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Economic-genetic approach to the institutionalization of spatial development models of industrial regions

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ABSTRACT
Relevance. The effective management of spatial development is fundamental for Russia with its vast territory. Industrial regions, whose spatial structures are characterized by high inertia, warrant particular attention as this inertia complicates their adaptation to new economic realities. This raises the question of which spatial development models should be institutionalized.
Research Objective. The study aims to develop the methodological foundations and tools of the economic-genetic approach to the institutionalizion of spatial development models, focusing on the industrial regions of the Russian Federation.
Data and Methods. The study's methodology comprises five sequential steps that develop and test tools using Frobenius norms to determine how well an industrial region's genotype is considered in strategic spatial planning.
Results. The findings call for a rethinking of spatial organization and development processes in industrial regions to ensure sustainability. Regions with the greatest potential for implementing diverse spatial structures tend to institutionalize a functional zoning model. Conversely, regions exhibiting internal conflict in their inheritance determinants prefer a model focused on supporting lagging territories. The third group, needing to build a framework of inter-territorial links to minimize gaps in the core genotype, shows equal interest in both functional zoning and support for lagging territories.
Conclusions. Incorporating the economic, social, and administrative-managerial inheritance of territories will enable a more informed choice of spatial transformation directions when developing and implementing regional socio-economic development strategies. These results can assist government authorities in refining spatial development models and enhancing the effectiveness of regional strategy implementation across the Russian Federation.

KEYWORDS
economic-genetic approach, spatial development model, genotype, inheritance determinant, industrial region, strategies, genotype formula, socio-economic development

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Экономико-генетический подход к институционализации моделей пространственного развития индустриальных регионов

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АННОТАЦИЯ
Актуальность. Для Российской Федерации, имеющей огромную территорию, эффективное управление пространственным развитием имеет принципиальное значение. Особого внимания заслуживают индустриальные регионы, большинство из которых характеризуются высокой инерционностью пространственных структур, существенно осложняющей их адаптацию к новым экономическим реалиям. Это заставляет задуматься о том, какие модели пространственного развития необходимо институционализировать.
Целью исследования является разработка методологических основ и инструментария экономико-генетического подхода к инсти-

КЛЮЧЕВЫЕ СЛОВА
экономико-генетический подход, модель пространственного развития, генотип, детерминанта наследственности, индустриальный регион, стратегии, формула генотипа, социально-экономическое развитие

туционализации моделей пространственного развития регионов.
Данные и методы. Исследование предполагает последовательно выполнение пяти методических шагов, которые, раскрывая экономико-генетический подход, содержат разработку и апробацию инструментария, использующего нормы Фробениуса в двух аспектах: для расчета величины ядра и определения формулы генотипа, отражающей доминирующие детерминанты наследственности территории. Предлагаемый подход определяет степень учета генотипа индустриальных регионов при стратегическом моделировании пространственного развития их территорий.
Результаты. Полученные результаты исследования позволяют переосмыслить организацию пространственных структур и процессов развития индустриальных регионов в целях обеспечения устойчивого пространственного развития. Выявлено, что регионы, имеющие наибольший потенциал успешной реализации различных пространственных структур, ориентированы на институционализацию модели функционального зонирования, тогда как регионы с внутренним конфликтом изменчивости детерминант наследственности предпочитают обращение к модели содействия развитию отстающих территорий. Регионы, которым необходимо выстраивать каркас активирующих связей межтерриториального взаимодействия, обеспечивающих минимизацию разрывов в ядре генотипа, в одинаковой степени проявляют интерес как к функциональному зонированию, так и к поддержке отстающих территорий.
Выводы. Учет экономической, социальной и административно-управленческой наследственности территорий позволит обеспечить грамотный выбор направлений пространственных трансформаций при разработке и реализации стратегий социально-экономического развития всех российских регионов. Полученные результаты могут быть использованы органами государственной власти при уточнении моделей пространственного развития, а также для повышения результативности реализации региональных стратегий РФ в целом.

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经济遗传学视角下工业区空间发展模式的制度化研究

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摘要
现实性：对于幅员辽阔的俄罗斯联邦而言，对空间发展进行有效管理具有根本性的重要意义。其中，工业区尤其值得关注，因为它们大多具有空间结构高度惯性的特点，这极大地阻碍了其适应新经济现实的能力。这不禁让人思考，究竟需要将哪些空间发展模式制度化。
研究目标：建立方法论基础以及一套工具，来用于从经济遗传学角度将区域空间发展模式制度化。
数据与方法：该研究拟分五个步骤循序渐进地开展。这些步骤在阐释经济遗传学方法的同时，还包含开发并验证一套工具。这套工具从两个方面运用了弗罗贝尼乌斯范数：用于计算核心的规模，以及确定反映区域主导遗传决定因素的基因型公式。所提出的方法，旨在明确在对工业区空间发展进行战略建模时，对其基因型的考量程度。
研究结果：研究成果使人们得以重新思考工业区空间结构与发展进程的组织方式，以期实现可持续的空间发展。研究发现，最具成功实施各种空间结构潜力的地区，倾向于将功能分区模式制度化；而存在遗传决定因素变异内部冲突的地区，则更倾向于采用扶持落后地区发展的模式。对于那些需要构建能够激活区域间互动联系、从而最大限度缩小基因型核心差距的框架的地区，它们则对功能分区和扶持落后地区都同样感兴趣。
结论：考虑各地区的经济、社会及行政管理的遗传特性，将有助于在制定和实施全俄各地区社会经济发展战略时，做出明智的空间转型方向选择。研究成果可供国家权力机关在完善空间发展模式时参考，也可用于提升俄罗斯联邦各地区整体战略的实施成效。

关键词
经济遗传学方法、空间发展模式、基因型、遗传决定因素、工业区、战略、基因型公式、社会经济发展

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Introduction

The transformation of socio-economic space has long been a focal point of scholarly attention. Research focuses on both developing models for the optimal spatial organization of economic systems, settlement, and infrastructure, as well as on methodologies for determining the effective localization of economic entities (Druzhinin & Kolosov, 2025; Leksin, 2016). For the Russian Federation, whose vast territory comprises significantly diverse regions, effective spatial development management is particularly important. The controversial decisions and reforms of the post-Soviet period, which significantly distorted the logic of economic localization, have only heightened the necessity of formulating a new spatial development model for the Russian economy. The controversial decisions and reforms of the post-Soviet period, which significantly distorted the logic of economic localization, have only heightened the need to formulate a new spatial development model for the Russian economy (Challenges …, 2020; Topoleva, 2022).

Spatial development processes at the regional level deserve particular attention (Chen, 2025), as regional transformations can reproduce macro-level trends associated with negative effects such as hyper-centralization, increased fragmentation, and the narrowing of economic space. Furthermore, the spatial organization of a regional economy is often a zone of accumulated structural imbalances and persistent problems.

Industrial regions hold particular significance, as most have centuries-long development histories. The current stage of technological advancement, marked by shifting technological paradigms and the profound modernization of production and consumption models, requires the dynamic reorganization of economic activity (Romanova & Sirotin, 2022). It should be acknowledged that spatial transformations exhibit high inertia compared to economic transformations, significantly complicating the adaptation of a region's spatial characteristics to new economic realities. This systemic contradiction creates ambiguity around the spatial organization features that should characterize a region whose economic system can function most effectively under both current and future conditions. This raises the question of which model should underpin managerial decisions for transforming industrial region space — a question that formulates the research's scientific problem: the theoretical and methodological rethinking of spatial development and the institutionalization of organization models that account for historically established economic linkages and relationships.

The study aims to methodologically rethink spatial organization in industrial regions by developing the economic-genetic approach to institutionalization of spatial development models. To achieve this goal, the following tasks should be addressed:

1. Justify the necessity of applying the economic-genetic approach to organizing spatial development in industrial regions.
2. Develop and test tools for formalizing the inheritance determinants of industrial regions to determine the value and formula of their genotype core.
3. Determine the extent to which industrial regions' genotypes are considered when institutionalizing spatial development models for their territories.

The results obtained can be used by state authorities and local self-government bodies in developing new trajectories of spatial development and improving existing ones, as well as in refining mechanisms to enhance the effectiveness of regional strategies for socio-economic development across the Russian Federation.

Article structure. The literature review outlines the core categories of the economic-genetic approach — namely, the economic, social, and administrative-managerial inheritance of industrial regions. The determinants of this inheritance constitute the core of the genotype, and its functions in ensuring spatial development are defined. The materials and methods section describes tools for determining the size of the genotype core in industrial regions and for identifying its formulas. These formulas reveal the dominant inheritance determinants responsible for organizing spatial development. The results section presents a ranking of industrial regions based on their genotype core size. The formulaic description of genotypes enables a classification of regions according to two criteria: the dominant determinant and the variability of determinants across economic, social, and administrative-managerial inheritance. The matrix synthesis of these criteria identifies the most suitable spatial development benchmarks for each regional group. To determine whether hereditary spatial develop-

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ment benchmarks align with implemented models, a substantive analysis of regional socio-economic development strategies is conducted. This analysis systematizes the models of spatial transformation currently undergoing institutionalization. The discussion examines identified patterns and draws conclusions on the extent to which hereditary determinants are considered in organizing the spatial development of industrial regions. The conclusion summarizes the author's scientific and practical findings, demonstrating how they address the research problem and goal related to developing the economic-genetic approach to the institutionalization of spatial development models.

Theoretical Framework

Within the economic-genetic approach (Myslyakova et al., 2021; Myslyakova & Neklyudova, 2021), spatial development is understood as the transformation of a region's established economic linkages. This process enables territories to adapt to crisis phenomena or new trends in the national economy, considering the determinants of their social and economic heredity. These determinants are embedded in the genotype of each region, which the authors, developing the ideas of economic genetics, conceptualize as multilayered memory of a territory. This memory underpins the reproduction of its society's economic structure, as well as the modes of interaction between economic entities and the connections among them (Kirdina, 2014; North, 1989; Polanyi, 2002; Stepin, 2011; Volchik & Kot, 2013).

Economic heredity manifests in the production activities of basic industries, whose effectiveness is primarily historically conditioned by their location within a natural-resource framework — minerals, fertile soils, climatic zones, and rivers. The significance of this heredity as a factor of spatial development is evident in the studies of P. Bogoslovskiy, who introduced the concept of the "Ural mining and manufacturing civilization". He describes it as "a specific system of settlement of two hundred city-factories, in which everything is interconnected: the ability to do business with ancient pagan demands, the customs of the people with the deafness of forests and the inaccessibility of mountains, the smelting of iron with the amount of snow in narrow rocky valleys, etc." (Bogoslovskiy, 1927; Minenko & Apkarimova, 2006). Also noteworthy are Myrdal's ideas on centrifugal forces of territorial development, generated by leading industries that act as hubs attracting factors of production (Myrdal, 2013). These forces form growth poles, which function as stable components of regional spatial development — a concept explored by F. Perroux (1961), J. Boudeville (1966), P. Pottier (1963), J. Friedman & W. Alonso (Regional …, 1975), M. Porter (2021), and others. Consequently, spatial development requires identifying an industry "point" that can potentially serve as an active growth node. Such a point would subsequently receive state investment in infrastructure, business incentives, preferential tenders, and other forms of support (Konnov & Talagaeva, 2023).

This focal point is often represented by dominant industries (Aghion & Howitt, 2009; Drucker, 2002; Romer, 1986) responsible for regional industrial specialization and the formation of specific technological chains and competencies (Lebedinskaya, 2025; Filatov et al., 2026). Consequently, the process of creating new-quality knowledge depends on their innovative base (Bloom et al., 2019; Cherif & Hasanov, 2025; Deming, 2022; Kerr & Robert-Nicoud, 2020; Mankiw et al., 1990; Ustinova & Alekseeva, 2020). The type of knowledge generated depends primarily on the industry, as its dissemination occurs among companies within the same industry and can only be supported by the concentration of its enterprises in a specific territory (Hatti, 2017; Kolomak, 2018) and the initiation of innovation diffusion processes, as noted in the works of T. Hägerstrand (Brum-Bastos & Paez, 2023) and E. Rogers (2003). The type of knowledge determined by specialization shapes human capital and the professional competencies of the population rooted in a specific territory. Therefore, one option for strengthening a region's centrifugal and centripetal forces is to increase investment in high-performance workplaces and R&D. As proven in global economic practice, such investment significantly impacts the pace of territorial economic growth (Romer, 1990; Rozhdestvenskaya & Tambovtsev, 2019; Zolait, 2020).

Social inheritance represents collective memory through which past states of territorial systems are recorded and established types of social relations, or specific aspects of these relations, are reproduced (Liu & Choi, 2025; Elkhova & Makulina, 2025). Collective memory preserves not only the pinnacles of cultural achievement,

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in the form of humanity's social values, but also everyday experiences embodied in people's consciousness (memory) and in the alienated products of their activities. Spatial development manifests during certain periods when society breaks with inherited programs, which in turn leads to the reassessment of individual values and initiates processes of worldview change. At the same time, as B. Ilizarov notes, the very process of mastering social inheritance "is even more susceptible to changes. Each new generation faces the choice of what from the inheritance should be forgotten, what needs to be preserved, and what from the preserved should be used, but in a new quality" (Ilizarov, 2021; Ilizarov, 2023). Therefore, if we consider spatial development through the prism of territory's social inheritance, the factors ensuring it are socio-cultural determinants of society. These manifest both in the population's quality of life and in intergroup interactions, shaping the economic behavior of economic entities (Cerisola & Panzera, 2022; Smith, 2012).

Another important type of inheritance affecting regional spatial development is administrative and managerial. This began to actively form in industrial territories as early as the 18th century, when the dynamics of private capital inflow were shaped by regional policies aimed at attracting successful entrepreneurs. These policies often involved providing assistance and, at times, making material sacrifices to deviate from the existing feudal legal order. Factory owners received broad powers in the exploitation of natural and human resources for production. An analysis of 21st-century management mechanisms in industrial territories reveals that defects in this inheritance can lead to negative outcomes in the economic and social spheres. In the economy, this manifests as production stagnation, job reduction, limited infrastructure, lack of investment in purification facilities, and the absence of productive entrepreneurship. Social inheritance is disrupted in the following ways: deterioration of population health; out-migration, especially of youth, to capital cities and territories that are more favorable; aging of the workforce and population; increased social tension and dependency caused by declining quality of life; and worsening criminal situation. This indicates that management based on low-quality administrative methods and the formation of a powerless command-administrative system inevitably leads to economic stagnation and barriers that hinder the country's spatial development.

We argue that the triad of hereditary determinants is embedded in the core of industrial regions' genotype — a hereditary mechanism that implements the patterns and evolution ensuring the transmission of values and experiences from earlier territorial socio-economic systems to later ones. The core is generated by the integrative links of interaction between government bodies, enterprises, and the population, allowing for the identification of the individuality of industrial territories (e.g., heterogeneity of economic specialization, uneven distribution and development of industrial production, innovative infrastructure). As a result of current activity, these genetic carriers act as nuclear forces of spatial development, including determining the region's predisposition to accelerate or slow down technological transformations, thereby sustaining the industrial development of territories.

Within the economic-genetic approach, spatial development occurs through established intra-regional connections. On one hand, these connections act as the roots of its origin; on the other, as elements of each region's genotype. Some connections are protective, while others are activating. The first type ensures the preservation of historically established socio-economic structures and their relationships (supporting reference to the past development path), while the second increases the susceptibility of economic entities to change and accelerates the exchange of energy both among themselves and with the external environment (Myslyakova, 2025). Collectively, these connections perform four key functions in ensuring spatial development:

— *Resource function***:** accumulates various types of territorial capital.

— *Relational function:* constructs the spatial structure of society, which possesses an individual development genotype. Being rooted in this community, this genotype ensures its restoration (Maiminas, 2016).

— *Historical-cultural function:* reduces the task of ensuring spatial development to searching among the diversity of established forms of inter-territorial interaction for the one that is more perfect and viable in a specific territory — whose effects from implementation grow and develop continuously. This function is evident in technogenic civilizations, whose reserves are formed by expanding innovative transformations and information technologies to ensure a new quality of life. Here, culture values the constant generation of new ideas and models, partially realized in the present and partially recorded in the future activity programs of subsequent generations.

— *Institutional function:* sanctions the movement of goods and individuals when entering, participating in, and exiting the economic process (Gerashchenko & Gerashchenko, 2022). According to D. North, society's institutional matrix represents its inherent basic structure of property rights and political system, in which economic and political institutions are interdependent (North, 2010). This force of spatial development comprises stable informal rules, customs, and traditions, which primarily shape stereotypes of economic behavior and, more broadly, economic culture (Volchik & Shiriaev, 2025).

The functionality of these connections determines how the triad of regional inheritance determinants influences spatial development. This necessitates considering the genotype of territories to ensure their self-development along the path set by history, enabling the gradual transformation of spatial development models or the institutionalization of new ones in response to changes in the external environment.

Method and Data

The proposed methodology is grounded in the premise that each region possesses an individual development genotype. This is understood as the economic inheritance of a territory, representing a set of historically established patterns of economic relations within the same territorial basis, shaped by the synthesis of knowledge, consensus of decisions, and technologies. Accordingly, the methodological steps of this research first concern developing tools to determine the size of the industrial region's genotype core, then establishing its formula to identify the dominant determinants of territorial inheritance, and finally identifying the spatial development models being institutionalized in regions with consideration of their genotype.

Step 1: Determining the structure of determinants of economic, social, and administrative-managerial inheritance of industrial regions. Since inheritance is embedded in the region's genotype core — representing a set of active, historically established elements and the connections between them — it is first necessary to determine its morphology. This morphology ensures the movement of territories along economic development trajectories in the context of innovative societal transformations, which is particularly relevant for industrial regions. For example, knowledge generated by the population represents building blocks for regional growth in the form of a "critical mass"—concentration of scientific and research resources on a specific topic capable of generating technological ideas (Berry & Glaeser, 2005; Kunwar & Ulak, 2023). These resources, having reached a certain level of economic return, become institutionalized in the economy's structure and exert a lasting impact on its technological development (Viale & Cucchiarini, 2025). Technologies generated by enterprises, in turn, affect public welfare through changes in thinking habits and behavioral standards in society (Mai et al., 2019). According to T. Veblen, human thought and behavior transform institutions of industrial development through adaptation to changing economic conditions (Veblen, 2006). Therefore, the consensus among key actors involved in the technological transformation of the regional economy is equally important, as it determines the principles for ensuring the territory's economic development on a scientific and technological basis that benefits all participants. Consequently, the activity of government bodies contributes to the spatial distribution of technologies (considering their sectoral specialization) and the spread of industrial production culture, which should be aligned with the socio-economic development goals of a specific region as articulated in its development strategies. This rationale underpins the following structure of active determinants of economic, social, and administrative-managerial inheritance of the region (Table 1).

Step 2: Formalization of the industrial region's genotype. This step integrates the active determinants of inheritance into a comprehensive indicator characterizing the territory's core genotype. This will be implemented using a matrix that reflects the variability of these determinants, calculated relative to the previous year for each period under study (Formula 1).

$$A = \begin{vmatrix} FP1 & FS1 & FI1 \\ FP2 & FS2 & FI2 \\ FP3 & FS3 & FI3 \end{vmatrix}$$

Table 1

Morphological Structure of Active Hereditary Determinants Ensuring the Development of Industrial Regions

I	Determinants of Administrative-Managerial Inheritance	P	Determinants of Economic Inheritance	S	Determinants of Social Inheritance
I1	Regulatory legal framework of scientific, technical, and innovative policy (strategies, programs, territorial planning schemes), as well as designated territories for the development of scientific and/or innovative activities and measures of their state support	P1	Activities of enterprises reflecting the innovative characteristics of the economic specialization of regions (the share of organizations that participated in joint projects for research and development and had ready technological innovations developed by their own efforts)	S1	Social foundation of transformations in terms of the educational mentality of the population (the share of the employed population with higher education)
I2	Organizational support of scientific, technical, and innovative policy (specialized coordinating bodies for scientific, scientific/technological, and/or innovative policy)	P2	P2 Investment activity of enterprises (volumes of expenditures for the implementation of technological transformations of production chains)	S2	Scientific and practical activity of the population, reducing public resistance to the innovative transformation of the regional economy and increasing the population's trust in the protection of intellectual property (the number of patents granted for inventions)
I3	Participation of regions in federal scientific, technical, and innovative policy (the number of scientific, scientific-technical, and innovative projects that received federal support)	P3	Effectiveness of innovative activities of enterprises (the share of innovative goods, works, services in the total volume of shipped goods; newly introduced or significantly modified)	S3	Scientific and technological potential of the population, forming the basis for the territorial expansion of innovative solutions (developed advanced production technologies).

Source: compiled by the authors

$$\text{or } A = \begin{vmatrix} a11 & a12 & a13 \\ a21 & a22 & a23 \\ a31 & a32 & a33 \end{vmatrix} \quad (1)$$

The calculation of each determinant of heredity is proposed to be carried out according to formula 2:

$$F_{I/P/S} = 1/n \cdot \sum_{i=1}^{n} \frac{x_i^r - x_i^{\min}}{x_i^{\max} - x_i^{\min}}, \quad (2)$$

where $F_{I/P/S}$ — determinant of heredity of the industrial region; n — number of indicators reflecting the active elements of the region's genotype; x_i^r — value of the i-th indicator characterizing the active element of the region's genotype; r — region; $x_i^{\min}$ — minimum value of the i-th indicator; $x_i^{\max}$ — maximum value of the i-th indicator.

When calculating the determinants of heredity, it is important to consider only their active (incorporated) elements. Furthermore, the application of significance coefficients is not required here, since within the economic-genetic approach, weights do not possess a static nature and do not exert linear influence on the region's behavioral characteristics, including its effectiveness. Emphasis is placed instead on the interconnectedness of hereditary determinants and synergistic effects, as their impact is largely determined by the specific territory's operating conditions and environment, as well as by the connections among elements of the genotype core. Collectively, these factors determine the region's individual capacity to adapt to changes in the external environment or to negative crisis processes — in other words, its evolutionary spatial development.

The dimensionality of the region's genotype core is then determined using Frobenius norms, which reflect the positive and negative transformations of its hereditary determinants. This method was chosen because it can account for the cumulative contribution of each determinant (as an element of the matrix) while preserving their morphology. On one hand, it allows for assessing the heredity core as a whole; on the other, it enables comparison of the direction (positive/negative) and magnitude (greater/less, based on vector length) of the variability of hereditary determinants — that is,

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whether they promote or hamper territorial development. Here, Frobenius norms perform an integrative function, allowing for the comparison and typologization of regions according to their genotype formula (Formulas 3, 4, and 5).

$$\|A^{+}\| = \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}^{2}} \text{ when } a_{ij} > 0, \quad (3)$$

$$\|A^{-}\| = \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}^{2}} \text{ when } a_{ij} < 0, \quad (4)$$

$$Core\_Gen = A^{+} - A^{-}, \quad (5)$$

where: *Core_Gen* — the core of the genotype of an industrial region, A^{+} — the positive norm of the matrix, A^{-} — the negative norm of the matrix, a_{ij} — the elements of matrix *A*.

Step 3: Determining the genotype formula. The second indicator for formalizing the industrial region's genotype core is its formula. To obtain this, we identify the dominant hereditary determinants, taking into account the polarity of their variability directions (Formulas 6–8).

$$FF^{+}_{(I/P/S)} = \sqrt{\sum_{i=1}^{m} F^{2}_{(I/P/S)i}} \text{ when } F_{(I/P/S)i} > 0, \quad (6)$$

$$FF^{-}_{(I/P/S)} = \sqrt{\sum_{i=1}^{n} F^{2}_{(I/P/S)i}} \text{ when } F_{(I/P/S)i} < 0, \quad (7)$$

$$\text{Core\_Genotype} = \begin{cases} I = FF^{+}_{(I)} - FF^{-}_{(I)} \\ P = FF^{+}_{(P)} - FF^{-}_{(P)} \\ S = FF^{+}_{(S)} - FF^{-}_{(S)} \end{cases} \quad (8)$$

Formula 8 allows formalizing the genotype core of industrial regions and then typologizing them (Table 2).

The obtained genotype formula helps identify the drivers of economic and spatial development in Russian industrial regions. For example, the dominance of the administrative-management determinant of inheritance — present in the genotypes of China's provinces, South Korea, and the Persian Gulf countries — manifests when local authorities initiate long-term state programs for financing technological development, as well as investments in science-intensive companies and scientific megaprojects. The dominance of the economic determinant is exemplified by the independent digitalization and robotization of large network businesses. Cases such as Siemens, Bosch, and Volkswagen (developing Industry 4.0 in Germany); Telerik (IT sector, Bulgaria); Infobip (IT sector, Croatia) — which have made their countries major European clusters — and CropX (contributing to Israel's "startup nation" phenomenon) demonstrate that companies competing for new market niches elevate countries not only economically but also politically. The dominance of the social determinant is possible when key decisions regarding territorial development are "raised from below" through referendums in which the population participates to determine budget expenditure goals aimed at improving quality of life. Thus, the genotype formula enables the identification of effective levers of economic behavior in the studied regions and determines the tools for institutionalizing their spatial development models.

Step 4: Analyzing spatial development models in regional strategies. The next methodological stage involves analyzing current socio-economic development strategies of all Russian regions and identifying the spatial transformation models embedded within them. Referring to strategic planning documents as a source of expert thought worthy of attention in scientific research is a common practice in regional studies (Aranguren et al., 2023; Ferreira et al., 2025). This step entails

Table 2

Formula of the genotype of industrial regions

Genotype with a Dominant Administrative-Managerial Determinant Core_Genotype, I > p, s	Genotype with a Dominant Economic Determinant Core_Genotype, P>i, s	Genotype with a Dominant Social Determinant Core_Genotype, S > p, i
$I^{+}p^{+}s^{+}$	$i^{+}P^{+}s^{+}$	$i^{+}p^{+}S^{+}$
$I^{+}p^{-}s^{+}$	$i^{-}P^{+}s^{-}$	$i^{+}p^{-}S^{+}$
$I^{+}p^{-}s^{-}$	$i^{-}P^{+}s^{+}$	$i^{-}p^{-}S^{+}$
$I^{+}p^{+}s^{-}$	$i^{+}P^{+}s^{-}$	$i^{-}p^{+}S^{+}$

Source: compiled by the authors.

a detailed examination of individual sections of regional strategies devoted to spatial development issues. Particular attention should be paid to analyzing the target settings through which the desired image of the region's spatial organization is described, as well as identifying the specific changes that, according to strategy developers, the regional space requires. Identifying the selected transformation vectors will allow for the recognition of spatial development models institutionalized through goal-setting documents.

Step 5: Determining prospects for integrating the genotype. The final methodological stage determines the prospects for considering the genotype of industrial regions in developing and improving their spatial development models. This is achieved by comparing the characteristics of the genotype core (size and formula) with the trajectories of spatial organization embedded in socio-economic development strategies.

Results

The proposed methodological steps are tested on industrial regions, which play a fundamental role in ensuring the spatial development of the Russian Federation amid dynamic external condi-

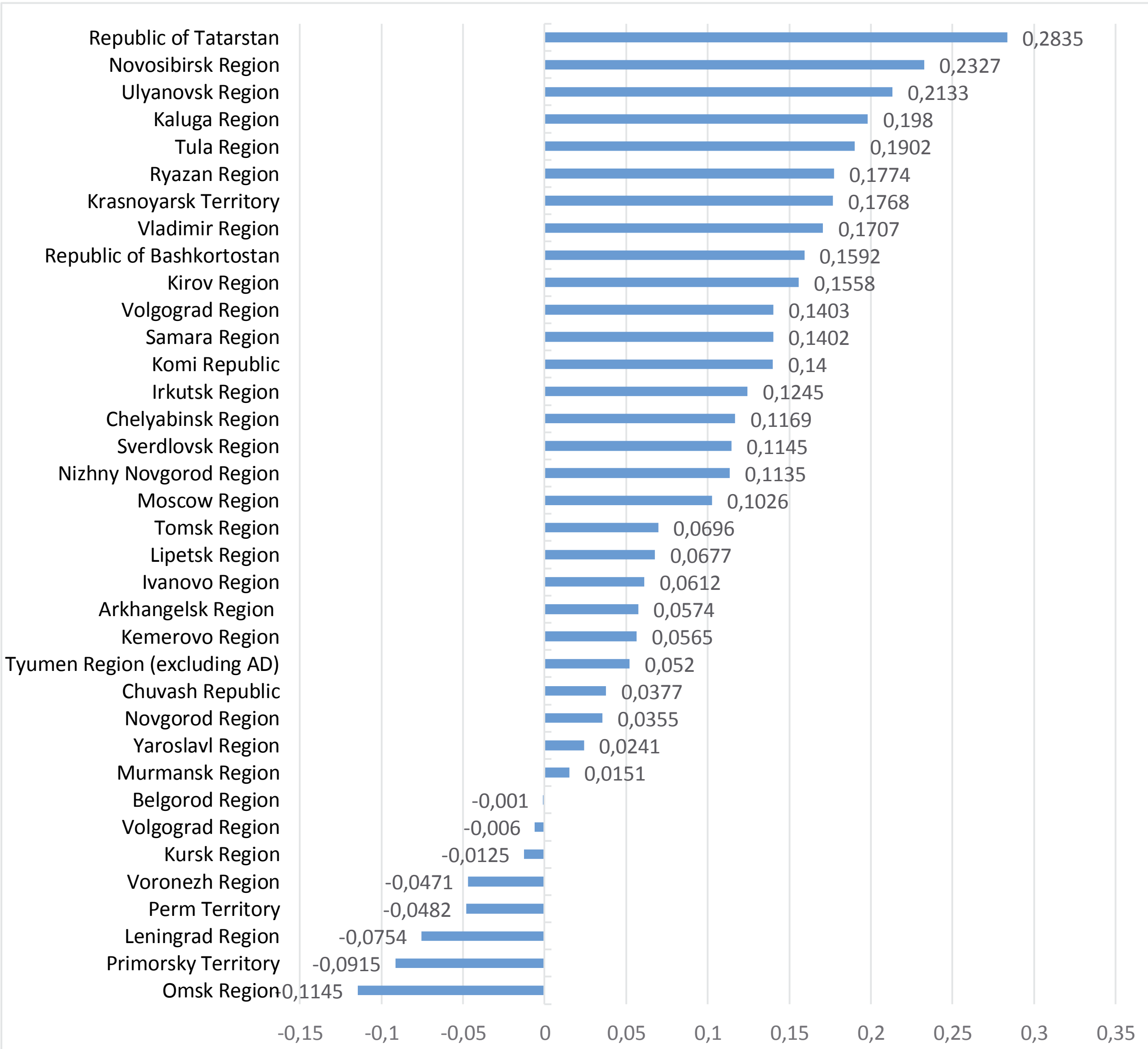

Figure 1. *Ranking of Industrial Regions by Genotype Core Size (Core_Gen), 2008–2023 гг.*

Source: compiled by the authors based on their own calculations of innovation policy quality indicators from Russian Regional Innovation Scoreboard (Retrieved from: https://www.hse.ru/primarydata/rir (date of access: 15.01.2026)), as well as indicators of innovative technological and socio-economic development of Russian regions published by the Federal State Statistics Service (Retrieved from: https://rosstat.gov.ru/folder/10705 (date of access: 15.01.2026)).

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tions. The pool of industrial regions consists of industrially developed territories (where the share of manufacturing industries in GRP is at least 25 %) and economically developed industrial regions with broad sectoral specialization.

Moscow and St. Petersburg were excluded from the sample to enhance statistical homogeneity and avoid dominance by the two megacities. The study period spans 2008 to 2023, allowing for the assessment of both long-term socio-economic indicators and the process of strategizing industrial region development.

The top ten leaders by genotype core value comprise regions whose Core_Gen value significantly exceeds the average for all industrial regions (Core_Gen = 0.084). These regions exhibit positive variability in their hereditary determinants, which is maximally favorable for self-development and adaptation to dynamic external conditions. The leaders are Republic of Tatarstan (+237 %), Novosibirsk Region (+176 %), Ulyanovsk Region (+153 %), Kaluga Region (+135 %), Tula Region (+126 %), Ryazan Region (+111 %), Krasnoyarsk Territory (+110 %), Vladimir Region (+103 %), Republic of Bashkortostan (+89 %), and Kirov Region (+85 %) (Figure 1).

The ranking outsiders, those with the most unfavorable inheritance, which significantly slows territorial development, are Belgorod, Vologda, Kursk, and Voronezh regions; Perm Territory; Leningrad Region; Primorsky Territory; and Omsk Region. These regions exhibit the strongest negative vectors of variability in their inheritance determinants.

To identify the dominant hereditary determinants — including those that explain the regions' ranking positions — the formulas describing their genotypes were identified (Table 3).

As a result of this methodological step, it was revealed that the most significant determinants are those of administrative-managerial inheritance, which is confirmed not only by pairwise comparison of the variability of the elements of the genotype of industrial regions but also by the size of its core, which determines the leadership positions of the regions. In the lowest-ranked regions (Figure 1), the rate of change of the determinants of this type of inheritance is negative, while the determinants of economic and social inheritance are unable to compensate for and change the inhibiting dynamics of the variability of the genotype as a whole. Moreover, the analysis of the hereditary determinants in industrial regions allows for the classification of genotypes that influence their spatial development. The criteria are, on the one hand, the dominant hereditary determinants that have more significant variability, and on the other, their vector of variability (Table 4). The leaders of the ranking are highlighted in bold, which emphasizes the influence of active determinants of administrative-managerial inheritance in all three types of genotypes of industrial regions.

The obtained classification of region genotypes of regions allows for the proposal of the following focuses of spatial development of their territories:

— regions of the first genotype have the greatest potential for successful implementation of various spatial structures (special economic zones, clusters, industrial parks, TOR (monocities and closed administrative-territorial formations), etc.), which can have an innovative technological base characteristic of their specialization;

— for regions of the second genotype, spatial development should build a framework of activating inter-territorial interaction aimed at reducing socio-economic heterogeneity and minimizing gaps in the core of inheritance;

— regions of the third genotype exhibit an internal conflict of variability of the hereditary determinants, therefore their spatial organization should strengthen the positions of the dominant element of inheritance and enhance protective connections within the core, ensuring its integrity in the context of external activation of inter-territorial interaction, increasing its connectivity with the determinants of other types of inheritance.

It is argued that the developmental focus of these industrial genotypes should inform the socio-economic development strategies of the Russian Federation regions. Therefore, further, to identify this accountability in the study, a substantive analysis of the main sections of regional documents was conducted with the aim of systematizing the models of spatial transformation laid down in the strategies, concerning the documents of 82 subjects of the Russian Federation. The specifics of the tasks set determined the exclusion from the number of studied strategies those created for cities of federal significance; moreover, new territories for which socio-economic devel-

Table 3

Formalization of the Genotype of Industrial Regions, 2008–2023*

	FFI+	FFI-	I	FFP+	FFP-	P	FFS+	FFS-	S
Arkhangelsk Region	0,284	0,138	0,146	0,306	0,330	–0,024	0,043	0,057	–0,014
Belgorod Region	0,199	0,194	0,004	0,147	0,161	–0,014	0,065	0,047	0,018
Vladimir Region	0,366	0,179	0,187	0,079	0,066	0,013	0,031	0,075	–0,044
Volgograd Region	0,392	0,240	0,152	0,091	0,107	–0,016	0,039	0,026	0,013
Vologda Region	0,357	0,355	0,002	0,109	0,134	–0,026	0,026	0,014	0,012
Voronezh Region	0,341	0,367	–0,026	0,092	0,193	–0,101	0,133	0,092	0,041
Ivanovo Region	0,363	0,250	0,113	0,054	0,059	–0,005	0,062	0,176	–0,114
Irkutsk Region	0,294	0,139	0,156	0,108	0,130	–0,022	0,098	0,074	0,024
Kaluga Region	0,422	0,200	0,223	0,103	0,083	0,020	0,062	0,106	–0,045
Kemerovo Region	0,258	0,197	0,061	0,104	0,101	0,003	0,031	0,030	0,001
Kirov Region	0,495	0,306	0,189	0,053	0,153	–0,100	0,018	0,019	–0,001
Krasnoyarsk Territory	0,379	0,131	0,248	0,095	0,158	–0,063	0,084	0,085	–0,001
Kursk Region	0,302	0,320	–0,018	0,188	0,182	0,006	0,026	0,026	0,000
Leningrad Region	0,132	0,244	–0,112	0,132	0,104	0,028	0,039	0,019	0,020
Lipetsk Region	0,355	0,295	0,060	0,140	0,107	0,033	0,031	0,030	0,001
Moscow Region	0,176	0,149	0,027	0,176	0,059	0,117	0,204	0,150	0,054
Murmansk Region	0,263	0,222	0,040	0,096	0,143	–0,048	0,002	0,003	–0,001
Nizhny Novgorod Region	0,366	0,175	0,191	0,117	0,119	–0,002	0,040	0,172	–0,132
Novgorod Region	0,492	0,433	0,059	0,151	0,203	–0,051	0,033	0,050	–0,017
Novosibirsk Region	0,414	0,170	0,244	0,092	0,078	0,014	0,039	0,046	–0,008
Omsk Region	0,291	0,427	–0,136	0,146	0,098	0,048	0,021	0,048	–0,027
Perm Territory	0,270	0,295	–0,025	0,061	0,138	–0,077	0,034	0,028	0,005
Primorsky Territory	0,345	0,432	–0,087	0,116	0,143	–0,027	0,033	0,035	–0,002
Republic of Bashkortostan	0,512	0,342	0,170	0,101	0,126	–0,026	0,064	0,037	0,027
Komi Republic	0,321	0,156	0,165	0,120	0,130	–0,009	0,008	0,009	–0,001
Republic of Tatarstan	0,669	0,433	0,237	0,185	0,034	0,152	0,222	0,102	0,120
Ryazan Region	0,251	0,039	0,212	0,172	0,103	0,069	0,040	0,069	–0,029
Samara Region	0,398	0,250	0,148	0,091	0,127	–0,037	0,143	0,082	0,061
Sverdlovsk Region	0,289	0,166	0,123	0,099	0,102	–0,004	0,062	0,028	0,033
Tomsk Region	0,300	0,216	0,083	0,183	0,182	0,001	0,037	0,023	0,015
Tula Region	0,489	0,306	0,182	0,181	0,124	0,057	0,042	0,036	0,006
Tyumen Region (excluding autonomous districts)	0,374	0,293	0,081	0,165	0,193	–0,027	0,059	0,084	–0,025
Ulyanovsk Region	0,446	0,222	0,224	0,177	0,116	0,061	0,386	0,315	0,071
Chelyabinsk Region	0,269	0,154	0,115	0,129	0,085	0,044	0,033	0,052	–0,019
Chuvash Republic	0,408	0,292	0,116	0,126	0,253	–0,127	0,044	0,066	–0,022
Yaroslavl Region	0,214	0,210	0,005	0,154	0,116	0,038	0,021	0,021	0,001

* *Note*: The most significant hereditary determinants are highlighted.

Source: compiled by the authors based on their own calculations.

opment strategies have not yet been prepared or are in the development stage were not included in the review. As a result of the analysis, it was found that spatial aspects of development are not addressed in all the examined documents: the section characterizing the directions of spatial transformation is contained in the strategies of 72 regions (Figure 2).

Overall, it should be noted that the substantive analysis of the sections of these regional doc-

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Table 4

Classification of Industrial Regions Based on the Genotype Formula

	Genotype with a Dominant Administrative-Managerial Determinant Core_Genotype, I>p, s	**Genotype with a Dominant Economic Determinant Core_Genotype, P>i, s**	**Genotype with a Dominant Social Determinant Core_Genotype, S > p, i**
Genotype 1 — regions with stable positive variability of heredity determinants	$I^+p^+s^+$ Kemerovo Region **Republic of Tatarstan** Tomsk Region **Tula Region** **Ulyanovsk Region** Lipetsk Region	$i^+P^+s^+$ Moscow Region Yaroslavl Region	$i^+p^+S^+$
Genotype 2 — regions with polar variability of heredity determinants	$I^+p^-s^+$ Volgograd Region Irkutsk Region **Republic of Bashkortostan** Samara Region Sverdlovsk Region	$i^-P^+s^+$ Leningrad Region	$i^+p^-S^+$ Belgorod region Vologda region
	$I^+p^+s^-$ **Vladimir Region** **Kaluga Region** **Novosibirsk Region** **Ryazan region** Chelyabinsk Region	$i^+P^+s^-$	$i^-p^+S^+$
Genotype 3 regions with internal hereditary tension	$I^+p^-s^-$ Arkhangelsk Region Ivanovo Region **Kirov Region** **Krasnoyarsk Territory** Murmansk Region Nizhny Novgorod Region Novgorod Region Republic of Komi Tyumen region (excluding AD) Chuvash Republic	i^-P+s^- Kursk Region Omsk Regioni	$i^-p^-S^+$ Voronezh Region Perm Territory

Note: Primorsky territory was not included in the classification, as it has negative variability of all heredity determinants.

Source: compiled by the authors based on their own calculations.

uments allowed for the identification of four basic Russian models of spatial development in the context of strategic goal-setting for spatial development:

— *the model of priority development of territories with the greatest potential* implies the identification or formation of the most promising territorial units (for example, leaders of technological development, agglomeration systems, innovation centers) and their transformation into growth poles that generate development impulses to their surroundings;

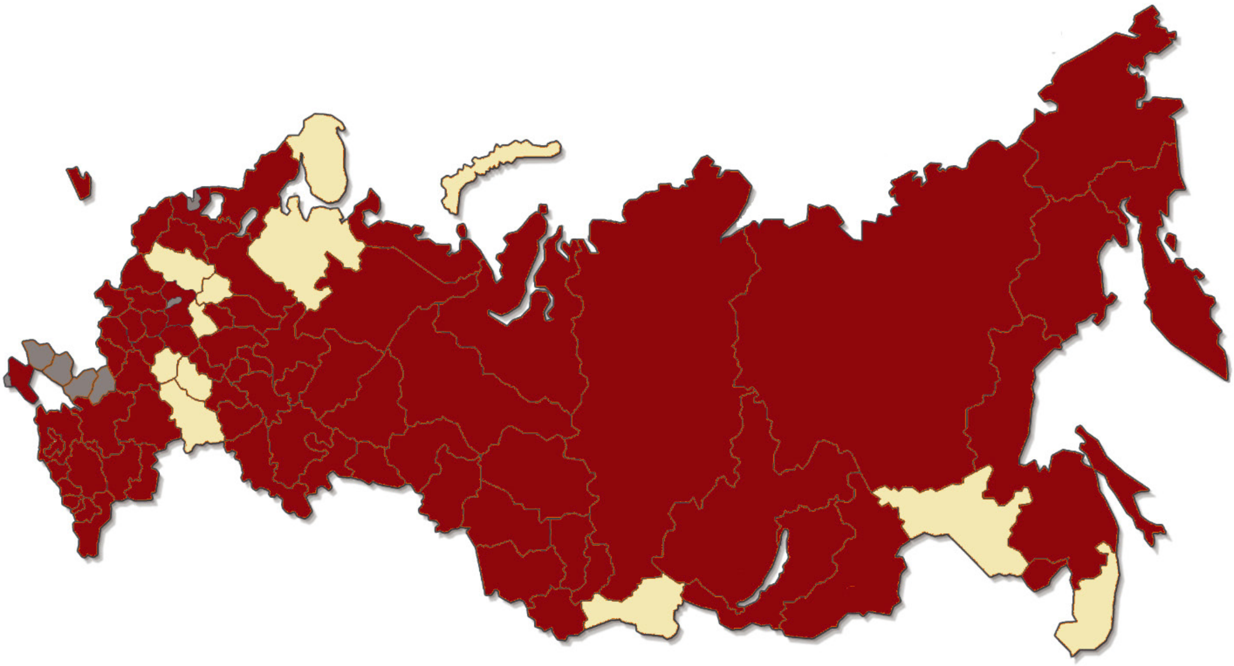
— *the model of assistance in the development of lagging territories* is oriented towards reducing inter-territorial differentiation and provides for priority support to "outsiders";

— *the model of functional zoning* implies the division of the region's space into separate parts (areas), each of which has its own development benchmark and its own place in the socio-economic complex of the subject of the Russian Federation;

— *the model of hierarchical organization of space* implies the ordering of individual territorial units, differing in the scale of the tasks they implement, into a multi-level system, the parts of which are closely interconnected.

After systematizing spatial development models, the final step of the research was to compare them with the genotypes of each industrial region. This comparison revealed the following patterns.

Firstly, in the strategies of a number of industrial regions (Omsk, Ryazan, Samara, Yaroslavl re-



■ Regions whose development strategies contain a section devoted to spatial transformations
■ Regions whose development strategies do NOT contain a section devoted to spatial transformations
■ Regions whose documents were not analyzed

Figure 2. *Geographical Distribution of Regions Addressing Spatial Development in Their Strategies*
Source: socio-economic development strategies of the Russian regions (available on the official websites of these regions).

gions, and Perm Territory), it is impossible to unambiguously identify a model (or models) of spatial development due to the weak elaboration of the section of the document dedicated to spatial transformations or the lack of clarity regarding the desired orientation of this sphere of transformations. Such regions are representatives of each of the highlighted groups within the framework of the grouping, taking into account the prevailing hereditary determinants and types of territories.

Secondly, in the majority (18 out of 35) of strategies, several models of spatial development are simultaneously laid as the basis for transformations, with the largest number characteristic of regions where the administrative-management determinant predominates (Table 5).

Table 5

Average Number of Spatial Development Models per Region in Each Group

	Genotype with a Dominant Administrative-Managerial Determinant	Genotype with a Dominant Economic Determinant	Genotype with a Dominant Social Determinant	Average Across Several Groups of Regions
Genotype 1 — Regions with stable positive variability of heredity determinants	2,7	0,5	–	**2,1**
Genotype 2 — regions with polar variability of heredity determinants	1,5	1	1	**1,4**
Генотип 3 — regions with internal heredity tention	1,7	1,5	1,5	**1,6**
Average Across Several Groups of Regions	**1,8**	**1**	**1,3**	

Source: compiled by the authors based on their own calculations.

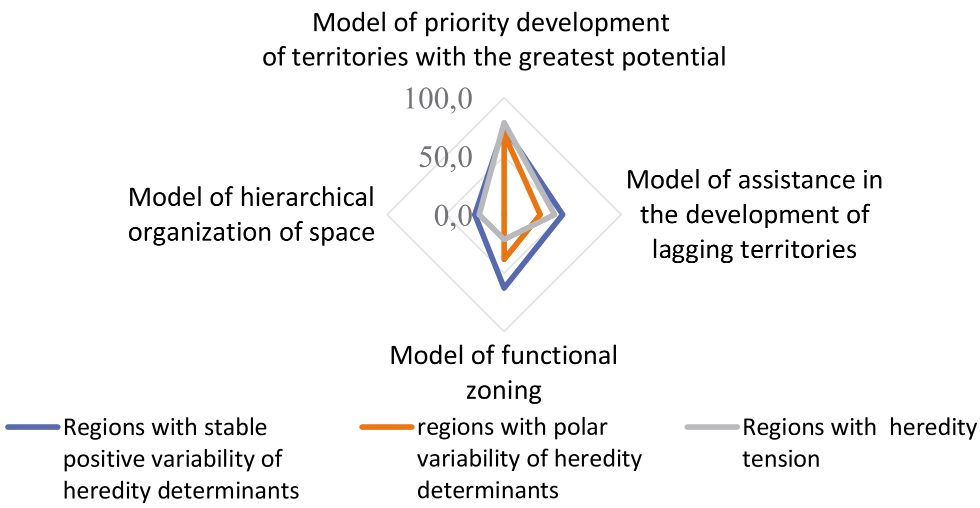


Figure 3. *Share of Regions by Preferred Spatial Development Direction*
Source: compiled by the authors based on their own calculations.

For instance, the strategy of Lipetsk Region — which belongs to this group — states that the target settings for spatial transformations are related to "ensuring speed, comfort, and safety of movement; development of agglomeration processes with core centers: Lipetsk — Yelets; reconstruction and revival of the settlement system of small towns and rural areas"[1], three models were developed (the model of priority development of territories with the greatest potential, the model of assistance in the development of lagging territories, and the model of functional zoning). In the strategy of Belgorod Region, which belongs to regions with a genotype dominated by social determinants, the emphasis is placed on "reducing intra-regional differences in the level and quality of life of the population"[2], and the predominant model is the model of assistance in the development of lagging territories.

Thirdly, the model of priority development of territories with the greatest potential has gained the most widespread acceptance among industrial regions: 74% of the subjects of the Russian Federation chose it as a target or one of its main models. Such prioritization is also characteristic of each of the three groups of regions identified within the framework of the classification that takes into account the parameters of the core genotype (Figure 3).

However, while there is widespread agreement on the most popular model of spatial development among regions of different types, the choice of the "second" most significant model is less clear. Thus, regions with stable positive variability of hereditary determinants (genotype 1) are oriented towards the implementation of the model of functional zoning (62.5% of such territories), while regions with hereditary tension (genotype 3) prefer to turn to the model of supporting the development of lagging territories (42.9%). Regions with polar variability of hereditary determinants (genotype 2) equally show interest in both functional zoning and support for lagging territories.

The model of hierarchical organization of space is presented in a very limited number of strategies of industrial regions and has not received the same distribution as other models in the processes of institutionalization of spatial development. This is largely due to the higher complexity of its implementation in regional policy: it requires a comprehensive approach to the development of the territory, careful consideration of the placement of individual elements of space relative to each other, as well as the establishment of a system of inter-territorial interactions.

Conclusions

The findings extend the economic-genetic approach, allowing for a rethinking of the organization of spatial structures and development pro-

[1] Law of Lipetsk Region No. 207-OZ of October 25, 2022 "Strategy for the Socio-Economic Development of Lipetsk Region for the Period until 2030".

[2] Resolution of the Government of Belgorod Region No. 371-pp of July 11, 2023 "On the Approval of the Strategy for the Socio-Economic Development of Belgorod Region for the Period until 2030".

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cesses of industrial regions in order to ensure sustainable spatial development. The main categories of the approach are the determinants of economic, social, and administrative-managerial inheritance, which make up the structure of the core genotype — the institutional mechanism that ensures the evolutionary development of territories. Spatial development is realized within the framework of established intra-regional connections, which determine its origins and define the directions of further transformations. In total, hereditary connections, acting as elements of the core genotype of the region, perform resource, relational, historical-cultural, and institutional functions to ensure its spatial development. This necessitates taking into account the regional genotype and its strongest determinants to ensure the self-development of territories in the direction set by history, and enable the gradual transformation of existing models of spatial development or the institutionalization of new ones as an adaptive response to changes in the external environment.

As part of the economic-genetic approach, a toolkit has been developed for the formalization of the core genotype of industrial regions, using Frobenius norms in two methodological aspects: for calculating the size of the core and for determining the genotype formula that reflects the dominant determinants of heredity. Applying this toolkit yielded a ranking of regions, the leaders of which are: the Republic of Tatarstan, Novosibirsk, Ulyanovsk, Kaluga, Tula, Ryazan regions, Krasnoyarsk Territory, Vladimir Region, the Republic of Bashkortostan, and Kirov Region. In addition, the formalization of the genotypes of industrial regions allowed for the development of their classification according to two criteria: the dominant determinant and the variability of the determinants of economic, social, and administrative-managerial heredity of the territories. The obtained characteristics of the genotypes allow for the identification of spatial development guidelines that are most suitable for the selected groups of regions.

To establish whether the guidelines for spatial development laid down by heredity coincide with the models of its implementation, we conducted a substantive analysis of the main sections of regional strategies for socio-economic development, within which the models of spatial transformation were systematized (priority development of territories with the greatest potential; assistance in the development of lagging territories; functional zoning and hierarchical organization of space). The analysis reveals that the strategies for the development of industrial regions are characterized by by a strong consideration of heredity. Thus, regions with the greatest potential for successful implementation of various spatial structures (genotype 1) are oriented towards the implementation of the functional zoning model, while regions with internal conflict of variability of hereditary determinants (genotype 3) prefer to turn to the model of assistance in the development of lagging territories. Regions that need to build a framework of activating inter-territorial interaction links, ensuring the minimization of gaps in the core of heredity (genotype 2), show equal interest in both functional zoning and support for lagging territories. Nevertheless, these hereditary traits must be systematically integrated when developing and implementing socio-economic development strategies for all Russian regions, which fully corresponds to one of the principles of the country's Spatial Development Strategy[3], as recorded in the document, and thus implying the use of a differentiated approach to the development of various territories and consideration of the entire multitude of factors determining the issues and prospects of their transformations. Thus, addressing the economic-genetic approach at the goal-setting stage will allow regional management structures to competently approach the selection of directions for spatial transformations.

The further direction of research will be to identify deeper causal relationships that determine the choice and technological basis of spatial development models, taking into account the economic specialization of regions, as well as their hereditary predisposition to innovative development.

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[3] Decree of the Government of the Russian Federation dated December 28, 2024, No. 4146-r "On the Approval of the Spatial Development Strategy of the Russian Federation for the Period until 2030 with a Forecast until 2036".

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