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Research article

Technological modernization of the national economy as an indicator of green finance: Data analysis on the example of Russia

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Abstract: *Background:* In Russia, there is no publicly available information to analyze green finance, but companies claim significant amounts of raised funds that are labeled as green. Green finance and technological modernization are interrelated processes. Therefore, the focus of the research is to find an answer to the question: has green finance had an impact on the technological modernization of Russian industry? *The goal* is to find indicators that confirm the real, not imaginary, nature of green finance. *The research method* is based on statistical analysis with presentation of consolidated data in graphical and tabular form. Assessment of the degree of penetration of the green economy is carried out through analyzing the ongoing changes in the structure of industry. *Results:* The available green finance has not had an impact on the technological modernization of the Russian industry. The creation of a new green segment of the national financial market is blocked by the conservative structure of the economy. *Conclusions:* The results of this study provide a methodological basis for the development of solutions on how to properly build the mechanism of accumulation of financial resources for the purposes of green transformation of the economy. Another significant contribution of our study is the convincing, empirically based and verifiable evidence that green economy and technological modernization are two sides of the same coin. Financing investment projects that do not lead to technological modernization is not green and generally sustainable financing.

Keywords: sustainable development; green economy; technological modernization; investment process; green investments; green finance; sustainable finance; climate finance; national economy; industrial production

JEL Codes: O11, O14, O16, F65

1. Introduction

Since the second half of the 20th century, the global system of economic transformation has been increasing based on the principles of sustainable development. Numerous discussions held on the topic of sustainable development under the auspices of the United Nations have largely been framed in terms of the policy of different countries' responses to numerous global crises (Le Blanc, 2015). Within this framework, sustainable development is to be achieved through the implementation of various technological transformations that set out to modernize the crisis-prone traditional economic model in the direction of a new more sustainable economic model, which is also widely referred to as the green economy (Mingaleva et al., 2022).

Since building a new sustainable economic model is a major modernization project, involving the commitment of colossal resources, countries must be properly motivated to implement the required technological transformations. The UN Technology Facilitation Mechanism (TFM) created on the UN platform for this purpose is defined by paragraph 70 of UN Resolution A/RES/70/1 "Transforming our World: The 2030 Agenda for Sustainable Development", which was adopted in 2015 (UN Resolution A/RES/70/1, 2015). This mechanism, which comprises four major elements, is designed to support technological transformations across a wide range of accumulated socio-economic development problems (UNTFM, 2015). The directions of transformations are determined by the sustainable development goals (SDGs) as set out in UN Resolution A/RES/70/1.

An integral part of the modernization process involves the formation of a sustainable financial segment, whose development at the national level requires a coordination of efforts between the state and the private sector (Glass and Newig, 2019; Khurshid, et al., 2022). Systematic progress in this direction entails the implementation of an institutional environment for green and sustainable financing (Tolliver, et al., 2021; Varkey et al., 2021). Thus, a successful approach to the formation of national financial market regulation policies motivates investors to finance the most appropriate solutions to current development problems at the same time as ensuring the greatest stability of the national financial market and the national economy (Yakovlev, et al., 2020; Hess, 2022; Yakovlev and Glukhov, 2023).

The United Nations Framework Convention on Climate Change (UN FCCC) Technology Mechanism, which was formed before the creation of the TFM, aims to accelerate the development process and transfer of new technologies to ensure the achievement of the goals of the UN FCCC and subsequent Paris Agreement. This goal is integrated into the UN Resolution A/RES/70/1 in the form of SDG 13, representing one of 17 sustainable development goals (SDGs). The development of the technology mechanism and directions of its transformation has long been the topic of open discussion by policymakers from all countries of the world as a means of transforming the economic model in the direction of reducing its carbon intensity (Kabir, 2024). However, it may be objected that the high priority given to the proposed transition to a low-carbon (or even carbon-free) economy as a means of

tackling climate change has tended to push other sustainable development problems into the background.

Today, most countries are engaged in constructing mechanisms in almost every developmental sector to stimulate the desired technological transformation. For example, such activities take place in areas of the circular economy (Agrawal, et al., 2024), energy (Mingaleva and Shpak, 2015; Li et al., 2021; Hossin et al., 2024), in the agricultural sector (Mingaleva, 2018; Liu, 2023), waste management (Mingaleva et al., 2020), the banking industry (Miralles-Quirós et al., 2019; Rahman et al., 2022), etc. While differing in the degree of implementation, such mechanisms are congruent with the aims of the TFM and the UN FCCC Technology Mechanism to promote the dissemination of new technologies and concentrate financial resources in certain sectors of the economy.

Despite many apparent successes, serious obstacles have been encountered on this path (Farrell and Löw Beer, 2019). Research conducted by the UN indicates that, despite the efforts of countries and international financial institutions to develop green finance for green technologies, the financial architecture has proven inadequate to mobilize predictable, long-term, and large-scale financing to support investments for sustainable development (Our common agenda, 2024).

Based on numerous intergovernmental and multilateral consultations held by the UN in 2022–2023 and guidance from UN Member States, six areas of the international financial architecture have been identified as requiring urgent reform. Three of these are directly related to the mechanism of financing sustainable development, i.e., green finance. Table 1 sets out these areas along with key challenges requiring reforms at the national level.

Table 1. Areas of the international financial architecture subject to reform and key challenges to the functioning of the international financial architecture, which are significant for green finance[1].

Area	Key challenges
International public funding	(1) Lending by multilateral development banks is low by historical standards, as shareholders have not increased their stakes in line with global economic growth and the need for investment in sustainable development; (2) The amounts mobilized from the private sector for sustainable development are far below what the World Bank called for in 2015, indicating that the current model for mobilizing private capital is ineffective; (3) There is a lack of coordination on development finance among multilateral development banks, as well as between them and the broader system of public development banks; (4) The policies of multilateral and public development banks aimed at sharing risks to create an enabling environment for sustainable development investment and their business models for mobilizing capital are ineffective.
Reviewing the rules of the financial system to ensure stability and sustainability	(5) Financial markets are not aligned with the SDGs; (6) There is disagreement on how financial institutions should adapt to the risks that arise when taking into account business impacts on climate change and other factors that affect the achievement of the SDGs;
Debt relief and lower cost of sovereign debt	(7) There is no accessible financing for investments in achieving the SDGs

[1] Source (Our common agenda, 2024).

Thus, the following questions arise:

1. If UN studies state that there is no effective green financing mechanism at the global level due to the unsuitability of the global financial architecture, and independent experts identify disparate attempts by different countries to build mechanisms for financing technological modernization in individual sectors of the national economy, can these efforts of countries be recognized as effective actions to build a new sustainable green economy?

2. If the current state of the global financial architecture prevents countries from jointly building an effective global green financing mechanism, is it possible for individual countries to integrate a green financing mechanism into the national financial system, representing an element of the global financial system?

3. If countries justify state support for technological transformations of individual sectors of the national economy according to their special significance for the socio-economic development of the country and/or technological sovereignty, how valid are the claims that the investments attracted to these sectors are green and that a green financing mechanism has actually been formed?

4. If a country's statements about targeted actions to build a green economy within the boundaries of national jurisdiction are accepted as credible, how can this be confirmed as what is actually happening? Will it be sufficient to demonstrate that investment flows are ensuring the modernization of the national economy on a new technological basis?

The importance of confirming the real and not imaginary "greenness" of money and processes that are clearly associated with the green economy is enhanced by familiarity with the course of the discussion on the UN ESCAP platform about what should be understood as sustainable/climate financing (ESCAP, 2023). The official reason for initiating the discussion on overcoming terminological divergence consists in a recognition of the increasing importance of having reliable information about:

1. How many financial resources are needed to achieve the sustainable development goals in general and the climate agenda in particular;
2. What flows are being generated by countries for these purposes;
3. To which goals these financial flows are being directed;
4. What successes are being achieved along this path.

The vector along which countries are expected to move is subject to terminological uncertainty. Based on the example of the definition of climate finance, the Committee at UNESCAP identified the following causes of divergence in the concepts used by different countries:

- Differences in the views and expectations of countries regarding what the scope of financing should be;
- Differences in the purposes and interpretative approaches for using a term;
- Discrepancies between operational definitions of the term and reporting practices;
- Presentation of the definition of financing in unstructured formats and with different levels of detail.

On this basis, countries were offered a problem-solving algorithm in the form of a guide for developing a consensus definition, comprising four sets of elements and twelve decision points, which may be summarized as follows:

1 – *Defining the scope and context of use* (purpose (1), geographical scope (2), user of the definition, and wider stakeholder group (3));

2 – *Grouping the definition by topic and activity and applying criteria or guidance for application of the definition, if necessary* (structure and detail (4), topic categories (5), discussion of the

classification of activities and how to qualify them (6), and climate-related inclusion and exclusion criteria (7));

3 – *Financial components of the terminology* (reported sources, recipients, and channels of financing (8) and reported financial instruments (9));

4 – *Accounting component of the terminological apparatus* (accounting methods used to determine the share of financial flow related to climate issues (10), the stage at which the financial flow is measured (11), and methods for attributing financial amounts measured as climate financing to specific sources and entities (12)).

With this approach, attention is insufficiently focused on the formation of conditions that improve the quality and efficiency of managing the process of technological transformations leading to sustainable development. It is focused on recognizing financing as "climate-related" based on formal characteristics, since relating primarily to the "entry" stage of an investment project and the stage of its implementation. Unfortunately, not all investments achieve the goals for which they are planned. Especially when advanced in the field of innovation, investment projects are characterized by increased risk and uncertainty; thus, significant deviations from the planned results may occur, whether positive or negative. Any progress towards a low-carbon economy as part of a new sustainable green economic model will certainly involve innovation, for which climate finance will be required. Therefore, without in any way diminishing the importance of overcoming the terminological inconsistency in relation to what is recognized today[1] as climate financing, we note that the question of how much finance declared as sustainable actually is sustainable and is concerned not so much with how to choose the right term, but rather about how to correctly build a mechanism for accumulating financial resources for the purposes of sustainable development and achieving these goals based on the results of implementing investment projects. Accordingly, the question facing policymakers of how to define and measure the technological modernization of the economy that corresponds to its transformation in the direction of sustainable development necessarily involves the question of the validity and effectiveness of committing enormous financial resources.

Since 2016, our research group has conducted a number of studies focused on identifying effective forms of organization and implementation of green financing, together with indicators that confirm the actual transformation of the national economy towards a green economy. The answers to these questions can be used to justify the feasibility and extent of state support for businesses implementing green investments while informing the selection of effective forms, types, and measures of state support.

Some of the conclusions of our previous studies are also relevant to this work. The first concerns the definition of what is the priority of sustainable development of the country. Our research suggests this should be seen in terms of ensuring positive dynamics of socio-economic development indicators. The second describes financial support for achieving sustainable development priorities as based on a financing mechanism corresponding to the level of the problem being solved and an objectively sufficient volume of financial resources. The third conclusion concerns the reaction of socio-economic systems of countries to technological transformations. Our studies of both the processes taking place in the Russian economy and in foreign countries have shown that the strategic impulse for sustainable socio-economic development of the country is yet to be fully accepted by either society or the state.

[1] The specificity of the current moment is that many countries find themselves at the beginning of the path of technological modernization, due in this case to the transition to a low-carbon economic model.

This may be explained as due to the ineffectiveness of the transmission channel or because it has not yet been implemented in the form of specific projects and programs.

Such conclusions pointed to an increased role for research into green financing, presented as a mechanism for financing technological transformations across a wide range of accumulated development problems.

Summarizing the above-stated positions, we formulate the following research hypotheses:

Hypothesis 1: Green financing must lead to a real transformation of the structure of the national economy, which must be confirmed by statistical data. Otherwise, it is mere "greenwashing".

Hypothesis 2: The transition to a new sustainable green economic model requires simultaneous and coordinated changes in the principles of organizing and financing economic activity.

2. Materials and methods

2.1. Justification of the method and indicators

International experience shows that sustainable development projects can be financed both from the state budget (state support) and from private capital. The logic of state support is based on the assumption that private sector investments can be attracted through the use of a number of proven instruments that help reduce investment risks and, thus, the cost of capital. As a result, in some countries, state money supplements private-sector investments and attracts market financing (bonds and loans), while in others, it is, if not the main, then a significant flow of green financing. The set of state support measures presented in Table 2 in a generalized form reveals their distribution in terms of forms of support and implementation institutions.

The concept that "the market should regulate everything", which continues to dominate the thinking of the Government of the Russian Federation, erodes the case for state support. Therefore, the Ministry of Economic Development repudiates the need to stimulate sustainable investments, while the Ministry of Finance takes a similarly tough position on any claims for budget support. Accordingly, Russia can be described as a country in which the system of national green financing relies exclusively on the market, and where, until recently, priority was given to debt instruments.[2] An additional negative factor is that the system of investment tax incentives is configured in such a way that support is received mainly by investments in traditional industries and activities, including those related to the extraction of minerals and natural resources (Pinskaya and Steshenko, 2024).

The system of sustainable financing being actively formed in the Russian Federation, in which the major financial instruments are bonds, consists of three key elements: (1) A taxonomy of sustainable projects; (2) a verification system; and (3) bond standards. The State Corporation (SC) "VEB.RF" has developed a Russian green methodology (VEB.RF, 2024a) that takes into account national characteristics of achieving sustainable development goals. On this basis, the RF Government Resolution of 09/21/2021 No. 1587, "On approval of the criteria for sustainable (including green) development projects in the Russian Federation and the requirements for the verification system of sustainable (including green) development projects in the Russian Federation" was issued. This document introduces a national taxonomy of green economic activities.

[2] the onset of a period of high interest rates from the second half of 2022.

Table 2. Forms of state support and implementation institutions.

Resource accumulation mechanism	Implementation institutions	Forms of state support		
Funds provided by the budget	Program budget expenditures	Subsidies	Public procurement contracts	Investments in specially created financial instruments
	Non-program budget expenditures	Subsidies to cover the expenses of an entity implementing green investments or related activities		
Special investment funds	Target funds created by the state	Subsidies		Guarantees
Credit organization	Specialized credit organizations/Development banks	Long-term lending at below-market rates		Other financial products, including guarantees
Tax system	Environmental taxes and fees	Tax incentives for economy green sectors and types of activities		Increased taxation of resource-intensive, hydrocarbon-consuming sectors

Source (Kabir, 2019)

The list of verifiers is published on the official website of the national development institute – SC "VEB.RF" (VEB.RF, 2024b). The list of recognized sustainable development instruments is also posted here (as of 10/01/2024, it included 9 issues of debt securities (8 green bonds and one adaptational bond) and one credit instrument). It is noteworthy that there is a discrepancy between the information presented on the English and Russian versions of the site (VEB.RF, 2024c). The Russian version reports 18 issues of debt securities. The most likely reason for the discrepancy in data is that the Russian version of the site includes bonds issued by large companies before the National Green Guidelines came into force.

In cooperation with competence centers in the private sector, VEB.RF Group has developed a Quality Assessment and Certification System for Projects Promoting the Creation or Modernization of Green Infrastructure Facilities (IRIIS) (VEB.RF, 2023). A draft taxonomy of social projects has been prepared (VEB.RF, 2024d). However, this information is not available in the English version of the site (VEB.RF, 2024e).

There are two exchanges in Russia that organize the circulation of financial instruments of sustainable development (bonds) recognized by them: Moscow Exchange MICEX-RTS (Moscow) and St. Petersburg Exchange (St. Petersburg). Thematic sectors have been created for the circulation of such financial instruments on the exchanges (MOEX, 2024; SPB Exchange, 2024). The listing rules of both exchanges (MOEX, 2023; SPB Exchange, 2023) establish the procedure for including bonds in the sustainable development sector, making reference to the targeted nature of the issue of these bonds and the need to draw up a document (report) on the proper use of funds received from the placement of bonds as confirmed by an annual independent external assessment. These same listing rules establish requirements for compliance of financial instruments with international and/or Russian principles and

standards. In line with the global trend for financial regulators to issue recommendations for supervised organizations on risk management for sustainable development, the Bank of Russia has been actively working in this direction since 2021. According to Bank of Russia Instruction No. 5959-U dated 10/01/2021, amendments were made to Bank of Russia Regulation No. 706-P dated 12/19/2019 "On Securities Issue Standards" to establish the procedure for additional identification of a bond issue (program) using the markings "green", "social" or "sustainable" bonds. This document establishes additional requirements for information on the bond issue, both in terms of the issuer's reporting and its verification by persons recognized as qualified verifiers of VEB.RF Group, as well as integrating the ICMA principles into the national rules for the placement of securities (not in detail, but generally complete). However, there remains a gap in regulating the criteria and process for labeling investment funds. Additionally, valid approaches to recognizing individual investment accounts as "sustainable" have yet to be defined.

Since November 28, 2022, Russian issuers have been able to issue new types of bonds (adaptation bonds, bonds linked to sustainable development goals, and climate transition bonds) thanks to the amendments introduced by Bank of Russia Instruction No. 6195-U of July 4, 2022, to the above Regulation. The range of instruments for financing sustainable development has been expanded. Issuers can raise funds to transform their business provided that the structure of the financial instrument is linked to the presence of a strategy for changing the organization's activities to transition to a low-carbon economy (for climate transition bonds) or to the disclosure of a sustainable development strategy and the fulfillment of key performance indicators in the field of sustainable development declared by the issuer upon issue (for bonds linked to sustainable development goals). Thus, a base of methodological recommendations has been formed in Russia from the Bank of Russia, the Ministry of Economic Development of the Russian Federation, and VEB.RF. National regulators and development institutions are actively attempting to solve two interrelated problems: (1) Integrating sustainable development issues into the activities of financial institutions; and (2) stimulating the non-financial sector to disclose information on sustainable development. All of this activity aims to form a sustainable segment of the national financial market.

Active rule-making does not lead to significant activity of financial institutions and issuers. A study conducted in 2024 by the Financial Research Institute of the Ministry of Finance of the Russian Federation[3] showed that interest in financing sustainable development is shown mainly by large credit institutions that are joint-stock companies.[4] Russian banks offer the following as instruments for financing sustainable development: Sustainable credit products (seven banks), sustainable deposits (two banks), and bond issues (eight banks) aimed at sustainable development (green bonds; social bonds; sustainable development bonds). Five banks also provide non-banking ESG products, such as managing sustainable development support funds, consulting services in the field of sustainable development, preparing ESG bond issues, etc.

Questions concerning the overall magnitude of green financing in Russia continue to be debated. Russia lacks an overall system for accounting for green finance or a uniform approach to aggregating information. Since the Bank of Russia is responsible for the stability of the financial market, its focus is on outstanding debt on bonds. VEB.RF and exchanges count instruments issued on their platforms,

[3] The report has not been officially published.

[4] 29 credit organizations (9% of the total) out of 320 credit organizations with a valid banking license from the Bank of Russia, which account for 80% of the country's total banking capital.

so over-the-counter placements are not included in their statistics. Because the Ministry of Economic Development counts market volumes from the adoption of the national taxonomy in 2021, nothing that was issued before that moment is taken into account, even if it received independent verification. Thus, while these institutions were there when the companies directed this money to projects in Russia, they do not consider historical placements of green and social Eurobonds on foreign markets.

If we focus on the most optimistic estimates, the volume of verified bonds, whose structure is presented in Table 3, amounted to 667 billion rubles by the end of 2023. It is assessed that 2024 will add approximately 70 billion rubles of sustainable bonds.

Table 3. Structure of the issue of bonds for financing sustainable development (cumulative total, 2018–2023).

Type	Issue volume (billion rubles)	Number of issues (units)
Green	460.00	31
Social	169.59	15
Transitional/Adaptive	5.00	1
Sustainable Development	32.84	2
Total	667.43	49

Source: (INFRAGREEN, 2023)

Estimates of green bank loans are more variable, since loans, unlike bonds, are not verified: One can take only the bankers' word for it. According to various estimates, unverified green loans may reach as much as 5 trillion rubles. Furthermore, experts characterize the trend of green financing in the medium term as downward. The main objective in developing the green segment of the national financial market is to achieve sustainable development by carrying out large-scale modernization of the economy while taking social and environmental components into account. Therefore, there should be an accumulation of green financing aimed at achieving sustainable development. In the absence of such an accumulation, accusations of "greenwashing" may start to become undeniable. An analysis of the Russian experience has shown the existence of a framework for green market financing. In this regard, it is logical to assume that the modernization process of Russian industry has been launched to form the basis of a Russian economy focused on sustainable development. Accordingly, a question arises about the effectiveness of the implemented policy and the ability of Russian industry to meet the demand for a new type of financial instruments.

The search for methods and indicators that can be used to record the actual movement of countries toward building a new sustainable economic model is attracting increasing attention (Fu et al., 2023). The main research question concerns identifying indicators and processes for confirming that the ongoing changes indicate a genuine transformation towards a new sustainable green economic model. Many experts simply assume that the movement towards a green economy is established by the confirmed fact of technological modernization. Here, the ensuing discussion is formed around the questions of how to record, measure, and evaluate this fact. Nevertheless, the question of assessing the sustainable development of the economy continues to occupy a prominent position. Some researchers respond by considering individual indicators of sustainable development (for example, negative ones associated with the level of technologies used – CO_2 emissions) in conjunction with macroeconomic indicators or indicators of the development of a particular sector of the economy. For example, Gilli et

al. (2017) estimate the impact of income and technological factors on CO_2 emissions per capita. Khalil et al. (2024) differentiate R&D investments into general and environmental categories to estimate their impact on a firm's market value and CO_2 emissions. The estimates are given using developing and developed countries as examples. Pang and Xie (2024) assess the impact of economic growth targets on the pollution index across provinces in China. The study by Candra et al. (2023) uses the SVAR model to prove the negative impact of the renewable energy sector on the increase in CO_2 emissions. Another approach to assessing sustainable development is based on the study of processes. For example, the investment approach (Kabir and Rakov, 2023) is based on identifying and measuring the strength of the influence of factors motivating Russian companies to green investing. Tang and Yang (2024) investigate the impact of social trust on the ESG performance of companies. Other assessment models constructed within the framework of the process approach also focus on the role of business in building a sustainable economic model. An example is the work of Bouras and Sofianopoulou (2023), where they assess the impact of sustainable development policies implemented in business processes by companies on their sustainability based on the indicators that make up the SDGs. However, the presented model considers the external manifestations of sustainable development of companies to a greater extent than the process of modernization of industrial production, taking into account, among other things, social and environmental factors (in a broader sense – ESG factors).

There are also models directly aimed at assessing the technological modernization of the industry (Gali, 1999; Collard and Dellas, 2007). However, when developing these models, the authors fail to consider the social and environmental components of sustainable development. Additional limitations are revealed when attempting to reproduce the above-mentioned models in independent analysis. For example, it is very difficult to combine many diverse (both in direction and in strength of action) factors in one model and to compile the necessary database for them for a country. This is also true in the case of Russia, where statistical data capable of satisfying the requirements of the model are only provided for short periods of time and for a limited range of indicators, often not in a quarterly sample format. Thus, relying on our own experience and the results of other researchers, we conclude that an approach to assessing sustainable economic development based on static analysis, in which consolidated data is presented in graphical and tabular form, may be more informative and consistent with the current situation (or, at least, our understanding thereof) than building a model.

Rather than carrying out a direct study of green financial flows, the degree of penetration of the green economy will be assessed by analyzing the changes taking place in the industrial structure. This is due to a number of reasons. First, as shown above, there is no reliable data on green finance. Second, more than 50% of investments in fixed assets in Russia are made using private funds in which it is almost impossible to single out the green component. Third, the share of the exchange market for sustainable development financing bonds is recognized as insignificant by all experts. For example, according to the authoritative international organization Climate Bonds Initiative, their value did not exceed 0.12% of GDP for the period 2019–2021. According to the most optimistic Russian experts, the 2021 figure was 0.16% of GDP. Fourth, despite the existence of a national taxonomy of green projects and a soft regulatory framework, there is no direct government support for green financing. Furthermore, despite the lack of objective high-quality data on green financing of Russian companies and the small volume of issued sustainable development bonds, 85 of 275 largest Russian companies, which together account for 66% of the total industrial production, have published at least one non-financial report disclosing their sustainable development policies and taking into account ESG factors in their business development strategy. If, in 2015, there were 32 such companies, then by 2022, their

number had increased to 63. In the banking sector, such reports are already prepared by 29 Russian banks, which account for 80% of all Russian banking capital. Since indicating the involvement of large Russian businesses and financial capital in building a green (sustainable) economic model, this requires an assessment of the technological modernization of Russian industry.

The technological modernization of the Russian economy towards a new sustainable model will be analyzed according to three vectors of sustainable development: Economic, social, and environmental (WCED, 1987). Since business is recognized as the main driver of implementing the sustainable development agenda, the analysis is focused on assessing the contribution and role of the private sector than government policy.

The economic block identifies key sectors of the Russian economy, whose structural changes are assessed in terms of manufactured products and investments. In the case of ongoing modernization involving technological transformations, it is assumed that the economy will experience significant structural changes and a sharp increase in manufactured goods and investments. An equally important fact is the assessment of the depreciation of fixed assets. With active technological modernization, old funds should be completely written off and replaced with new ones.

Since human labor is the main productive force that forms the added value of manufactured goods, the social block can be used to assess the state of human capital. The transition to a new technological structure within the framework of sustainable development should stimulate the influx of new labor force into industry due to the emergence of new jobs, a significant increase in wages, and improved working conditions. Such a transition should also contribute to the greater attraction of highly qualified personnel.

The environmental block examines the structure of final energy consumption in terms of major energy sources and the degree of environmental pollution by industries. By increasing energy efficiency and switching from fossil fuels to renewable and other alternative energy sources, sustainable development should result in great transformations of the energy balance of industrial sectors. In addition, the introduction of new technologies should reduce the negative impact on the environment.

2.2. Data used

We use data on large and medium-sized organizations posted on the official website of the Federal Service for State Statistics (Rosstat) and in the information and analytical system FIRA PRO (a paid resource), which accumulates data from open sources and provides them in a systematized form for subsequent analysis.

The FIRA PRO information and analytical system (Fira Pro, 2024) is a source of the following data: Investments in fixed capital; investments in machinery, equipment, and vehicles; accrued taxes and fees payable in the current year to the consolidated budget of the Russian Federation; revenue (net) from sales; profit (loss) from sales; total volume of financial investments; the average number of employees on the payroll (excluding external part-time workers); and accrued wages fund for employees on the payroll (excluding external part-time workers).

The following data used in our analysis is drawn from the official website of Rosstat:

1. The value of fixed assets and their depreciation, the final energy consumption of industrial sectors by types of energy resources – the collection "Industrial Production in Russia" (Rosstat, 2024a);
2. Statistics on the number of people employed by the level of education in the context of kind of economic activity – the collection "Labor and Employment in Russia" (Rosstat, 2024b);
3. Data on gross value added, damage to the environment (emissions of pollutants into the atmosphere, discharge of contaminated wastewater into surface water bodies, production and consumption waste, use and disposal of production and consumption waste) – the official website of the Federal State Statistics Service and the collection "Industrial Production in Russia" (Rosstat, 2024a).

The chronological framework of the study covers the period from 2006 to 2023, representing the maximum available period for collecting comparable statistical data in the context of this kind of economic activity.

Russian statistics discloses data in the context of kind of economic activity according to two classifications: NACE Rev. 1.1 for 2006–2016 and NACE Rev. 2 for 2017–2023. This significantly complicates data collection since requiring their comparison. Table 4 discloses the matching algorithm used for this purpose.

All statistical data with monetary value have been adjusted for the consumer price index (base year – 2015), information on which is also presented on the official website of Rosstat. Except for growth rates of investments, profit, labor force, and wages, which are calculated using the arithmetic mean, average growth rates are calculated based on the geometric mean. Return on sales is calculated as the ratio of profit (loss) to revenue from the sale of goods multiplied by 100. The tax burden is taken as the ratio of accrued taxes and fees payable in the current year to the consolidated budget of the Russian Federation to revenue from the sale of goods multiplied by 100. The intensity of financial investments is understood as the volume of financial investments per 1 ruble of investment in fixed capital. Non-recyclable production and consumption waste is calculated as the difference between the generated production/consumption waste and the used and neutralized production/consumption waste.

Table 4. Comparison of statistical data on types of economic activity under NACE Rev. 1.1 and NACE Rev. 2.

Summary data	NACE Rev. 1.1	NACE Rev. 2
Mining and quarrying	Mining and quarrying	Mining and quarrying
Manufacturing	Manufacturing	Manufacturing
Manufacture of food products, beverages, and tobacco	Manufacture of food products, beverages, and tobacco	Manufacture of food products Manufacture of beverages Manufacture of tobacco products
Manufacture of textiles and textile products	Manufacture of textiles and textile products	Manufacture of textiles Manufacture of apparel
Manufacture of leather and leather products	Manufacture of leather and leather products	Manufacture of leather and related products
Manufacture of wood and wood products	Manufacture of wood and wood products	Manufacture of wood and products made of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Manufacture of pulp, paper, and paper products; publishing and printing	Manufacture of pulp, paper, and paper products; publishing and printing	Manufacture of paper and paper products Printing and reproduction of recorded media Publishing activities
Manufacture of coke and refined petroleum products	Data is provided according to NACE Rev. 2	Manufacture of coke and refined petroleum products
Manufacture of chemicals and chemical products	Data is provided according to NACE Rev. 2	Manufacture of chemicals and chemical products
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Data is provided according to NACE Rev. 2	Manufacture of basic pharmaceutical products and pharmaceutical preparations
Manufacture of rubber and plastic products	Manufacture of rubber and plastic products	Manufacture of rubber and plastic products
Manufacture of other non-metallic mineral products	Manufacture of other non-metallic mineral products	Manufacture of other non-metallic mineral products
Manufacture of basic metals and fabricated metal products	Manufacture of basic metals and fabricated metal	Manufacture of basic metals Manufacture of fabricated metal products, except machinery and equipment
Manufacture of electrical and optical equipment	Manufacture of electrical and optical equipment	Manufacture of computer, electronic, and optical products Manufacture of electrical equipment
Manufacture of machinery and equipment n.e.c.	Manufacture of machinery and equipment n.e.c.	Manufacture of machinery and equipment n.e.c.
Manufacture of transport equipment	Manufacture of transport equipment	Manufacture of motor vehicles, trailers and semi-trailers Manufacture of other transport equipment
Manufacturing n.e.c.	Manufacturing n.e.c.	Manufacture of furniture Other manufacturing
Electricity, gas, and water supply	Electricity, gas, and water supply	Electricity, gas, steam, and air conditioning supply Water collection, treatment, and supply

Source: (European Commission, 2002; European Commission, 2008)

3. Results

3.1. Economic block

In Russia, industrial production accounted for 29% of all gross value added in the period 2020–2023. While its proportion in the economy's structure decreased by 1% in 2006–2023, its growth in value terms amounted to 3.1% on average per year.

Table 5 below reveals the change in the sectoral structure of Russian industry. Three sectors are highlighted for which an increase in share is observed: "Mining and quarrying" (+10%), "Manufacture of basic metals and fabricated metal products" (+2%), and "Manufacture of chemicals and chemical products" (+1%). The opposite results were shown by "Manufacturing" (–8%), in particular, "Manufacture of coke and refined petroleum products" (–6%), and "Electricity, gas and water supply" (–2%). The shares of more than nine sectors remained virtually unchanged. Among these, the most significant ones include "Manufacture of transport equipment" (3.8% of GVA for 2020–2023) and "Manufacture of electrical and optical equipment" (3.1% of GVA for 2020–2023).

In Russian industry, the mineral extraction sector is developing more actively than manufacturing. The average annual growth rates of these activities' gross value added in 2006–2023 were 4.6% and 2.2%, respectively. Moreover, the production and distribution of electricity, gas, and water were developing at a slightly lower rate of 2.1%. In the manufacturing industry, the highest average annual growth rates were observed in "Manufacture of basic pharmaceutical products and pharmaceutical preparations" (10.1%) and "Manufacture of chemicals and chemical products" (6.1%). Thus, high rates are observed in the extractive industry or those occupying a small share of industry in Russia, while in general, the values for the manufacturing industry are not high.

Table 6 presents the grouping of industries depending on the volume of fixed capital investments and depreciation of fixed assets. Note that the proportions of investment distribution by type of activity correspond to the proportions of distribution by gross value added.

The data grouping clearly demonstrates that, in most key sectors of Russian industry, there is significant depreciation of fixed assets, despite significant investment volumes. This category also includes "Mining and quarrying" and "Manufacturing". In particular, in the manufacturing industry, "Manufacture of coke and refined petroleum products" concentrates 8.4% of all industrial investments, while the depreciation of fixed assets, at 54.3%, continues to increase by 0.76% per year. Only "Electricity, gas and water supply" and "Manufacture of chemicals and chemical products" are characterized by relatively low depreciation of fixed assets (45.9% and 40.3%, respectively), involving a gradual decrease (by 0.02% and 0.55% on average per year). Most sectors have high depreciation of fixed assets and a low level of investment activity. However, there are also certain industries (Manufacture of basic pharmaceutical products and pharmaceutical preparations; Manufacture of wood and wood products) for which a relatively low depreciation of fixed assets is characteristic of the observed low level of investment, but for which absolute growth rates of depreciation are positive (2.65% and 1.13% on average per year).

In general, the depreciation of fixed assets of industrial production, already having reached 52.1% (more than half of the fixed assets are worn out), continues to increase by 0.27% on average per year despite the growth of investments.

Analysis of the proportion of completely worn-out fixed assets of industrial production indicates a deepening of the negative trend manifested in the significant increase in the share of such funds in all

kinds of economic activity of industrial production in 2006–2021. In particular, in the extractive industries, the proportion of completely worn-out machinery and equipment increased from 24% to 36%, while in the manufacturing industry, the corresponding figure varied from 20% to 26% (Figure 1).

Table 5. Dynamics and structure of gross value added for 2006–2023.

Kind of Economic Activity	2006–2009		2020–2023		Average growth rate for 2006–2023, %
	RUB billion	% of total	RUB billion	% of total	
The share in GVA has increased significantly (changes of more than 1%)					
Mining and quarrying	5537	32.3	11249	42.5	4.6
Manufacture of basic metals and fabricated metal products	1895	11.1	3365	12.7	2.9
Manufacture of chemicals and chemical products	575	3.4	1286	4.9	6.1
The share in GVA has decreased significantly (changes of more than 1%)					
Manufacturing	9706	56.7	12893	48.7	2.2
Manufacture of coke and refined petroleum products	1837	10.7	1219	4.6	−3.1
Electricity, gas, and water supply	1881	11.0	2356	8.9	2.1
Manufacture of food products, beverages, and tobacco	1536	9.0	1824	6.9	1.9
Manufacture of machinery and equipment n.e.c.	597	3.5	446	1.7	0.2
Manufacture of other non-metallic mineral products	592	3.5	594	2.2	1.8
The share in total GVA has remained virtually unchanged (changes less than 1%)					
Manufacture of basic pharmaceutical products and pharmaceutical preparations	80	0.5	356	1.3	10.1
Manufacture of transport equipment	592	3.5	996	3.8	3.1
Manufacture of electrical and optical equipment	495	2.9	812	3.1	4.6
Manufacture of textiles and textile products	160	0.9	238	0.9	2.5
Manufacture of leather and leather products	30	0.2			
Manufacture of rubber and plastic products	212	1.2	314	1.2	3.4
Manufacturing n.e.c.	172	1.0	229	0.9	2.6
Manufacture of wood and wood products	223	1.3	266	1.0	0.4
Manufacture of pulp, paper and paper products; publishing and printing	386	2.3	478	1.8	1.8
Total	17124	100.0	26499	100.0	3.2

Table 6. Fixed capital investments and depreciation of fixed assets in industrial production.

Kind of Economic Activity	Fixed capital investments				Depreciation of fixed assets	
	2020–2023			Average growth rate for 2006–2023, %	2020–2022	Average absolute change for 2006–2022, %
	RUB billion	% of total	% machines and equipment		%	
High level of investment and high degree of depreciation of fixed assets (more than 50%)						
Mining and quarrying	2291	41.1	23.5	3.01	57.0	0.27
Manufacturing	2322	41.6	50.9	5.12	50.9	0.37
Manufacture of basic metals and fabricated metal products	482	8.6	60.8	4.04	51.0	0.43
Manufacture of coke and refined petroleum products	466	8.4	25.0	10.65	54.3	0.76
Manufacture of transport equipment	174	3.1	61.0	8.56	53.8	0.04
Manufacture of food products, beverages, and tobacco	227	4.1	70.2	0.53	53.5	1.00
High level of investment and relatively low level of depreciation of fixed assets (less than 50%)						
Electricity, gas, and water supply	967	17.3	35.2	6.14	45.9	-0.02
Manufacture of chemicals and chemical products	435	7.8	40.4	9.52	40.3	-0.55
Low level of investment and high level of depreciation of fixed assets (more than 50%)						
Manufacture of electrical and optical equipment	98	1.8	59.7	13.34	52.9	0.31
Manufacture of other non-metallic mineral products	83	1.5	58.5	1.92	53.7	0.98
Manufacture of pulp, paper, and paper products; publishing and printing	79	1.4	69.5	6.03	51.1	0.57
Manufacture of machinery and equipment n.e.c.	50	0.9	68.6	7.71	51.4	0.35
Manufacture of rubber and plastic products	40	0.7	83.1	5.30	56.0	0.73
Manufacturing n.e.c.	13	0.2	66.1	0.25	52.9	0.87
Manufacture of leather and leather products	1	0.0	78.9	7.74	52.8	1.01
Low level of investment and relatively low level of depreciation of fixed assets (less than 50%)						
Manufacture of basic pharmaceutical products and pharmaceutical preparations	58	1.0	44.4	15.12	39.1	2.65
Manufacture of wood and wood products	41	0.7	71.8	4.79	46.7	1.13
Manufacture of textiles and textile products	9	0.2	68.8	9.50	48.9	0.39
Total	5 581	100.0	36.9	4.09	52.1	0.27

Note: A significant share of investments in the industry is considered to be more than 3% in industrial production, while a high level of depreciation of fixed assets is 50% or more.

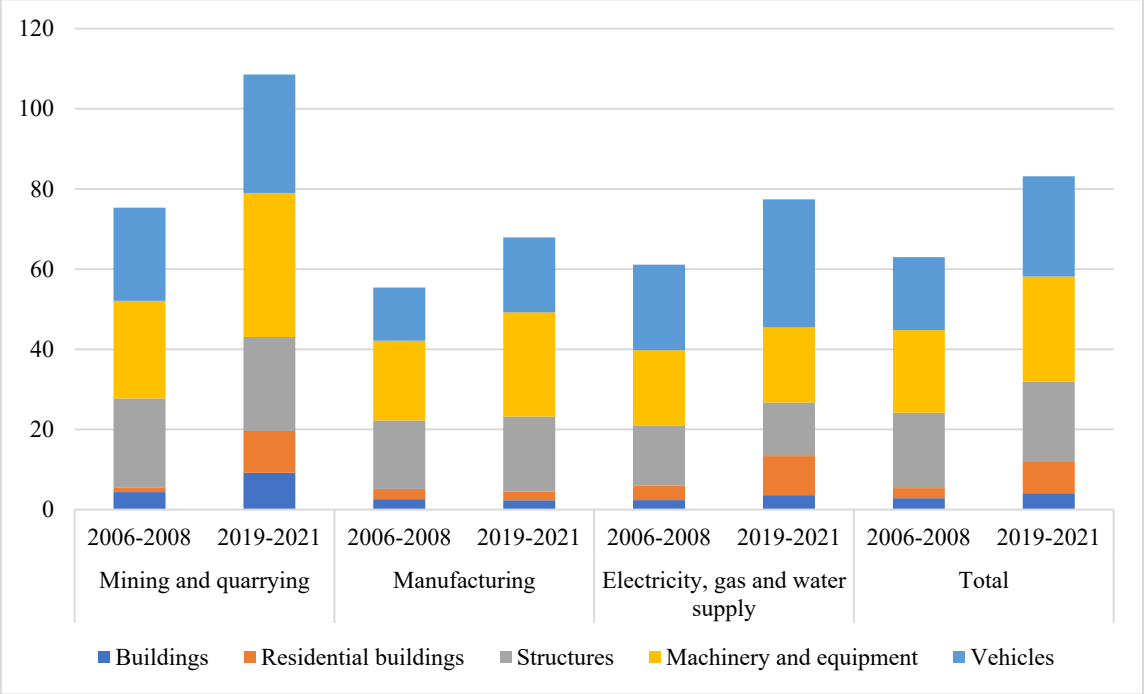

Figure 1. The proportion of completely worn-out fixed assets of industrial production, %.

From our analysis of the structure of shipped goods, fixed capital investments, and depreciation of fixed assets, we can conclude that the Russian industry is extremely conservative. Over the past two decades, new industries, including those that can be classified as high-tech such as "Manufacture of electrical and optical equipment" and "Manufacture of machinery and equipment n.e.c.", have not developed significantly. Another problem in the area of Russian industry identified during the analysis is the insufficiency and/or inefficiency of investments. This leads to the accelerating obsolescence of fixed assets and/or their complete depreciation, which reduces the possibility of creating conditions for stimulating technological modernization, including within the framework of sustainable development.

Further, Table 7 shows the factors influencing the formation of the structure of industrial production. First, since profit maximization is a key factor for company management, sales profitability is considered. Second, due to the final profit of the company being affected by the amount of taxes levied on business, the tax burden on each type of activity is analyzed. Third, the possibility that a company might direct its capital not to its own development but to the financial market, where returns can be significantly higher than sectoral profitability, is taken into account. Therefore, the intensity of financial investments, representing the ratio of financial investments and fixed capital investments, is also studied.

As can be seen from Table 7, the most high-tech kinds of economic activity (Manufacture of electrical and optical equipment; Manufacture of machinery and equipment n.e.c.; manufacture of rubber and plastic products and manufacture of transport equipment) have relatively low profitability and a high tax burden; in addition, companies in these industries tend to direct significant amounts of capital into financial investments rather than their own development. Additionally, more traditional industries (mining and quarrying; manufacture of chemicals and chemical products; manufacture of basic metals and fabricated metal products; and manufacture of coke and refined petroleum products) have high profitability and/or a low tax burden compared to other industries.

Table 7. Key factors influencing the development of industries.

Kind of Economic Activity	Return on sales, %		Tax burden, %		Intensity of financial investments, 1 ruble of investment	
	Average for 2020–2023	Average absolute change for 2006–2023, %	Average for 2020–2023	Average absolute change for 2011–2023, %	Average for 2020–2023	Average absolute change for 2006–2023, %
High profitability (sorted by decreasing profitability)						
Manufacture of basic pharmaceutical products and pharmaceutical preparations	28.6	0.5	7.4	0.5	18.4	0.9
Manufacture of chemicals and chemical products	25.9	0.5	3.4	0.2	8.7	0.5
Mining and quarrying	23.4	−0.1	41.0	0.7	7.3	0.5
Manufacture of basic metals and fabricated metal products	17.3	−0.5	5.4	1.1	18.5	−0.7
Manufacture of pulp, paper, and paper products; publishing and printing	17.2	0.4	9.0	0.4	16.9	1.1
Low profitability and tax burden (sorted by increasing tax burden)						
Manufacture of coke and refined petroleum products	11.5	0.0	4.7	−0.3	24.4	−2.1
Manufacture of wood and wood products	12.5	0.0	4.9	0.4	14.5	2.0
Manufacture of transport equipment	4.0	0.0	5.6	0.3	26.2	0.4
Electricity, gas, and water supply	8.6	0.3	7.3	0.4	12.6	0.6
Manufacturing	13.6	0.1	8.4	0.2	18.0	0.3
All other types of economic activity (sorted by increasing intensity of financial investments)						
Manufacture of textiles and textile products	12.3	0.6	14.4	0.8	13.5	0.3
Manufacture of rubber and plastic products	11.2	0.4	10.0	0.6	14.4	1.1
Manufacture of other non−metallic mineral products	14.0	−0.1	12.9	0.7	14.5	0.9
Manufacturing n.e.c.	9.7	0.4	12.2	1.6	16.5	1.3
Manufacture of food products, beverages and tobacco	10.1	0.2	20.7	0.4	19.0	1.5
Manufacture of leather and leather products	9.0	0.4	17.0	1.2	21.8	0.9
Manufacture of electrical and optical equipment	11.8	0.4	13.1	0.2	24.2	1.3
Manufacture of machinery and equipment n.e.c.	10.4	0.3	13.3	0.4	30.1	1.5
Industry	15.4	0.1	16.3	0.4	12.7	0.5

Note: the threshold value for high profitability is considered to be the value calculated as the average for the entire Russian industry (15.4%), while the threshold value for the tax burden is the average for the manufacturing industry (8.4%).

3.2. Social block

The concentration of human resources in the industries of Russia significantly diverges from the concentration of shipped goods and investments in terms of fixed capital. The major indicators here are profitability and the growth of average wages. Thus, the largest share of workers is employed in the manufacturing industries (manufacture of basic metals and fabricated metal products; manufacture of food products, beverages and tobacco; and manufacture of transport equipment), which continue to be characterized by low wages. While the number of workers employed in the extractive industries and a number of manufacturing industries is significantly smaller (manufacture of coke and refined petroleum products and manufacture of chemicals and chemical products), wage levels are higher, which may also indicate higher labor productivity in these industries (See Table 8).

In most branches of industrial production and in industry as a whole, there is a general outflow of workers, especially from activities with lower wage levels. Furthermore, the growth rate of average monthly salaries is significantly lower in some activities than the growth rate of profits, e.g., "manufacture of textiles and textile products", "manufacture of wood and wood products", and "manufacture of transport equipment".

Despite the outflow of labor from industrial production in Russia, the structure of employment according to level of education underwent positive changes in 2006–2022. The share of workers with higher and secondary specialized education has increased, especially in the manufacturing industry (Figure 2).

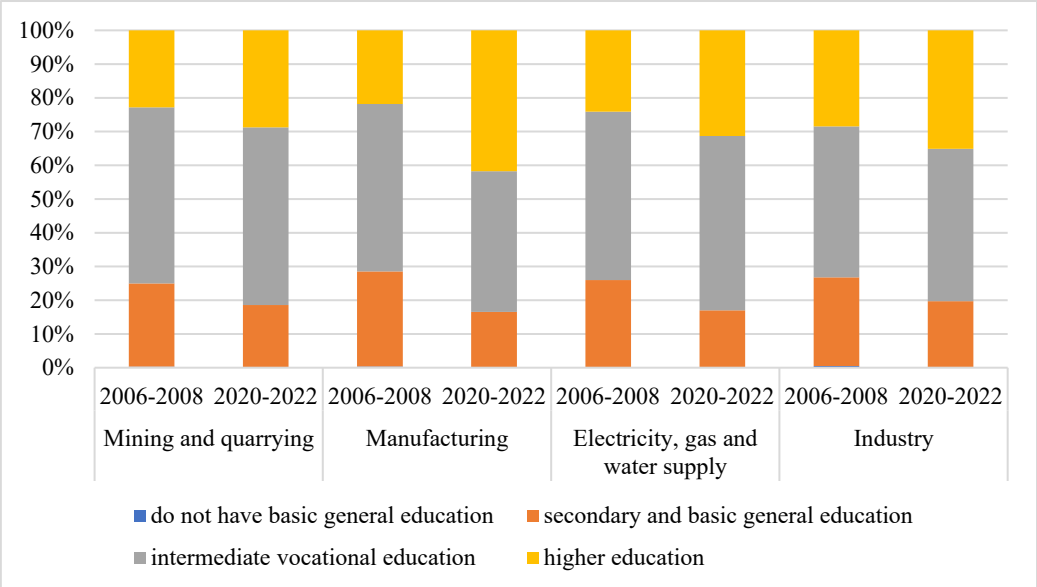

Figure 2. Structure of employment by level of education and types of economic activity.

Table 8. Labor, wages, and profits.

Kind of Economic Activity	Wage		Profit growth rate for 2006–2023, %	Labor force		
	RUB	Average growth rate for 2006–2023, %		Thousand people	% of total	Average growth rate for 2006–2023, %
Mining and quarrying	82 264	2.8	8.9	973	12.9	0.5
Manufacture of coke and refined petroleum products	68 105	2.1	18.8	131	1.7	0.2
Manufacture of basic pharmaceutical products and pharmaceutical preparations	61 429	5.7	17.7	84	1.1	1.9
Manufacture of chemicals and chemical products	52 652	4.5	19.3	317	4.2	−2
Manufacture of pulp, paper, and paper products; publishing and printing	49 058	3.4	9.3	153	2.0	−2.8
Manufacture of electrical and optical equipment	47 083	5.2	14.4	543	7.2	1.7
Manufacture of basic metals and fabricated metal products	46 971	3.6	7.5	900	11.9	0.0
Manufacture of transport equipment	45 453	4.1	31.3	817	10.8	−1.7
Manufacture of machinery and equipment n.e.c.	44 891	4.5	8.3	293	3.9	−5.4
Manufacturing	44 800	4.2	6.6	5 113	67.6	−2.0
Electricity, gas, and water supply	43 704	2.7	11.6	1 482	19.6	−1.2
Manufacture of rubber and plastic products	40 736	4.3	12.6	146	1.9	−0.6
Manufacture of other non-metallic mineral products	40 674	3.9	7.7	283	3.7	−3.5
Manufacture of food products, beverages, and tobacco	37 722	3.7	7.2	826	10.9	−1.7
Manufacturing n.e.c.	35 219	3.7	8.8	98	1.3	−2.4
Manufacture of wood and wood products	32 357	3.9	56.5	115	1.5	−4.1
Manufacture of leather and leather products	27 838	4.9	10.9	24	0.3	−3.2
Manufacture of textiles and textile products	22 483	4.7	17.1	137	1.8	−4.2
Total	49 406	3.9	6.9	7 569	100	−1.6

3.3. Environmental

The structure of final energy consumption by industry remains virtually unchanged. In particular, the mining and manufacturing industries continue to be characterized by a heavy reliance on fossil fuels and their derivatives, thus demonstrating a lack of modernization of industrial production processes aimed at more sustainable development. However, a reduction in the share of heat energy consumption in industry may indicate the introduction of more energy-efficient materials in the construction of buildings and structures (Figure 3).

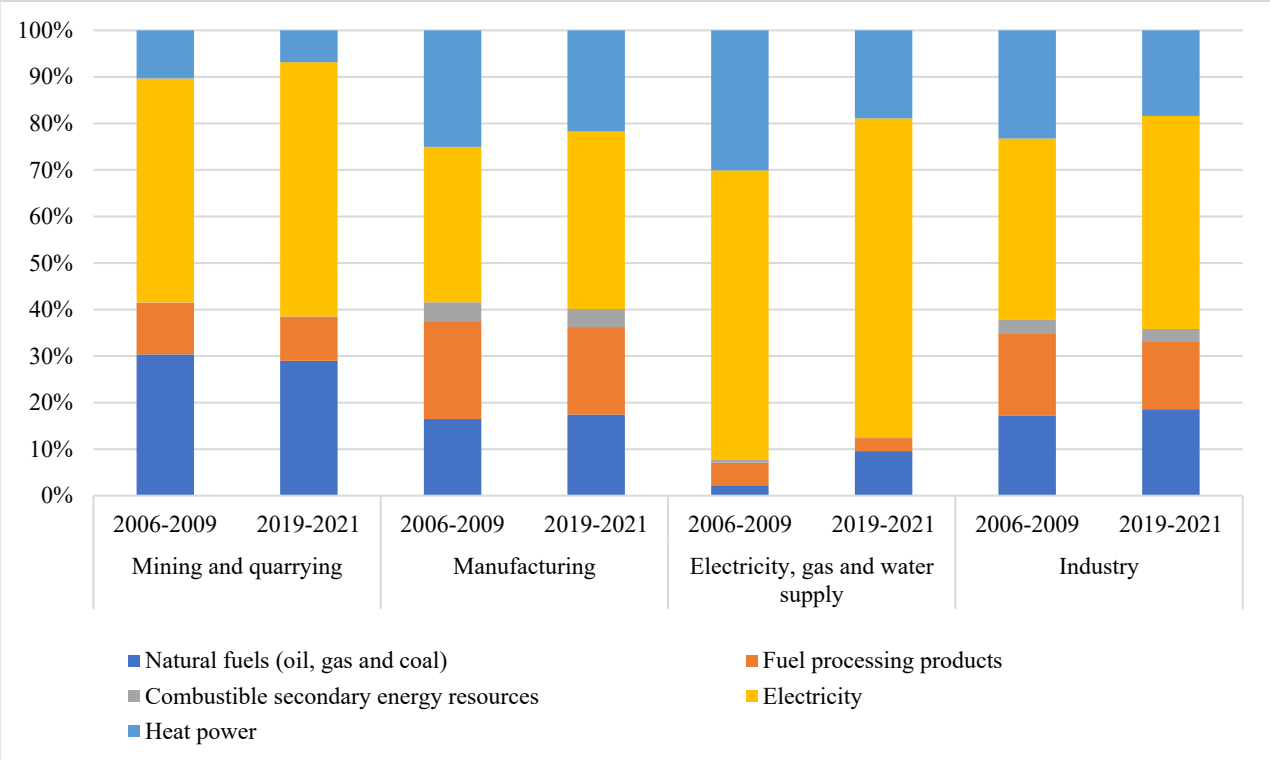

Figure 3. Structure of final energy consumption of industrial sectors by types of energy resources.

Table 9 provides data indicating that the largest share of pollution (by three and two sources of pollution) falls on the industries that occupy the largest share of industrial production in Russia. Thus, the most significant environmental pollution is caused by the mining industry, which accounts for 42% of gross added value, 48% of emissions of pollutants into the atmosphere, 4.2% of discharges of pollutants into surface waters, and 95% of non-recyclable waste from production and consumption of industrial production. Here, it should also be noted that the average annual growth rates for several pollutants for this industry remain in positive territory (Table 7).

While such economic activities as “manufacturing” and “production and distribution of electricity, gas, and water” also have a significant negative impact on the environment, the intensity of this impact tends to gradually decrease (Table 7).

Table 9. Key environmental factors and production volumes by types of economic activity for 2020–2022.

	Pollutant emissions in air			Discharge of pollutants into surface water sources			Non−recyclable production and consumption waste			Gross value added	
Kind of Economic Activity	Thousand tons	% of total	Average growth rate for 2006−2022, %	Thousand tons	% of total	Average growth rate for 2006−2022, %	million tons	% of total	Average growth rate for 2006−2022, %	% of total	Average growth rate for 2006−2022, %
Three sources of significant pollution (more than 1% of the total volume of industrial pollution)											
Mining and quarrying	6986	48.1	1.1	449	4.2	−5.3	4060	95.5	6.8	42.1	5.3
Manufacturing	3729	25.7	−4.2	1768	16.5	−4.5	230	5.4	2.4	48.8	2.2
Manufacture of basic metals and fabricated metal products	1432	9.9	−7.7	448	4.2	−2.5	71	1.7	−0.2	12.8	2.8
Manufacture of chemicals and chemical products	436	3.0	0.8	426	4.0	−4.2	88	2.1	8.2	6.2	7.9
Two sources of significant pollution (more than 1% of the total volume of industrial pollution)											
Electricity, gas, and water supply	3797	26.2	−0.7	8496	79.3	−0.7	−41	−1.0	−6.0	9.1	2.6
Manufacture of food products, beverages, and tobacco	273	1.9	3.1	27	0.2	−7.5	46	1.1	−0.3	6.8	2.0
One source of significant pollution (more than 1% of the total volume of industrial pollution)											
Manufacture of coke and refined petroleum products	661	4.6	−1.0	87	0.8	−5.6	0	0.0	−6.2	5.0	−2.9
Manufacture of other non−metallic mineral products	478	3.3	0.5	44	0.4	−1.9	4	0.1	2.9	2.2	1.9
Manufacture of textiles and textile products; Manufacture of leather and leather products	8	0.1	−4.8	4	0.0	−5.6	121	2.8	−22.7	0.9	2.1
Industry	14512	100.0	−1.1	10 713	100.0	−1.8	4249	100.0	6.4	100.0	3.4

Note: The kind of economic activity “manufacture of chemicals and chemical products” includes the production of medicines and materials used for medical purposes.

When analyzing the information on the "Manufacturing production" economic activity, we can identify the following areas characterized by a combination of high-intensity environmental pollution with a simultaneous concentration of financial resources and a high share of gross added value in the total volume of production: Manufacture of basic metals and fabricated metal products; manufacture of chemicals and chemical products; and manufacture of food products, beverages, and tobacco.

In our conclusion of the analysis, we adduce one more interesting fact. We also studied the information posted on the websites of 275 largest Russian companies. Here, the goal was to identify those who declare their commitment to sustainable development goals, the integration of ESG factors into their business strategies, and the presentation of the corresponding non-financial reporting. The following industry sectors were identified in which such companies are concentrated (the number of companies is indicated in brackets):

- Electric power industry (10),
- Oil and gas industry (9),
- Chemical and petrochemical industry (7),
- Ferrous metallurgy (7),
- Precious metals and diamond industry (4).

Here, we note that these companies comprise both Russian business flagships and key national exporters. Based on the results of the analysis presented above, it can be seen that the industry sectors to which these companies belong took leading positions in terms of their contribution both to gross added value and environmental pollution, as well as in the depreciation of fixed assets. This confirms findings (Kabir and Rakov, 2023) that the main motive of Russian companies for green financing is their continuing participation in the export agenda. Consequently, it can be stated that the national model of financing the green economy, i.e., based solely on the business's own investments and attracted market financing (bonds and loans), is not effective and does not create the necessary and sufficient conditions for modernizing the economy on a new technological basis – i.e., for building a green economy.

4. Discussion

Our purpose of this study was to identify indicators indicating technological modernization of the Russian industry in line with the concept of sustainable development. We now comment on the results.

Economy. Traditional industries (mining; production of food, beverages, and tobacco; metallurgy, etc.) aimed at exploiting natural resources continue to develop intensively in the Russian industry. These are characterized by excessive negative impact on the environment and depreciation of fixed assets, which has increased significantly during the period under review. Despite the high concentration of investment in fixed assets in these industries, the situation with depreciation of assets and negative impact on the environment is not improving. The findings coincide with the findings of the study by Golova and Sukhovey (2019), who draw attention to the concentration in the industrial structure of the Urals Federal District of energy-intensive industries that have a negative impact on the environment, and the lack of economic incentives for the development of environmentally friendly technologies.

A lack of technological modernization within the framework of sustainable development can also be observed in the *social vector*. First, this is indicated by the outflow of labor from both industries as a whole and from industries where wages are significantly lower. Second, there is a significant discrepancy between the growth rates of wages and profits, which indicates increasing exploitation of

the labor force. This does not contradict the findings of Suhányi et al. (2023) where that the introduction of new technologies will tend to preserve jobs while wages increase.

Environmental. Several manufacturing industries have seen a decrease in the negative impact on the environment. However, fixed assets are subject to severe depreciation and the structure of final energy consumption by types of energy resources remains virtually unchanged. The predominance of industries exploiting natural resources confirms the absence of a tendency toward industrial modernization on a new technological basis. This is consistent with the findings of Jänicke (2004), where environmental innovations do not lead to structural changes in the economy and technological modernization. In terms of the absence of significant changes in the energy balance, it also confirms the conclusions reached by Yakovlev et al. (2022) that no significant actions are planned in Russia for the fourth energy transition.

Thus, the first hypothesis of the study is confirmed. The conservation of the structure of the national economy at the level of the end of the last century clearly indicates both a lack of green financing for the national industry and the fact that the statistical analysis used offers a simple, accessible, and informative tool for assessing both the process (and progress, if any) of building a green economy in terms of sustainable development.

The second hypothesis also finds its confirmation – in particular, supporting the thesis that, in the absence of an active role played by the state in terms of making informed decisions and introducing effective tools, building a new economy while relying only on a new concept (idea) and hope for market regulation is characterized by a reliance on luck than on intentional and balanced actions that are properly managed and controlled by the appropriate economic actors.

5. Conclusions

The approach to assessing sustainable economic development implemented in this study, which is based not on building a model but on statistical analysis involving the presentation of consolidated data in graphical and tabular form, enables us to draw several conclusions regarding individual aspects characterizing the process of financing sustainable development in Russia.

First, the characterization of identified trends in the development of the country's economy as "unsustainable development" can be most justified by the inertia of events.

Second, an effective mechanism for green financing at the level of economic entities has not been formed. Businesses lack a serious motivation to implement sustainable investment projects. This is manifested in the varying degrees of activity of companies of various types of economic activity in implementing green investments, whose size is generally recognized as extremely insignificant. The negative aspect is that there are more sustainable and less sustainable types of economic activity – and that the gap between them is not narrowing.

Third, the national mechanism of green financing lacks a sufficient degree of recognition from the government; moreover, the efficiency and sustainability of economic development are not ensured by the failure to include its elements in the system for achieving strategic national development goals. This factor places a limit on the very possibility of technological transformation (modernization), since no impetus is created, initiatives are not actively supported, and new ideas for economic development are not formed. Nevertheless, the state will eventually have to make a decision on its financial involvement in the process of building a new sustainable economic model, as well as determine the instruments of state financing and support measures.

Altogether, the described situation forms the contours of a complex research task that requires rethinking traditional approaches to building a financial model of a new economy. Here, it will be necessary to find new approaches and sources of financing that lead to an intentional transition to a green economy.

The contribution of our research to solving this problem lies not only in offering adequate tools for assessing and recording the country's progress towards a green economy. In addition, the results of our analysis create a significant methodological basis for developing solutions on how to properly build a mechanism for accumulating financial resources for sustainable development. At a minimum, the presented analysis demonstrates how this should not be done. Another significant contribution of our study lies in its presentation of convincing, empirically substantiated, and verifiable evidence that the green economy and technological modernization are two sides of the same coin. The financing of investment projects that do not lead to technological modernization is not green financing. In conclusion, we would like to note once again that the actual, rather than formal, adoption of the concept of technological transformations across a wide range of socio-economic development issues developed by the UN can become a serious source of methodological support and an opportunity to use global agreements and approaches to solve the accumulated problems of socio-economic development of countries, which, after all, are inseparable from the goals of the green economy.

Author contributions

Conceptualization, *L.K.* and Zh.M.; methodology, *L.K.* and *I.R.*; software, *I.R.*; formal analysis, *I.R.*; data curation, *I.R.*; writing—original draft preparation *L.K.* and *I.R.*.; writing—review and editing, *L.K.*, *I.R.* and Zh.M.; visualization, *I.R.*.; supervision, *L.K.* and Zh.M.; project administration, *L.K.* and Zh.M.; funding acquisition, Zh.M. All authors have read and agreed to the published version of the manuscript.

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