	1.71	2.06	2.41	2.56
USA	2.62	2.50	2.71	2.79	3.47	3.67

Source: The authors' elaboration of the United Nations Development Programme database. URL: https://www.undp.org/ (retrieved on 20.03.2025).

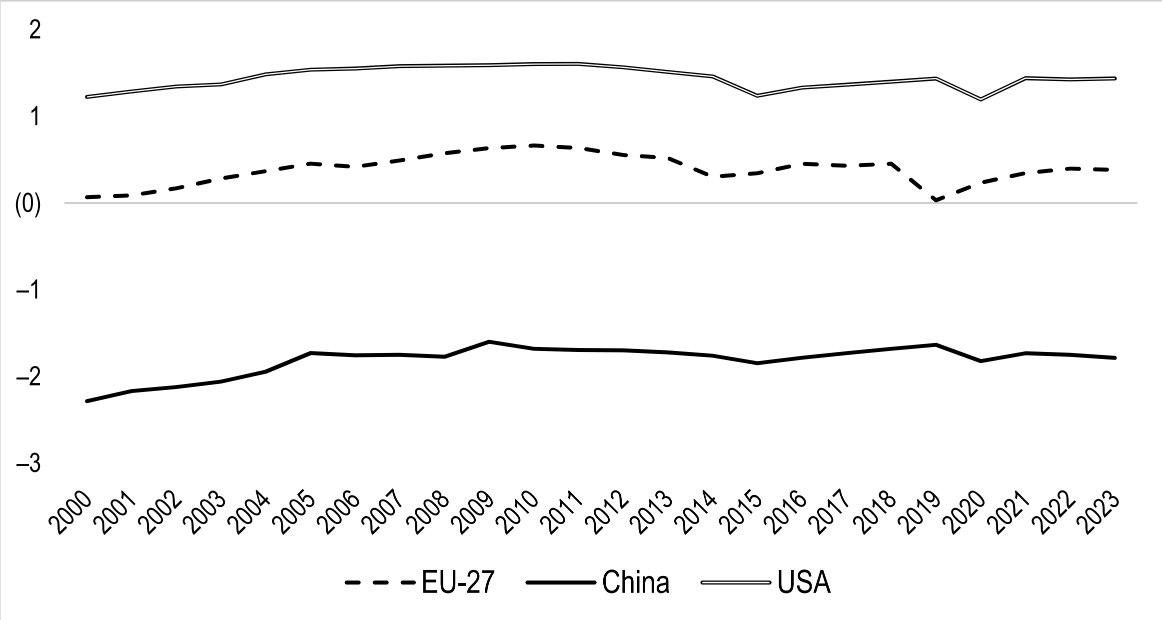

Fig. 4. **Composite index of the 'Infrastructure' subblock of the 'Global competitiveness' block**

Source: Authors' elaboration.

Table 5
UNCTAD Transport Infrastructure Index, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	52.10	53.30	55.10	49.20	44.90	48.64
China	28.30	34.10	37.80	36.80	37.30	38.09
USA	64.70	65.20	64.80	58.50	55.00	58.40

Source: Authors' elaboration on UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (retrieved on 10.03.2025).

for the three technological cores is absent during the whole studied period.

From 2000 to 2023, the European Union has successfully reduced the amount of CO_2 emissions by 10% (*Table 6*).

The United States managed to reduce CO_2 emissions by a substantial 24%. Concurrently, since the turn of the XXI century, China has demonstrated exactly the opposite dynamics. The amount of carbon emissions produced in China increased by a drastic 278% over the last two decades. In our opinion, considering the scale of the Chinese economy, such a tendency basically annihilates the efforts of the global community to promote a low-carbon economy.

By examining the composite index of the 'Global competitiveness' block, one can infer that over the whole interval under consideration, the USA demonstrated a continuous strengthening of competitive positions in the world economy (*Fig. 6*).

During the period of 2000–2023, the European Union has not sacrificed competitive positions

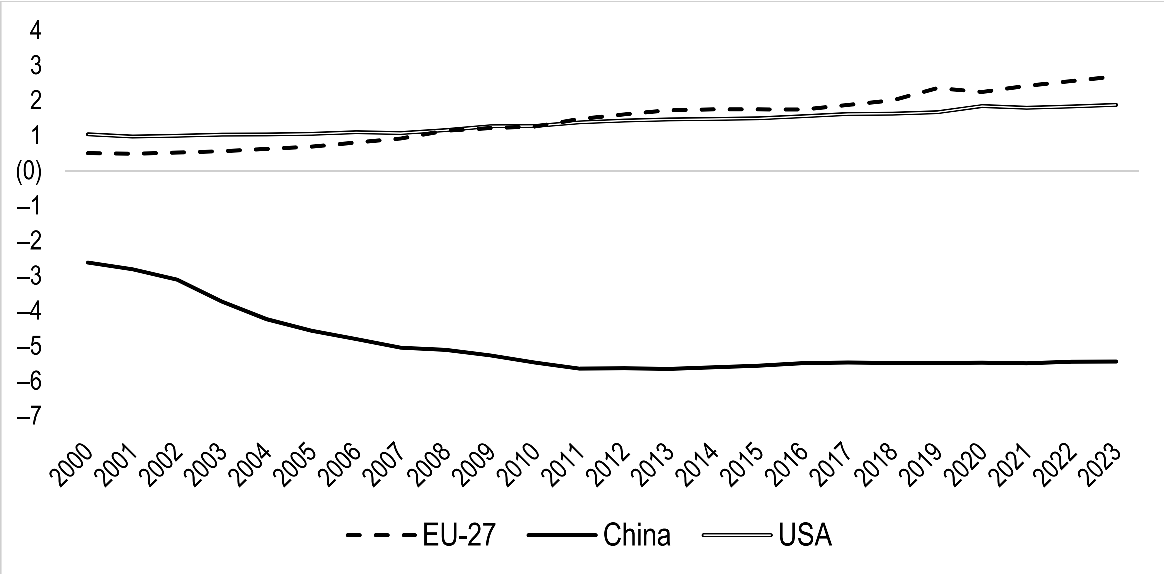

Fig. 5. **Composite index of the 'Ecology' subblock of the 'Global competitiveness' block**

*Source: A*uthors' elaboration.

Table 6

CO_2 emissions, index, 2000=100 points, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
EU-27	100.00	103.78	96.00	86.48	73.35	90.50
China	100.00	174.58	252.82	294.93	324.58	377.70
USA	100.00	99.53	93.41	86.02	74.31	75.80

Source: Authors' elaboration on World Bank Open Data. URL: https://data.worldbank.org/ (retrieved on 11.03.2025).

among technological cores. In the XXI century, China became a considerably larger geoeconomic power capable of preserving its actorness amidst global competition. The convergence of production and technological potential of the three cores is observed, which indicates the formation of a polycentric order in the global economy.

Figure 7 suggests that, according to the model, technologies and infrastructure are the most critical prerequisites of global competitiveness. The obtained results echo existing research on the role of innovations and servicing infrastructure, which supports the validity of the proposed methodology.

4.2. Strategic autonomy

Self-sufficiency in critical economic sectors

Figure 8 presents the composite index of the 'Self-sufficiency in critical economic sectors' subblock. Its values indicate that the USA is fairly independent from other countries in R&D and ICT. This allows American high-end manufacturing to leverage the risks of shocks originating in the global economy. China incrementally improves its self-sufficiency in critical industries. In 2023, the EU's domestic supply share in total R&D and ICT services consumption equals 87% and 83%, respectively, a level which might be considered low (*Table 7*). China's share of domestic value-added in the R&D sector is around 94%, whereas in the ICT industry it is only 88%. The USA maintains high self-sufficiency in both sectors.

Independence from products and final markets

Today, lowering dependence on foreign markets and specific traded products is one of the mainstays of achieving strategic autonomy of a national economy. To estimate the composite index of the 'Independence from products and final markets' subblock, the authors apply the Theil concentration index calculated separately for products and geographical partners in both exports and imports (*Fig. 9*).

The European Union is, to a large extent, independent from trade partners and certain goods among technological cores under consideration. The

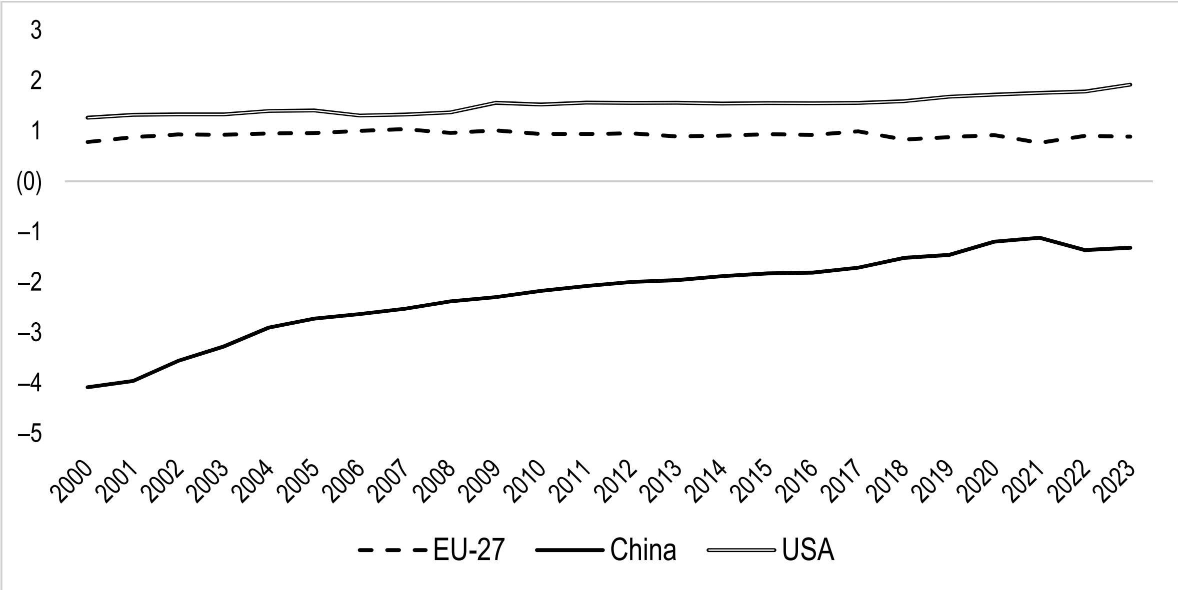

Fig. 6. **Composite index of the 'Global competitiveness' block**

Source: Authors' elaboration.

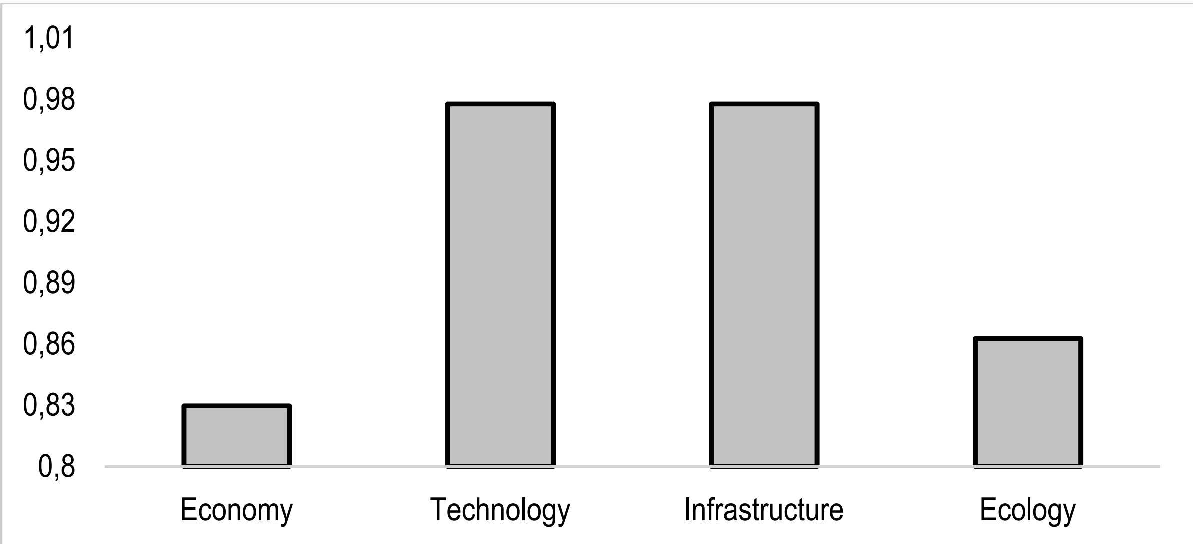

Fig. 7. **Aggregate contribution of specific subblocks in the composite index of the 'Global competitiveness' block, 2000–2023**

Source: authors' elaboration.

USA and China are much more dependent on the structure of their foreign trade. Nonetheless, China gradually diversifies its trade ties between different products and geographical partners. A considerable achievement of China is a notable expansion of the number of final markets: the Theil index has slumped from 3.0 points in 2000 to 2.1 points in 2023.

Resource autonomy

An important aspect of attaining strategic autonomy of a national economy is resource autonomy. The term 'resource' used in the calculation of the respective index (*Fig. 10*) encompasses arable land, natural resources, and energy in its various forms. In order to quantifiably estimate the self-sufficiency of technological cores in critical resources, the authors study the share of arable land, as well as the UNCTAD Index of accessibility of natural resources and the Index of energy accessibility.

As of 2023, the most autonomous in natural resources among technological cores is the European Union (*Fig. 10*). At the same time, the United States demonstrated a comparable trend. China's resource autonomy is relatively weak; however, by 2023, its gap with the EU and the USA will have considerably shortened.

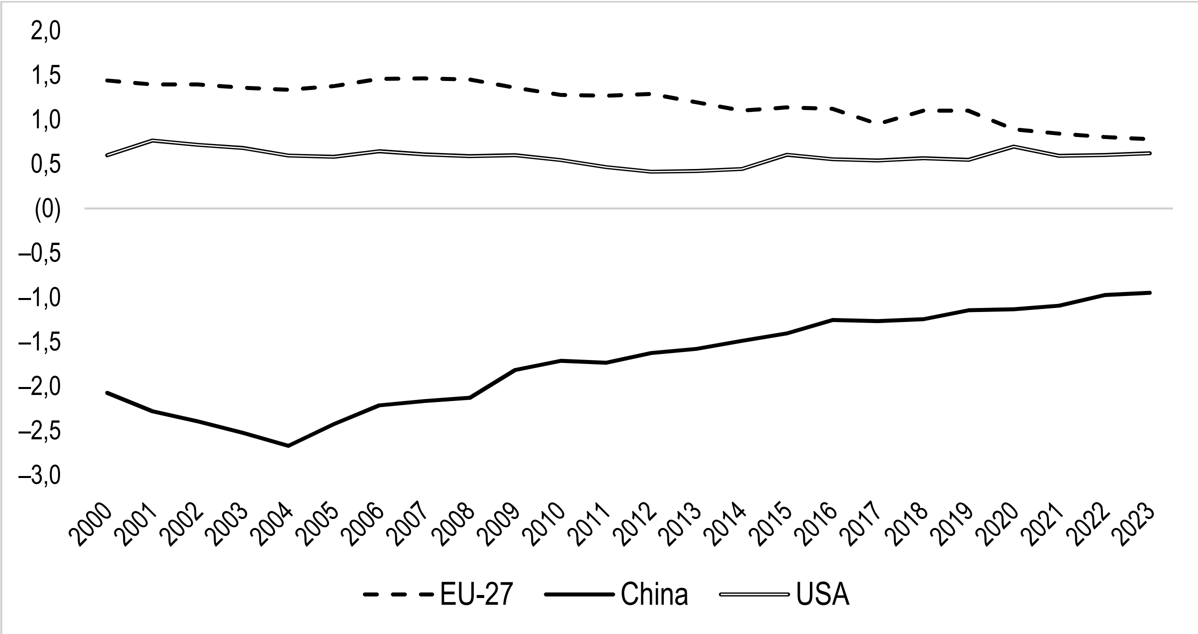

Fig. 8. **Composite index of the 'Self-sufficiency in critical economic sectors' subblock of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

Table 7

Share of domestic value-added in total R&D expenditures, %, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
	Domestic value-added, % of total R&D expenditures					
EU-27	93.68	93.22	92.99	90.69	88.52	87.17
China	87.70	77.60	85.41	87.88	92.07	94.15
USA	96.85	96.01	94.99	94.93	96.10	96.56
	Domestic value-added, % of total ICT consumption					
EU-27	91.71	91.29	90.04	85.62	85.65	83.39
China	91.73	90.55	91.69	89.47	88.66	87.94
USA	97.05	96.60	95.92	95.47	95.60	95.66

Source: authors' elaboration on OECD Data Explorer. URL: https://www.oecd.org/en/data/datasets/oecd-DE.html (retrieved on 11.03.2025).

According to *Table 8*, in 2023, the share of arable land in the EU was 24.7% — the greatest level among all three technological cores. This can be viewed as a serious competitive advantage for the European economy in terms of food security. The USA is placed second, with the respective index being equal to 16.5%. China has the lowest share of arable land in the sample, at only 11.4%.

Accessibility of natural resources is the parameter in which China maintains sustained leadership; in 2023, the value of the respective index for the country totalled 39%. In the same period, the EU's value of the index was equal to 25%, while for the USA it amounted to 27%. Meanwhile, China experiences a dramatic decline in the index value, having lost 10 p.p. since 2000.

Figure 11 presents the composite index of the 'Strategic autonomy' block.

The European Union remains the most autonomous among all three technological cores under study, despite its weakening over the last years. In its turn, the United States continues to be self-sufficient in critical economic sectors, while it is still reliant on several geographical passports in foreign trade. At the very turn of the XXI century, China was heavily dependent on external resources, technologies, and final markets. Nonetheless, over the past fifteen years, the country has gradually improved its autonomy, coming close to matching the EU and the USA in relative terms. This indicates a tendency among technological cores to attain strategic autonomy, which

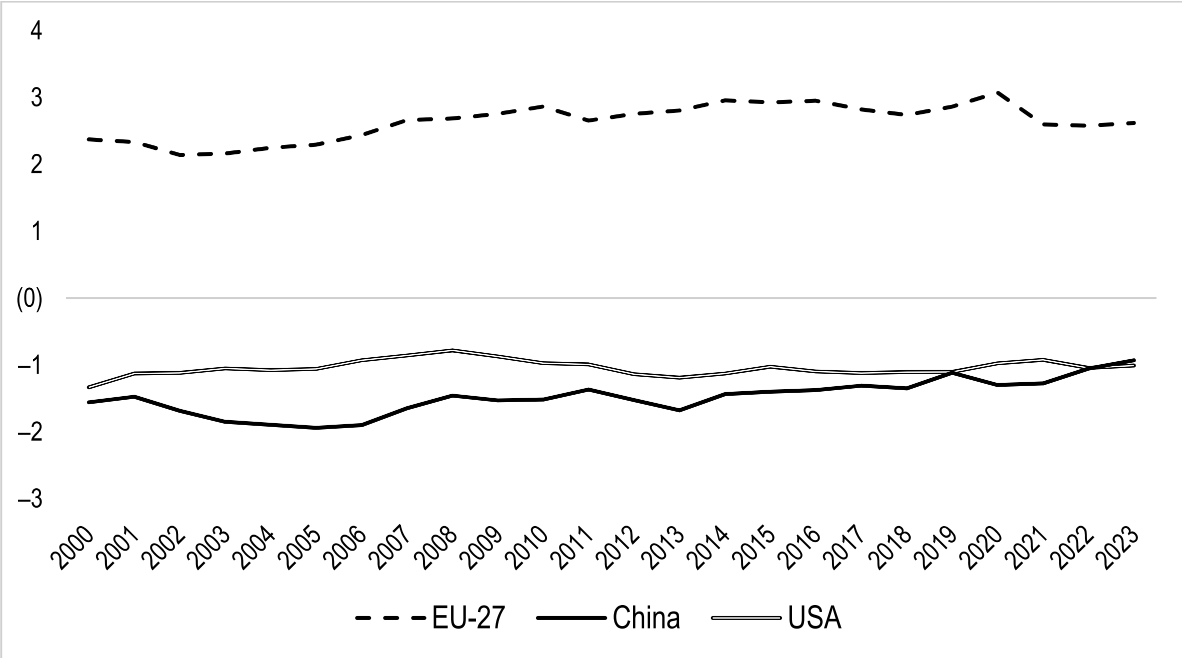

Fig. 9. **Composite index of the 'Independence from products and final markets' subblock of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

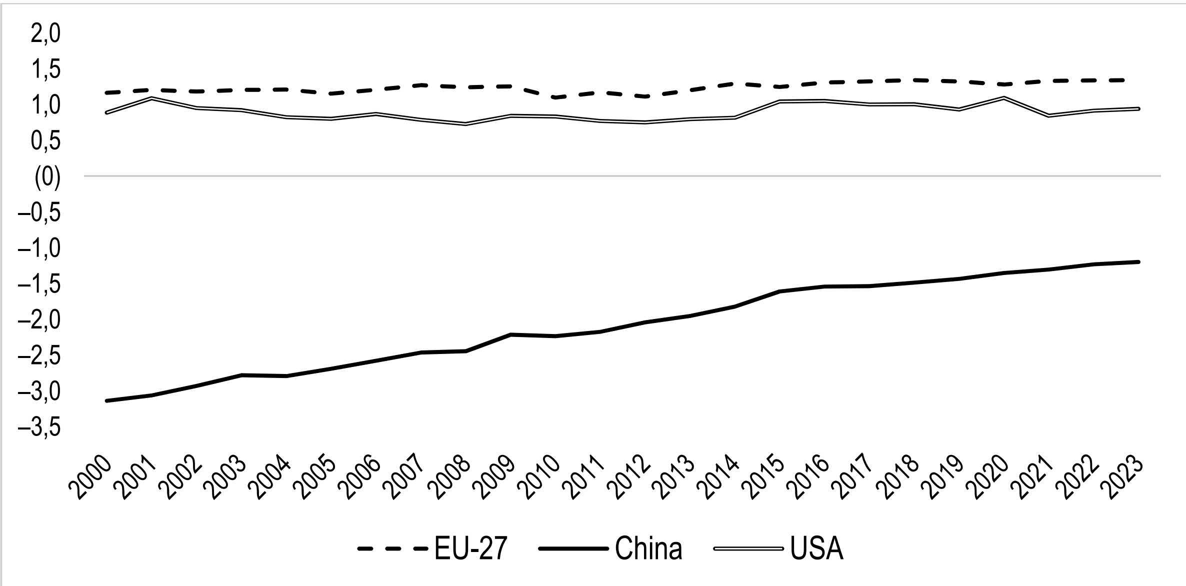

Fig. 10. **Composite index of the 'Resource autonomy' subblock of the 'Strategic autonomy' block**

Source: Authors' elaboration.

is also an argument in favour of the formation of a polycentric world order.

Finally, the composite index of the world economy technological core development calculated for the EU, the USA, and China is depicted in *Fig. 12*. It reveals several overarching trends of technological cores' formation in the XXI century.

Before the global financial crisis of 2008–2009, the general level of technological core development of the EU and the USA was comparable. Afterwards, an expanding gap between these two cores is observed; thus, the United States is now the largest technological core of the world economy with respect to both global competitiveness and strategic autonomy. The negative trend attributable to the European Union aligns with a commonly held academic conception of a serious crisis that the European economy is now facing. The above propositions are convincingly voiced by M. Draghi in his report entitled 'The future of European com-

Table 8

Arable land (% of total land) and UNCTAD Index of natural resources accessibility, 2000–2023

Technological core	2000	2005	2010	2015	2020	2023
	Arable land (% of total land)					
EU-27	27.41	25.99	25.30	24.99	24.85	24.72
China	12.68	12.85	12.80	12.24	11.58	11.38
USA	19.15	18.88	17.68	17.10	16.83	16.48
	UNCTAD Index of natural resources accessibility					
EU-27	29.60	28.10	27.80	25.80	24.80	24.77
China	47.80	48.10	47.50	42.00	39.80	39.16
USA	30.60	30.80	28.30	24.70	25.10	26.57

Source: authors' elaboration on UNCTAD Data Hub. URL: https://unctadstat.unctad.org/EN/ (retrieved on 10.03.2025).

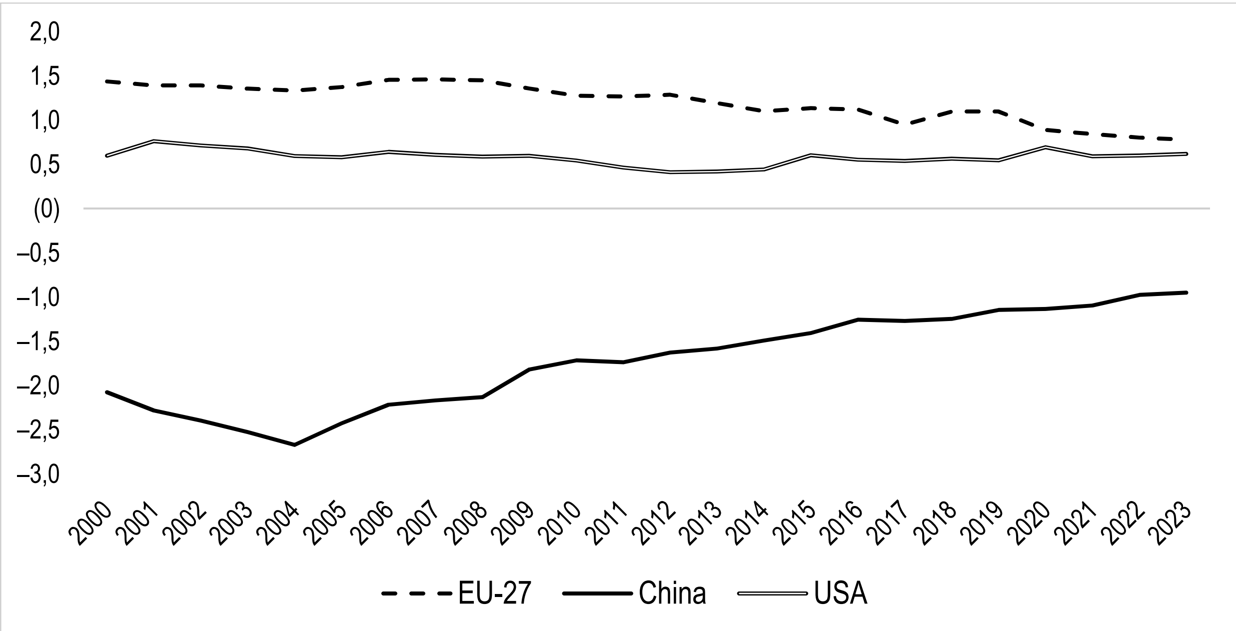

Fig. 11. **Composite index of the 'Strategic autonomy' block**

*Source: A*uthors' elaboration.

petitiveness'.[4] Nowadays, the European Union confronts a series of challenges posed by a diminishing share of its economy in global GDP, increasing dependence on resource and component supplies. This trend is particularly evident in electric car manufacturing, where a sheer amount of critical raw materials (i.e., dysprosium, neodymium, etc.) is supplied by China. In the present study, a growing dependence of the EU on vitally important services sectors (ICT and R&D) has been uncovered. The problem is not yet fully elaborated in academia. Meanwhile, the European Union favours a highly diversified foreign trade profile that is essentially a prerequisite for the long-term sustainability of a technological core amidst crises in the world economy [41].

Conceptually, the obtained results correlate with existing research. Russian researchers [42] highlight that an accelerated growth of China as a global technological superpower is largely predetermined by a unique combination of institutional reforms and effective structural policy, as well as a high capital accumulation ratio (reaching 44% of GDP). Another crucial factor behind Chinese technological core formation is a transition from a simple export-led model to a strategic positioning in the world economy — promoting new integration initiatives (BRICS, SCO), financial institutions, etc. [43].

[4] European Commission. The Draghi report on EU competitiveness. URL: https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en

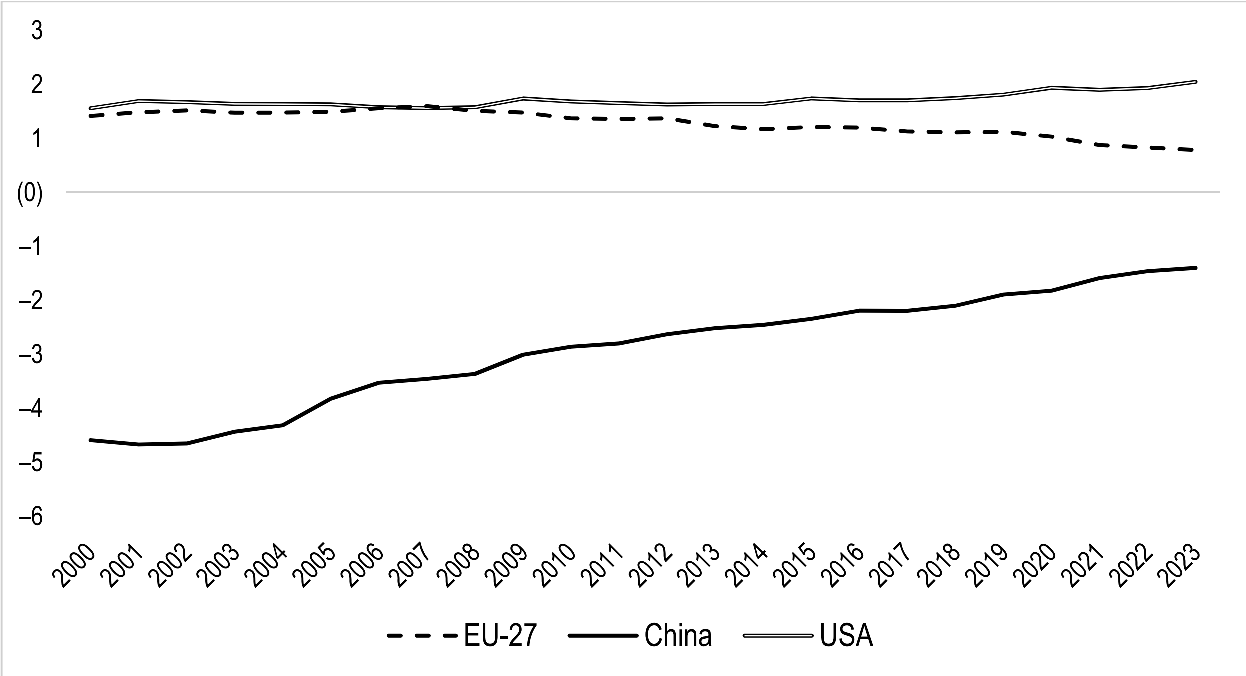

Fig. 12. **Composite index of the world economy technological core development calculated for the EU, the USA, and China, 2000–2022, with zero being a medium level**

Source: Authors' elaboration.

Summing up, over the course of the first quarter of the XXI century, China is rapidly reducing the gap with the USA and the EU. Nonetheless, according to our estimations, the variation coefficient of the difference between values of the composite index for three technological cores amounted to 34% in 2023, indicating a persisting high level of Chinese lagging behind the EU and the USA.

5. Conclusions

This article presents approaches to constructing an integral index of the formation of technological cores of the world economy, using the USA, EU and China as the empirical base. The integral index includes key indicators of global hypercompetition and strategic autonomy of technological cores in the context of a growing trend towards neo-protectionism. The baseline indicators are publicly available, which ensures the reproducibility of our results and allows for the assessment of the index dynamics in the future. In addition, the applied principal component method as a tool for combining individual indicators into a single index also allowed for obtaining separate sub-indices for individual blocks of hypercompetition and strategic autonomy. This facilitates the search for the root causes of trend development and the transformation of relationships between technological cores.

The empirical estimation of the proposed composite index indicates a qualitative growth of the competitive positions of China in the world economy. At the same time, our calculations indicate the existing gap between the PRC and the "Western" cores. According to the obtained values, the competitive positions of the EU and the USA are maintained at approximately the same level. At the same time, after the 2008 crisis, the situation of the European core has worsened [44].

In conclusion, it is worth highlighting some of the individual results that shed light on current aspects of the formation and development of the technological cores of the global economy. Firstly, as the analysis of the economic complexity indicator showed, the EU industry produces more complex and knowledge-intensive products than the USA and China. Secondly, in terms of the amount of investment in R&D in relation to GDP, China has currently overtaken the EU indicator, continuing its confident growth. Thirdly, the United States maintains its leadership in terms of the development of transport and logistics infrastructure. Since the beginning of the XXI century, China has experienced a stagnation in this sphere. Fourthly, China is showing negative dynamics in carbon dioxide emissions, the volume of which has increased almost threefold over the past two decades. Fifth, the European technological core is strengthening its strategic dependence in the key service sectors of the new order. In other words, high-end manufacturing in the EU is increasingly served by external technologies and communications. Sixth, the geographical structure of EU foreign trade is more diversified between individual sales markets than in the case of the USA and China. Last but not least, our analysis of the natural resource availability index showed that the PRC currently maintains a confident leadership in the degree of self-sufficiency in natural resources, primarily in critical raw materials of the new technological order.

To conclude, the presented method of constructing the integral index allowed for the identification of the current trends of three modern technological cores of the world economy, namely the USA, the European Union and China. The obtained results confirm the accelerated strengthening of the geoeconomic position of China. Future research could focus on examining the correlation between the novel index and the indicators of a country's or macroregion's institutional and political structure.

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