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Research article

Assessing agglomeration processes in Russian second-tier urban agglomerations

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Abstract: One of Russia's strategic objectives is to identify and create conditions to ensure accelerated development of promising centers of economic growth in the country's regions. In practice, most of these centers are cities of different levels of hierarchy, which create or have the potential to create urban agglomerations on their basis. At the same time, at present, most attention is paid to the study of the largest and large urban agglomerations not only in domestic, but also in the world science; while the real prerequisites and processes of second-tier agglomerations development are studied rather poorly. In this regard, the purpose of this paper was to analyze and identify the specifics of agglomeration processes in several Russian second-tier agglomerations. To achieve this purpose, we used a wide range of both general scientific (analysis, synthesis, structural-functional, etc.) and applied economic and mathematical methods (index method, correlation analysis, calculation of the Theil index). The main conclusions of the research was that the key trend of these agglomerations' development was the increasing concentration of an already high share of regional production, investment, and population against the background of growing intra-regional heterogeneity. At the same time, agglomeration processes themselves spread only to the territory closest to the core, which is manifested in the convergence of growth rates of these territories in terms of key socio-economic indicators. All this proves the underdevelopment of the satellite zone of second-tier agglomerations and the hypertrophied development of the core: weak interconnectedness of their reproductive processes, which may be a threat to the development of such agglomerations as integrated socio-economic systems and growth centers of regional and macro-regional significance in the future. The authors showed that a number of northern/arctic agglomerations (Surgut, Arkhangelsk) have a significant development potential due to not only the formed economic base of their satellite zone, but also socio-economic connectivity along

the line "core-satellite zone". The scientific novelty of the presented research lies in the development of approaches, substantiation of methodological tools for assessing agglomeration processes, and identification of the specifics of these processes in Russian second-tier agglomerations on the basis of its testing.

Keywords: urban agglomeration; second-tier agglomerations; large city; agglomeration processes; socio-economic development; spatial development; Russian Federation; constituent entity of the Russian Federation

JEL Codes: O18, P25, R12

1. Introduction

The Strategy for Spatial Development of the Russian Federation for the period until 2025 identifies urban agglomerations as one of the key priorities of the country's spatial development. The document defines 20 promising major centers of economic growth at the national level—cities forming large and largest urban agglomerations (Moscow, St. Petersburg); 22 promising centers of economic growth in the constituent entities of the Russian Federation—cities forming urban agglomerations with a population of more than 500 thousand people (e.g., Yaroslavl); and 23 promising centers of economic growth in the constituent entities of the Russian Federation, including those forming urban agglomerations with a population of less than 500 thousand people (so-called second-tier agglomerations, formed around a number of large cities: Belgorod, Arkhangelsk, Vladimir, Vologda, Kaluga, Komsomolsk-on-Amur, etc.).

The Strategy officially enshrines the concept of urban agglomeration, which is considered as a "set of compactly located settlements and territories between them with a total population of more than 250 thousand people, connected by joint use of infrastructure facilities and united by intensive economic, including labor, and social ties".

The classical scientific definition of urban agglomeration is given by the famous Russian scientist G.M. Lappo: "urban agglomeration is a compact territorial grouping of urban and rural settlements, united in a dynamic local system by a variety of intensive ties (industrial, business, labor, cultural, recreational and other), as well as the joint use of resources of the agglomeration area" (Lappo, 2012).

Agglomerations as a form of spatial organization of population and economy have a number of effects, which, in scientific research (Kutsenko, 2012), are grouped into 2 main types:
1. Marshall-Arrow-Romer effects (MAR effects) (clustering effects):
• positive effects: increase in the efficiency of production and services on the basis of functional specialization, reduction of production costs, increase in the efficiency of municipal budgets expenditures on housing and utilities, transport, environmental protection, etc.;
• negative effects: growth of certain transaction costs, for example, congestion of the transport system, possible increased bureaucratization and formalism, etc.;
2. Jacobs-effects (urbanization effects):
• positive effects: implementation of large development projects based on markets and resources expansion within the agglomeration, creation and dissemination of innovations,

promotion of goods and services outside the agglomeration based on the umbrella brand of the territory, increased mobility of the labor force, etc.;

• negative effects: population outflow from the region's peripheral areas, deterioration of the environmental situation in the agglomeration, etc.

The researchers in their studies (Grover et al., 2023) show the specifics of agglomeration processes and effects in developed and developing countries on the materials of 76 agglomerations from 34 countries of the world. It is proved that the elasticity of labor productivity in developing countries, as a rule, is higher than in the developed ones, but not more than by 1 p.p. These circumstances once again confirm that the development of urban agglomerations of different levels of hierarchy is a reserve for increasing the rate of economic growth in Russia amid geopolitical turbulence.

In this regard, in order to assess whether a set of urban and rural settlements and municipalities is an urban agglomeration, we need to assess the agglomeration processes and effects occurring here. The key trends in socio-economic development of municipalities, indicating the presence of agglomeration processes, are:

• increasing concentration of population, production, investment, innovation activities, the number of registered organizations (including nonprofit organizations) and individual entrepreneurs per 1,000 people in the agglomeration; engineering infrastructure facilities; growth in the density of the street and road network, housing provision, indicators of housing stock improvement, etc.;

• synchronization of the economic growth rates of municipalities included in the agglomeration;

• reduction of differences between municipalities in terms of the main parameters of socio-economic and infrastructural development, etc.

At the same time, we should note that the main attention in the world and Russian science, as well as in management practice, is currently focused on the analysis of processes and assessment of agglomeration effects in large and major agglomerations. In turn, the specifics of the development of second-tier agglomerations (with a population of less than 500 thousand people) are given much less attention. In this regard, the purpose of this paper is to analyze and identify the specifics of agglomeration processes in Russian second-tier agglomerations (the case of the 8 agglomerations identified in the Strategy for Spatial Development of the Russian Federation).

2. Literature review

The study of the leading domestic and foreign scientific publications, as well as the world practice, indicates that agglomeration forms of economic activity concentration differ significantly from each other by stage of development, composition of elements, place in the system of geographical division of labor, and a number of other features.

For example, Chinese researchers (Fang and Yu, 2020, 2017) categorize large agglomerations ("urban agglomeration") as among the most developed ones. Such agglomerations are a hierarchical system of interconnected cities of different sizes (usually more than 3), as well as over-agglomeration forms of settlement and economic activity ("metropolitan interlocking region"). At the same time, they include less developed agglomerations ("town agglomeration") in a separate category. According to them, such agglomerations are formed around cities of one hierarchical level, usually the small ones (with a population of less than 500 thousand people). Domestic researchers also address the issues of such agglomerations, including the "second-" and "third-tier" ones. These are specialists from the

Institute for Urban Economics (Institute of Urban Economics Foundation, 2020), the Center for Infrastructure Economics (Dmitriev et al., 2018), the Institute of Economics and Industrial Engineering, Siberian Branch of the Russian Academy of Sciences (Melnikova, 2017), and others.

In our study, we are interested in the "town agglomerations" phenomenon, which, in practice, are centers not of global, but of macro- and regional competitiveness and are formed not only in the regions with high-tech economy, but also in the areas of urbanization intensification and increasing connectivity of urban and rural territories. In our opinion, as far as Russia is concerned, "urban agglomerations" have more similarities with large and largest agglomerations enshrined in the Strategy for Spatial Development of the Russian Federation by their nature and role in the national economy (these are, first of all, Moscow and St. Petersburg agglomerations); and the remaining underdeveloped or only emerging second-tier agglomerations, the core of which are large and smaller cities (for example, 23 promising centers of economic growth), can be referred to as "town agglomerations".

At the same time, we should note that the condition for such agglomerations' sustainable development and their transition to more mature stages is to ensure the internal integration of the core city and its satellite zone not only in production, but also in social, infrastructural, environmental, and other spheres of intra-agglomeration space (Fang and Yu, 2020; Rastvortseva, 2013; Volchkova, 2016). The authors (Ezzahid et al., 2022) consider the impact of urbanization and agglomeration processes on the key parameters of social and infrastructural development of the corresponding regions in the case of African countries; they conclude that during the evolution, there is a balanced urban settlement system within agglomerations.

Currently, there is no universally recognized methodology for assessing agglomeration processes in the regional economy. One of the simplest approaches to assessing the concentration of economic activity is William K. Strange's approach (Strange, 2009), which was used when considering the emergence of agglomeration processes in Canada: They analyzed changes in the dynamics of urban population density; if the indicator increases at a faster rate than in other cities, one can talk about the emergence of the agglomeration process. Russian scientists (Sarymova and Guseva, 2022) proposed an interesting approach where they consider migration growth/displacement of population, average monthly wages, volume of investment in fixed capital per person, total floor area of residential premises put into operation for the year, coming on average per 1 inhabitant, etc. as key statistical indicators characterizing agglomeration processes. The presented indicators are calculated separately for municipalities included in the agglomeration and territories outside it, then the ratio of the indicator value for the agglomeration and the regional average is analyzed.

However, insufficient research into the specifics of socio-economic processes occurring in the second-tier agglomerations in terms of ensuring the co-development of the core and its satellite zone actualize the scientific and practical significance of the presented study.

3. Materials and methods

To achieve the purpose in view, the authors used the methods of economic, statistical, and comparative analysis, the monographic method, analysis of regulatory and legal framework, and methods of synthesis, generalization, and others.

The composition of the studied second-tier agglomerations was determined on the basis of simultaneous compliance with the following conditions:
- a core city with a population of at least 100 thousand people.

- 1.5-hour transport accessibility of administrative centers of urban and rural settlements of municipal districts (okrugs)[1] to the agglomeration core; they were included in the agglomeration if more than 2/3 of settlements were located within this isochrone;
- the references to agglomeration and its composition in strategic documents at the regional and municipal levels; in publications of leading Russian scientists and expert organizations.

In this study, we should take into account the assumption that, due to the limited availability of official statistics, data for the analysis will be taken for municipal districts/urban districts as a whole (although, perhaps, not all of their territory will be included in the selected agglomerations).

Foreign (Prakash et al., 2017; Pütz, 2016; Rigatti, 2009; Tripathi, 2018; Uchida and Nelson, 2010) and Russian researchers (Volchkova and Minaev, 2014; Grinchel and Antonova, 2012; Lappo, 2012, Lola, 2014; Mishchenko and Mishchenko, 2015; Pivovarov, 1999; Puzanov and Popov, 2017) use various indicators and criteria for the general assessment of agglomerations' development and typologization. The most common among them are the agglomeration population and its core, agglomerativity coefficient and index, development coefficient, and dynamism coefficient (urban population growth rate over 20 years). These approaches, as a rule, allow one to form a general idea about the development of urban agglomeration as a system, but do not actually emphasize the study of socio-economic processes occurring in the intra-agglomeration space.

Our proposed methodological approach to the study of the specifics of agglomeration processes around large cities consists in the realization of a number of stages and the solution of interrelated tasks within their complex:

Stage 1. Calculation of indicators characterizing the scale of agglomeration development as a spatial socio-economic system.

Calculation of the coefficient of the agglomeration urban settlements system development. Based on the methodology of the Institute of Geography of the Russian Academy of Sciences, the agglomeration development coefficient is calculated as follows:

$$C_{dev} = P \cdot (M \cdot m + N \cdot n), \tag{1}$$

where P is the population of the agglomeration (million people); M is the number of cities in the agglomeration; N is the number of urban-type settlements in the agglomeration; m is the share of the population of cities and towns in the total population of the agglomeration; and is the share of the population of urban-type settlements in the total population of the agglomeration.

Agglomeration development classes are determined based on the values of this coefficient:
1. more than 50 — the most developed (largest) urban agglomerations;
2. from 10 to 50 — strongly developed;
3. from 5 to 10 — developed;
4. from 2.5 to 5 — underdeveloped;
5. from 1 to 2.5 — least developed;
6. less than 1 — potential (promising) urban agglomerations (Polyan, 2014).

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[1] In accordance with the municipal-territorial structure of Russia, the territory of the constituent entities of the Russian Federation in which the analyzed town agglomerations are located consists of municipalities: urban okrugs, municipal districts, and/or municipal okrugs. Municipal districts also include towns and rural settlements; municipal okrugs were established on the territory of former municipal districts with the corresponding abolition of towns and rural settlements as independent municipalities. From the point of view of statistical analysis, municipal areas and municipal districts are equivalent.

Calculation of the gravity coefficient, which is a synthetic value and assesses the economic potential of interaction between municipalities of the agglomeration. To assess the degree of economic interaction between the municipalities included in the agglomeration, researchers (Volchkova et al., 2014; Kozlova and Makarova, 2014; Mirgorodskaya, 2017) propose to use gravity models by calculating a special indicator that takes into account the economic potential (volume of goods and services shipment or other indicators) and the distance between the agglomeration core and the center of the municipality included in it. An improved gravity indicator (economic power of agglomeration municipalities interaction) is proposed in a previous publication by one of the authors of this article (Voroshilov, 2019). The estimation of the *gravity indicator* in this case is carried out using the following Equation:

$$G_A = \frac{\sum_{j=1}^{n}(G_{cj} \cdot f_j)}{\sum_{j=1}^{n} f_j}, \tag{2}$$

where G_A is the gravity indicator (economic power of interaction) of agglomeration A, million rubles/km; G_{cj} is the indicator of interaction between the agglomeration core (c) with the municipality (j) included in it; f_j is the population of the municipality (excluding the agglomeration core) included in agglomeration A; and is the number of municipalities (excluding the core) included in the agglomeration.

In turn, the indicator of interaction between the agglomeration core (c) and municipal entity (j) included in the agglomeration (G_{cj}) is calculated according to Equation 3:

$$G_{cj} = \sqrt{\frac{p_c \cdot p_j}{d_{cj}^2}}, \tag{3}$$

where G_{cj} is an indicator of interaction between the agglomeration core (c) and the municipality (j) included in the agglomeration; p_c is the indicator of the agglomeration core municipality importance (volume of product shipment, population, etc.); p_j is the indicator of the municipality importance (j) included in the agglomeration (except for the agglomeration core: volume of product shipment, population, etc.); and d_{cj} is the distance between the agglomeration core (c) with the administrative center of the municipality (j) included in it.

The calculations of the gravity indicator will be based on statistical data on the indicator of "Own-produced goods shipped and works and services performed by own forces (without small businesses)" and data on the distance between the core city and the administrative center of the municipal entity (district, county) included in the agglomeration (determined via "Yandex Maps" service; https://yandex.ru/maps/).

In addition, this stage will include considering other indicators characterizing the scale of agglomeration development as a spatial socio-economic system: population, the share of the core city in the total population of the agglomeration, and the volume of product shipments per 1 inhabitant.

Stage 2. Assessing the orientation and degree of co-development of the core and territories of the agglomeration satellite zone.

Comparison of the growth rates of indicators of agglomeration municipalities' socio-economic development, including those between the core city and other territories of the satellite zone (index method). According to (Volchkova and Minaev, 2014), the presence of positive agglomeration effects

is evidenced by the level of differences in the municipalities' growth rates not exceeding 15 percentage points.

Correlation analysis of the dependencies between the values of indicators in the core city of agglomeration and the values of indicators of other municipalities, which will also indicate the synchronization of territorial development processes, obtaining the effects of sharing resources and combining the efforts of enterprises, organizations, and authorities within the agglomeration. In accordance with the Cheddock scale, a certain value of the correlation coefficient R (modulo) corresponds to the degree of closeness of connection between two parameters: 0.1–0.3 is weak connection, 0.3–0.5 is moderate connection, 0.5–0.7 is noticeable connection, 0.7–0.9 is high connection, and 0.9–0.99 is very high connection.

Stage 3. Assessing the influence of the studied second-tier urban agglomerations on the processes of formation of intra-regional socio-economic inequality based on the calculation of the Theil index.

The Theil entropy index (IT) was proposed in 1967 by the Dutch scientist Henri Theil to measure social inequality. Later, it was also interpreted to assess the scale of economic inequality, in particular, in R.M. Melnikov's work (Melnikov, 2006). The index allows us to decompose the indicator of overall regional inequality into two components reflecting the intergroup (ITinterg; among the groups of municipalities allocated on some basis) and the intragroup (ITintrag; among the municipalities within each allocated group) inequality:

$$IT = IT_{interg} + IT_{intrag}, \tag{4}$$

$$IT_{interg} = \sum_{k=1}^{n} \frac{X_k}{X} \cdot \ln\left(\frac{X_k/P_k}{X/P}\right), \tag{5}$$

$$IT_{intrag} = \sum_{k=1}^{n} \frac{X_k}{X} \cdot IT_k, \tag{6}$$

$$IT_k = \sum_{j=1}^{J_k} \frac{X_{kj}}{X_k} \cdot \ln\left(\frac{X_{kj}/P_{kj}}{X_k/P_k}\right), \tag{7}$$

where X_{kj} is the absolute value of the indicator of territory j included in group k; P_{kj} is the population of territory j included in group k; X_k is the absolute value of the indicator for group k; P_k is the population of group k; X is the total value of the indicator for all territories of the region; P is the total value of the population of the region; J_k is the number of territories (municipalities) included in group k; and is the number of allocated groups (types) of territories in the region.

In this study, we used the grouping of municipal districts and urban districts by periphery, i.e., their remoteness from cities. The approach outlined in the monograph by a team of authors led by A.Y. Trotskovsky (Trotskovsky, 2013) was used as a basis for determining the criteria for this grouping. In this paper, however, this approach is slightly refined to the extent that by the 1st and 2nd order near-periphery, we mean municipalities that are a part of urban agglomerations formed by major and large cities. This will allow us to assess the impact of agglomerations on the process of intra-regional differentiation, as well as the degree of inequality between the municipalities of each agglomeration. We will test the Theil index calculation in accordance with this approach in the case of 2 constituent entities of the Russian Federation (Arkhangelsk and Vologda Oblasts; Table 1), where the agglomerations we are considering are represented.

Table 1. Typology of Arkhangelsk and Vologda Oblasts municipal entities by periphery (remoteness from cities).

Territory type (group)	Arkhangelsk Oblasts	Vologda Oblasts
Near periphery	Arkhangelsk agglomeration: Arkhangelsk Urban Okrug, Novodvinsk Urban Okrug, Severodvinsk Urban Okrug, Primorsky Municipal District	Vologda agglomeration: Vologda Urban Okrug, Vologda, Gryazovets, Sokol Municipal Districts Cherepovets Agglomeration: Cherepovets Urban Okrug, Kaduysky, Cherepovetsky, Sheksninsky Municipal Districts
3rd order near periphery	Koryazhma Urban Okrug, Kotlas Urban Okrug, Velsky, Kargopolsky, Kotlassky, Mezensky, Nyandomsky, Onega, and Shenkursky Municipal Districts	Babaevsky, Belozersky, Velikoustyugsky, Vytegorsky, Kirillovsky, Nikolsky, Totemsky, Kharovsky Municipal Districts
Middle periphery	Pinezhsky, Plesetsky, Kholmogorsky Municipal Districts	Mezhdurechensky, Syamzhensky, Ust-Kubinsky, Ustyuzhensky Municipal Districts
Far periphery	Novaya Zemlya Urban Okrug, Verkhnetoemsky, Vilegodsky, Vinogradovsky, Konoshsky, Krasnoborsky, Lensky, Leshukonsky, Ustyansky Municipal Districts	Babushkinsky, Vashkinsky, Verkhovazhsky, Vozhegodsky, Kichmengsko-Gorodetsky, Nyuksensky, Tarnogsky, Chagodoshchensky Municipal Districts

Note: Near periphery of the 1st and 2nd order (simply near-periphery) are the municipalities that are part of agglomerations, the center of which is a large city; 3rd order near-periphery are the territories, the center of which is a small or medium-sized city; middle periphery are the territories that are outside the zone of active influence of the city and adjacent to the territories of the near-periphery; far periphery are the territories distant from the cities of the region.

All calculations in the paper were made on the basis of official statistics presented in the Rosstat Database of Municipal Entities Indicators (https://rosstat.gov.ru/dbscripts/munst/). It contains a considerable amount of information on the indicators of socio-economic development of all municipal entities of Russia since 2006, but for most of them the data is presented for the period of 2009–2010 (due to the fact that since January 01, 2009, the Federal Law No. 131-FZ "On General Principles of Organization of Local Self-Government in the Russian Federation", dated October 06, 2003, came into full force in all constituent entities of the Russian Federation; in accordance with this law, a new system of municipal-territorial structure was formed, for which the statistical information was collected). For the majority of value indicators, the data is presented for the period of 2013–2015 due to changes in the classifiers of economic activities types and in approaches to completeness of statistical information collection by municipalities.

4. Research results

In accordance with the above approach to determining the composition of urban agglomerations, we determined the composition of 8 second-tier Russian urban agglomerations, the center of which is a large city and the total population of the agglomeration does not exceed 500 thousand people (Table 2).

Table 2. Composition of 8 second-tier Russian urban agglomerations studied.

Agglomeration name	Agglomeration composition
Arkhangelsk	core: Urban Okrug of the city of Arkhangelsk; satellite zone: Urban Okrug of the city of Novodvinsk, Urban Okrug of Severodvinsk, Primorsky Municipal District
Vologda	core: Urban Okrug of the city of Vologda; satellite zone: Vologda, Gryazovetsky, Sokolsky Municipal Districts (these municipal districts have become municipal okrugs since January 1, 2023)
Kaluga	core: Urban Okrug of Kaluga; satellite zone: Babyninsky, Dzerzhinsky, Peremyshl and Ferzikovsky Municipal Districts
Norilsk	core: Urban Okrug of the city of Norilsk; satellite zone: Taimyr Dolgano-Nenets Municipal Districts
Surgut	core: Surgut Urban Okrug; satellite zone: Nefteyugansk Urban Okrug, Pyt-Yakh Urban Okrug, Surgut and Nefteyugansk Municipal Districts
Tambov	core: Urban Okrug of the city of Tambov; satellite zone: Urban Okrug of the city of Kotovsk, Urban Okrug of the city of Rasskazovo, Tambovsky, Rasskazovsky, Znamensky and Sampursky Municipal Districts
Khanty-Mansiysk	core: Khanty-Mansiysk Urban Okrug; satellite zone: Khanty-Mansiysk Municipal District
Yuzhno-Sakhalinsk	core: Urban Okrug of the city of Yuzhno-Sakhalinsk; satellite zone: Urban Okrug of the city of Korsakov, Urban Okrug of the city of Aniva, Urban Okrug of the city of Dolinsk

Stage 1. We shall start considering key indicators characterizing the scale of agglomeration development as a spatial socio-economic system with the development coefficient.

The obtained results show that only one agglomeration (the Surgut one; Table 3) belongs to the underdeveloped class, and 4 agglomerations (the Arkhangelsk, Vologda, Tambov, and conditionally the Yuzhno-Sakhalinsk ones) belong to the least developed class. Another 3 agglomerations (the Kaluga, Norilsk, and Khanty-Mansiysk ones) can be only conditionally classified as agglomerations by this criterion. This can be explained by the fact that the nuclei of the studied agglomerations are relatively small in terms of population (2022: 110 thousand people in Khanty-Mansiysk and 356 thousand people in Kaluga); there is a poorly developed settlement network of the agglomeration satellite zone (from 0 to 8 urban settlements)[2]. At the same time, we should note that in 2011–2022 the development coefficient in Kaluga, Surgut, and Khanty-Mansiysk agglomerations increased (by 2, 16, and 29%, respectively).

Surgut agglomeration is the leader among the considered agglomerations in terms of the gravity indicator (164 billion rubles/km), which is due to the developed urban network of the agglomeration territory (4 cities and 4 urban-type settlements) and specialization of this agglomeration in the fuel and energy complex with very high volumes of production and shipment of products. The minimum values of this indicator were recorded in the Norilsk agglomeration (4.2 billion rubles/km; this is due to the

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[2] Sometimes, quite noticeable changes in the development coefficient in 2022 compared to 2021 are due to the fact that for 2022, the information on the population of municipalities and urban settlements of the agglomeration is presented based on the results of the all-Russian population census conducted in 2021. In turn, the data for 2021 was presented in accordance with the current statistical accounting, which, as practice has shown, did not fully reflect the real situation for the period.

huge area of the municipal entities included in this agglomeration and the presence of only two relatively large settlements within it, Norilsk and Dudinka) and the Kaluga agglomeration (2.4 billion rubles/km; it has no urban settlements other than the city of Kaluga).

Table 3. Key development indicators of the studied urban agglomerations.

Agglomeration name	Agglomeration development coefficient				Gravity indicator in 2022, mill. rub./km	Product shipment volume per 1 resident in 2022, thousand rubles
	2011	2021	2022	2022 to 2011, %	2022	2022
Arkhangelsk	1.74	1.68	1.46	84.1	4725.4	622.7
Vologda	1.46	1.45	1.46	100.4	5920.6	472.4
Kaluga	0.82	0.83	0.83	101.7	2370.5	871.8
Norilsk	0.40	0.41	0.39	97.1	4252.7	5905.4
Surgut	2.36	2.72	2.74	116.0	164150.1	4444.7
Tambov	1.10	1.09	1.02	92.8	4901.9	500.0
Khanty-Mansiysk	0.09	0.11	0.11	129.1	71167.6	5608.5
Yuzhno-Sakhalinsk	0.96	1.02	0.94	97.6	3643.4	2306.4

Note: Gravity indicator is the indicator discussed above in the Materials and Methods section. Product shipment volume is the value of the indicator "Own-produced goods shipped and works and services performed by own forces (without small businesses)". The value indicators in this table are brought to prices comparable between the constituents of the Russian Federation, taking into account the adjustment of the initial values of indicators by the index of deviation of the value of the cost of a fixed set of goods and services in the corresponding constituent entity of the Russian Federation from the national average.

The Norilsk, Khanty-Mansiysk, and Surgut agglomerations (4.4–5.9 million rubles) are the leaders in terms of product shipment per 1 inhabitant, which is due to the leadership of these territories in the all-Russian scale in the development of the fuel and energy complex (Khanty-Mansiysk and Surgut), and in the extraction and processing of nonferrous metals (Norilsk). The laggards by this indicator are the Tambov and Vologda agglomerations (respectively 500 and 472 thousand rubles per 1 inhabitant), where the level of industrial sector development is not high enough.

Over the period of 2010–2022, the resident population of 4 agglomerations increased (Vologda by 0.1%, Kaluga by 3.2%, Khanty-Mansiysk by 28.6%, Surgut by 18.1%; Table 4), while the population reduction in Arkhangelsk (by 4.3%), Tambov (by 5.8%), and Yuzhno-Sakhalinsk (by 0.8%) agglomerations was noticeably lower than in the corresponding Russian Federation constituent entities as a whole.

In all agglomerations (except for the Kaluga and Norilsk ones), population concentration (increase in the share of the population of the constituent entity of the Russian Federation living in the agglomeration) increased by 1–4 percentage points during the study period. At the same time, the share of the core city in the total population increased by 0.2–5.7 percentage points in all 8 agglomerations. According to the results of 2022, 59% of the population of the Sakhalin Oblast lived in the Yuzhno-Sakhalinsk agglomeration, 54% of the region's population lived in the Arkhangelsk agglomeration, 50% in the Tambov agglomeration, 43% in the Kaluga agglomeration, 43% in the Surgut agglomeration, 38% in the Vologda agglomeration (this region also has the Cherepovets

agglomeration with 34% of the Oblast's population), 7% in the Khanty-Mansiysk agglomeration, and 7% in the Norilsk agglomeration (this region also has the rather large Krasnoyarsk agglomeration). The share of the core city in the total population of the agglomeration in 2022 was 55% in the Surgut agglomeration, 58% in the Arkhangelsk agglomeration, and reached 85% in the Khanty-Mansiysk and Norilsk agglomerations. According to the famous Russian geography scientist P. Polyan, the share reaching 66% is already quite impressive. At the same time, we should note that since the Soviet times, the tendency to strengthen the role of the core city continues, including at the expense of degradation of the agglomeration satellite zone. On the contrary, in many urban agglomerations of Western countries there is a long-term absolute reduction in the population of the centers, with a constant growth of the agglomeration satellite zone (Polyan, 2014).

Stage 2. Assessing the orientation and degree of co-development of the core and territories of the agglomeration satellite zone.

The maximum differences in the population growth rates of the core city and other municipalities in 2010–2021 (the figures for 2022 are revised data based on the results of the All-Russian Population Census, so they are not comparable with the data for previous years) are in Tambov agglomeration (103% in the city of Tambov and 79% in the Sampur District), Kaluga agglomeration (103% in the city of Kaluga and 79% in the Babyninsky District), Sakhalin agglomeration (110% in Yuzhno-Sakhalinsk and 93% in Dolinsk Urban District), Khanty-Mansiysk agglomeration (132% in Khanty-Mansiysk and 99% in Khanty-Mansiysk District), and Surgut agglomeration (128% in Surgut and 95% in Pyt-Yakh). At the same time, no significant differences in the population growth rates are observed in the municipal districts immediately adjacent to the core city. All this testifies to the spread of agglomeration processes and effects only on the territory adjacent to the central city and their weak influence on the periphery of the satellite zone.

Table 4. Dynamics of the permanent population of urban agglomerations, thousand people

Agglomeration and municipalities within it	2010	2015	2021	2022	2022 to 2010, %	2021 to 2010, %
Vologda Oblast	1201.2	1187.7	1139.5	1128.8	94.0	94.9
Vologda agglomeration	447.4	455.5	443.0	448.1	100.1	99.0
UO of the city of Vologda	310.0	320.6	313.4	318.1	102.6	101.1
Vologda MD	50.5	52.4	51.8	52.7	104.5	102.6
Gryazovets MD	35.6	33.1	31.2	32.1	90.0	87.5
Sokolsky MD	51.3	49.4	46.6	45.1	88.0	91.0
Agglomeration share*, %	37.2	38.4	38.9	39.7	+2.4 p.p.	+1.6 p.p.
Core share**, %	69.3	70.4	70.7	71.0	+1.7 p.p.	+1.5 p.p.
Arkhangelsk Oblast	1182.8	1130.2	1069.8	964.3	81.5	90.4
Arkhangelsk agglomeration	615.6	609.1	591.6	521.7	84.7	96.1
UO of the city of Arkhangelsk	355.6	358.3	349.2	303.4	85.3	98.2
UO of the city of Novodvinsk	40.6	38.9	36.8	32.8	80.9	90.8
UO of the city of Severodvinsk	193.1	186.1	180.7	156.7	81.2	93.5
Primorsky MD	26.3	25.8	24.9	28.8	109.6	94.9
Agglomeration share*, %	52.0	53.9	55.3	54.1	+2.1 p.p.	+3.3 p.p.
Core share**, %	57.8	58.8	59.0	58.1	+0.4 p.p.	+1.3 p.p.
Tambov Oblast	1089.7	1050.3	981.0	966.3	88.7	90.0

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Agglomeration and municipalities within it	2010	2015	2021	2022	2022 to 2010, %	2021 to 2010, %
Tambov agglomeration	515.5	518.1	502.7	485.4	94.2	97.5
UO of the city of Tambov	280.1	288.4	287.4	291.5	104.0	102.6
UO of the city of Kotovsk	31.8	30.7	28.3	26.3	82.8	89.2
UO of the city of Rasskazovo	45.4	44.2	41.8	47.0	103.5	92.1
Tambovsky MD	102.8	103.4	99.8	74.5	72.4	97.0
Rasskazovsky MD	22.9	21.8	19.4	20.5	89.2	84.7
Znamensky MD	18.3	17.1	14.7	14.0	76.1	80.1
Sampursky MD	14.1	12.6	11.2	11.8	83.3	79.4
Agglomeration share*, %	47.3	49.3	51.2	50.2	+2.9 p.p.	+3.9 p.p.
Core share**, %	54.3	55.7	57.2	60.0	+5.7 p.p.	+2.8 p.p.
Kaluga Oblast	1009.2	1009.8	1012.8	1070.9	106.1	100.4
Kaluga agglomeration	450.4	461.6	452.9	465.0	103.2	100.6
UO of the city of Kaluga	339.3	358.4	350.7	355.5	104.8	103.3
Babyninsky MD	21.0	18.7	18.0	20.7	98.6	85.8
Dzerzhinsky MD	60.2	53.6	52.6	56.6	94.0	87.3
Peremyshl MD	14.0	13.7	13.3	14.4	102.3	94.6
Ferzikovsky MD	15.8	17.3	18.3	17.8	112.6	116.0
Agglomeration share*, %	44.6	45.7	44.7	43.4	−1.2 p.p.	+0.1 p.p.
Core share**, %	75.3	77.6	77.4	76.5	+1.1 p.p.	+2.1 p.p.
Sakhalin Oblast	496.7	487.3	484.2	460.5	92.7	97.5
Yuzhno-Sakhalinsk agglomeration	273.6	284.1	292.3	270.4	98.8	106.9
UO of the city of Yuzhno-Sakhalinsk	188.9	200.7	208.7	187.4	99.2	110.5
UO of the city of Korsakov	41.3	40.2	40.0	39.9	96.6	96.9
UO of the city of Aniva	17.6	18.9	19.7	20.9	119.2	112.2
UO of the city of Dolinsk	25.8	24.3	23.9	22.2	85.9	92.5
Agglomeration share*, %	55.1	58.3	60.4	58.7	+3.6 p.p.	+5.3 p.p.
Core share**, %	69.1	70.7	71.4	69.3	+0.2 p.p.	+2.3 p.p.
Khanty-Mansiysk Autonomous Okrug-Yugra	1537.1	1626.8	170.2	1730.4	112.6	110.7
Khanty-Mansiysk agglomeration	100.0	116.6	125.3	128.6	128.6	125.3
UO of the city of Khanty-Mansiysk	80.5	96.9	106.0	109.7	136.2	131.6
Khanty-Mansiysk MD	19.4	19.6	19.3	18.9	97.1	99.2
Agglomeration share*, %	6.5	7.2	7.4	7.4	+0.9 p.p.	+0.9 p.p.
Core share**, %	80.6	83.2	84.6	85.3	+4.8 p.p.	+4.0 p.p.
Surgut agglomeration	632.1	682.9	736.0	746.8	118.1	116.4
UO of the city of Surgut	308.5	348.6	395.9	406.9	131.9	128.3
UO of the city of Nefteyugansk	123.3	125.4	128.7	125.0	101.4	104.4
UO of the city of Pyt-Yakh	41.5	40.9	39.3	40.3	96.9	94.7
Surgutsky MD	114.1	123.0	126.9	127.6	111.9	111.2
Nefteyugansky MD	44.7	45.0	45.2	47.0	105.1	100.9
Agglomeration share*, %	41.1	42.0	43.2	43.2	+2.0 p.p.	+2.1 п.п.
Core share**, %	48.8	51.1	53.8	54.5	+5.7 p.p.	+5.0 п.п.
Krasnoyarsk region	2829.1	2866.5	2849.2	2845.5	100.6	100.7
Norilsk agglomeration	210.4	211.0	215.9	205.4	97.6	102.6
UO of the city of Norilsk	176.1	178.1	184.6	175.5	99.6	104.9

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Agglomeration and municipalities within it	2010	2015	2021	2022	2022 to 2010, %	2021 to 2010, %
Taimyrsky Dolgano-Nenetsky MD	34.4	32.9	31.3	29.9	87.0	91.0
Agglomeration share*, %	7.4	7.4	7.6	7.2	−0.2 p.p.	+0.1 p.p.
Core share**, %	83.7	84.4	85.5	85.4	+1.8 p.p.	+1.8 p.p.

Note: * Agglomeration share in the indicator value for the constituent entity of the Russian Federation, %; ** Agglomeration core city share in the indicator value for the agglomeration as a whole, %. Designations here and in the following tables: UO—Urban Okrug, MD—Municipal District.

Average monthly wages in agglomerations, as a rule, for the whole analyzed period were higher than the wages in the corresponding constituent entity of the Russian Federation (Table 5). At the same time, all of them (except Kaluga agglomeration) showed positive growth rates of real wages: the highest were in Norilsk (132%) and Vologda (121%) agglomerations.

There are some positive points that we should note, this is the fact that the differences between the maximum and minimum values of wages among agglomeration municipalities have decreased: from 1.53 times in 2013 to 1.26 times in 2022 in the Vologda Oblast; from 1.30 to 1.26 times, respectively, in the Arkhangelsk Oblast; from 1.44 to 1.27 times in the Tambov Oblast; from 1.60 to 1.45 times in the Kaluga Oblast; from 1.62 to 1.58 times in the Yuzhno-Sakhalinsk Oblast; and from 1.59 to 1.38 times in the Surgut Oblast. In Khanty-Mansiysk and Norilsk agglomerations, the differences between the city and the adjacent district remain low (1.02-1.09 times and 1.3 times, respectively). In addition, the wage growth rates in the municipalities of all agglomerations were higher than the growth rates in the core city. In general, it can be noted that these trends are due to the leveling of wages of public sector employees (in order to implement the Decree of the President of the Russian Federation, dated May 07, 2012, No. 597 "On measures to implement the state social policy to increase wages of social sector employees"), as well as the processes of formation of common labor markets in agglomerations with the corresponding convergence of wages for the same (similar) specialties and professions.

Table 5. Dynamics of average monthly wages of employees of urban agglomerations organizations (without small businesses), thousand rubles.

Agglomeration and municipalities within it	2013	2015	2021	2022	2022 to 2013, %	2022 to 2013 (comparable*), %
Vologda Oblast	20.9	24.5	42.5	47.8	229.4	123.0
Vologda agglomeration	23.0	26.4	45.3	51.8	225.0	120.7
UO of the city of Vologda	29.1	31.5	51.1	59.1	203.3	109.0
Vologda MD	21.3	25.0	42.5	47.6	223.2	119.7
Gryazovets MD	22.7	26.7	47.4	53.7	236.5	126.8
Sokolsky MD	19.0	22.3	40.0	46.8	246.5	132.2
Arkhangelsk Oblast	29.5	35.4	56.8	63.2	214.4	115.0
Arkhangelsk agglomeration	33.5	39.5	64.5	69.8	208.3	111.7
UO of the city of Arkhangelsk	35.8	40.3	63.5	70.5	196.9	105.6
UO of the city of Novodvinsk	28.5	31.7	55.9	60.9	213.3	114.4
UO of the city of Severodvinsk	37.0	47.4	71.2	76.5	206.7	110.9
Primorsky MD	32.7	38.4	67.4	71.4	218.1	117.0

Agglomeration and municipalities within it	2013	2015	2021	2022	2022 to 2013, %	2022 to 2013 (comparable*), %
Tambov Oblast	18.0	20.7	33.2	38.4	213.6	109.9
Tambov agglomeration	18.5	21.0	32.4	38.1	205.9	106.0
UO of the city of Tambov	22.7	26.3	39.6	43.5	191.9	98.8
UO of the city of Kotovsk	15.8	18.0	29.6	36.3	229.9	118.3
UO of the city of Rasskazovo	17.7	19.4	30.1	34.3	193.8	99.8
Tambovsky MD	20.1	22.4	37.1	42.3	210.1	108.1
Rasskazovsky MD	18.9	21.7	30.0	34.5	182.7	94.0
Znamensky MD	18.3	19.7	30.1	34.8	190.8	98.2
Sampursky MD	15.9	19.4	30.0	40.6	254.9	131.2
Kaluga Oblast	22.7	26.2	40.1	44.5	195.7	96.7
Kaluga agglomeration	24.5	29.9	44.3	49.3	201.1	99.4
UO of the city of Kaluga	31.6	35.5	54.5	58.6	185.6	91.7
Babyninsky MD	25.7	28.3	43.9	48.8	190.1	93.9
Dzerzhinsky MD	25.3	29.6	43.6	49.2	194.3	96.0
Peremyshl MD	20.3	28.2	37.0	40.3	198.8	98.2
Ferzikovsky MD	19.7	28.0	42.8	49.5	251.3	124.2
Sakhalin Oblast	44.9	56.6	87.3	95.1	211.8	123.8
Yuzhno-Sakhalinsk agglomeration	48.2	59.7	90.7	98.3	204.1	119.3
UO of the city of Yuzhno-Sakhalinsk	63.6	78.8	115.2	125.8	197.9	115.7
UO of the city of Korsakov	48.3	67.2	94.4	103.6	214.6	125.5
UO of the city of Aniva	41.6	48.4	77.0	84.0	202.0	118.1
UO of the city of Dolinsk	39.2	44.5	76.0	79.6	203.3	118.9
Khanty-Mansiysk Autonomous Okrug-Yugra	54.5	60.4	86.6	98.5	180.7	107.5
Khanty-Mansiysk agglomeration	59.3	66.8	93.8	105.0	177.1	105.4
UO of the city of Khanty-Mansiysk	62.8	67.5	94.3	102.4	163.1	97.1
Khanty-Mansiysk MD	55.9	66.0	93.2	107.7	192.8	114.7
Surgut agglomeration	57.9	64.6	91.6	105.2	181.8	108.2
UO of the city of Surgut	68.7	75.8	100.5	116.4	169.4	100.8
UO of the city of Nefteyugansk	54.1	60.0	90.5	101.4	187.5	111.6
UO of the city of Pyt-Yakh	43.3	47.5	76.0	85.4	197.3	117.4
Surgutsky MD	62.9	70.7	98.6	118.0	187.5	111.6
Nefteyugansky MD	60.3	69.1	92.4	104.7	173.7	103.4
Krasnoyarsk region	26.8	30.7	48.7	55.9	208.6	117.0
Norilsk agglomeration	58.9	67.9	111.8	138.8	235.6	132.1
UO of the city of Norilsk	66.6	76.5	122.9	156.9	235.6	132.1
Taimyrsky Dolgano-Nenetsky MD	51.2	59.3	100.6	120.7	235.5	132.0

Note: * The indicator value is presented in comparable prices (taking into account the consumer price index for the corresponding constituent entity of the Russian Federation accumulated for the analyzed period).

In 2015–2022, all agglomerations showed positive growth rates in the volume of products shipped in comparable prices per capita; the highest growth rates were observed in Yuzhno-Sakhalinsk agglomeration (3.0 times; Table 6; largely due to the implementation of major projects, opening and expansion of production facilities in the field of mining in these areas) and Norilsk agglomeration (1.7 times).

Table 6. Dynamics of the indicator "Own-produced goods shipped and works and services performed by own forces (without small businesses)" of urban agglomerations per 1 inhabitant, thousand rubles.

Agglomeration and municipalities within it	2015	2021	2022	2022 to 2015, times	2022 to 2015*, times	Goods shipped per 1 square kilometer of territory, mill. rub.
Vologda Oblast	498.2	1243.6	1203.3	2.4	1.6	9.4
Vologda agglomeration	237.6	476.4	488.3	2.1	1.4	15.8
UO of the city of Vologda	258.3	473.8	506.5	2.0	1.3	1381.9
Vologda MD	112.3	158.6	173.9	1.5	1.0	2,0
Gryazovets MD	255.1	847.1	728.4	2.9	1.9	4.6
Sokolsky MD	224.4	598.5	556.7	2.5	1.7	6.1
Arkhangelsk Oblast	258.4	618.2	558.0	2.2	1.5	0.9
Arkhangelsk agglomeration	320.9	773.7	677.8	2.1	1.4	7.4
UO of the city of Arkhangelsk	225.0	459.1	472.6	2.1	1.4	486.9
UO of the city of Novodvinsk	803.7	1503.0	1610.5	2.0	1.4	1290.4
UO of the city of Severodvinsk	395.1	1193.9	857.1	2.2	1.5	112.6
Primorsky MD	389.2	1058.8	800.7	2.1	1.4	0,5
Tambov Oblast	210.0	368.5	399.2	1.9	1.2	11.2
Tambov agglomeration	260.8	403.2	448.9	1.7	1.1	32.7
UO of the city of Tambov	338.0	394.8	428.7	1.3	0.8	1252.5
UO of the city of Kotovsk	163.5	291.9	291.7	1.8	1.2	382.6
UO of the city of Rasskazovo	42.4	115.4	114.9	2.7	1.8	152.2
Tambovsky MD	164.1	637.3	893.7	5.4	3.5	25.5
Rasskazovsky MD	100.5	184.1	159.9	1.6	1.0	1.8
Znamensky MD	485.5	555.4	671.8	1.4	0.9	8.5
Sampursky MD	262.2	70.9	59.7	0.2	0.1	0.7
Kaluga Oblast	534.2	1159.2	904.6	1.7	1.1	32.5
Kaluga agglomeration	703.8	1393.2	871.8	1.2	0.8	78.9
UO of the city of Kaluga	830.8	1531.6	852.4	1.0	0.7	553.9
Babyninsky MD	193.3	433.9	399.1	2.1	1.3	9.8
Dzerzhinsky MD	343.6	1289.8	1286.0	3.7	2.4	54.5
Peremyshl MD	92.1	704.6	724.4	7.9	5.0	9.0
Ferzikovsky MD	223.9	483.6	612.2	2.7	1.8	8.7
Sakhalin Oblast	538.6	2549.0	2993.9	5.6	3.9	15.8
Yuzhno-Sakhalinsk agglomeration	649.4	1741.8	2805.6	4.3	3.0	87.6
UO of the city of Yuzhno-Sakhalinsk	878.8	995.9	1099.6	1.3	0.9	227.7
UO of the city of Korsakov	124.4	7420.7	13707.8	110.2	77.4	208.5
UO of the city of Aniva	49.4	92.2	130.4	2.6	1.9	1.0
UO of the city of Dolinsk	88.8	103.2	121.3	1.4	1.0	1.1
Khanty-Mansiysk Autonomous Okrug-Yugra	2514.3	3801.9	4415.1	1.8	1.3	14.3
Khanty-Mansiysk agglomeration	3081.5	5632.1	6239.7	2.0	1.5	17.3

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Agglomeration and municipalities within it	2015	2021	2022	2022 to 2015, times	2022 to 2015*, times	Goods shipped per 1 square kilometer of territory, mill. rub.
UO of the city of Khanty-Mansiysk	315.7	628.5	709.5	2.2	1.6	230.5
Khanty-Mansiysk MD	16744.2	33146.1	38409.6	2.3	1.7	15.7
Surgut agglomeration	2984.5	4271.4	4945.0	1.7	1.2	28.4
UO of the city of Surgut	1750.6	2405.9	2640.7	1.5	1.1	3035.9
UO of the city of Nefteyugansk	649.3	1441.7	1694.0	2.6	1.9	1376.7
UO of the city of Pyt-Yakh	592.2	1038.9	1047.8	1.8	1.3	657.9
Surgutsky MD	8695.9	12119.5	14788.8	1.7	1.2	18.0
Nefteyugansky MD	5615.2	9456.9	10150.5	1.8	1.3	19.4
Krasnoyarsk region	475.9	1167.8	1263.5	2.7	1.8	1.5
Norilsk agglomeration	2402.5	5244.6	6027.,3	2.5	1.7	1.4
UO of the city of Norilsk	2761.9	5471.3	6221.5	2.3	1.5	242.1
Taimyrsky Dolgano-Nenetsky MD	455.4	3906.2	4887.1	10.7	7.3	0.2

Note: * Growth rate of the indicator in comparable prices.

At the same time, there are significant differences in the growth rates of the indicator between the municipalities of each agglomeration, mainly due to the different structure of their economies, as well as the degree of economic specialization and diversification. In many municipalities, the values of the indicator of average per capita shipment of goods and services significantly exceed the values in the core city, as some cores mainly perform the functions of administrative, financial, cultural, transport, and logistics center of the agglomeration and the region, and large industrial production (including mining) is located in the agglomeration zone. Multidirectional trends are also observed in intra-agglomeration differences by this indicator: In 2015–2022, the differences in average per capita income in the average per capita volume of product shipment between municipalities increased from 2.3 to 4.2 times in Vologda agglomeration, from 11.4 to 15.0 times in Tambov agglomeration and from 17.8 to 113.0 times in the Yuzhno-Sakhalinsk agglomeration; the differences in Khanty-Mansiysk, Surgut, and Arkhangelsk agglomerations (53.0–54.1 times, 14.1–14.7 times, and 3.4–3.6 times, respectively) remained at approximately the same level; and the differences in Kaluga (from 9.0 to 3.2 times) and Norilsk (from 6.1 to 1.3 times) agglomerations decreased.

The volume of product shipment per 1 square kilometer of the municipality's territory is naturally maximum in the urban okrug-core of the agglomeration; it is also quite high in other urban okrugs of the agglomeration (for example, in Arkhangelsk, the value of this indicator is 487 million rubles/1 square kilometer, which is even lower than in Severodvinsk—1,290 million rubles/1 square kilometer). The density of product shipment is minimal in the municipal districts (mostly rural areas) included in the agglomeration; the districts lag behind the cities in terms of density hundreds and thousands of times. This indicates that the industrial potential of many municipalities in the satellite zone of the studied agglomerations is still rather weak.

We should also note that there is a significant concentration of the region-wide volume of production and investment in urban agglomerations. Thus, in 2022, the Arkhangelsk agglomeration accounted for 66% of the volume of goods shipment and 66% of the volume of investments in fixed assets for all territories of the Arkhangelsk Oblast (Table 7); the Vologda agglomeration accounted for 16 and 30%, respectively (the second agglomeration of the region, the city of

Cherepovets, is the leader of industrial production and investments in the Vologda Oblast); the Kaluga agglomeration accounted for 42 and 39%; Norilsk agglomeration—34 and 50%; Surgut agglomeration—46 and 48%; Tambov agglomeration—56 and 50%; Khanty-Mansiysk agglomeration—11 and 21%; and Yuzhno-Sakhalinsk agglomeration—55 and 77%. At the same time, over the 7-year period, the share of 7 agglomerations in the region's product shipment volume decreased by 1%–18%, as well as the share of the core in the agglomeration itself by this indicator (except for the Khanty-Mansiysk agglomeration). As for the volume of investment in fixed capital, the share of agglomeration in 2010–2022 decreased in 4 agglomerations (Vologda, Kaluga, Surgut, and Tambov agglomerations) and the share of the core in agglomeration decreased in 6 agglomerations (except for Tambov and Yuzhno-Sakhalinsk agglomerations). In many respects, these trends may be due to the fact that all constituent entities of the Russian Federation have set and are currently facing strategic tasks to diversify the region's economy in order to prevent excessive concentration of production and investment in urban agglomerations. To a certain extent, these tasks can be solved. In addition, the agglomerations' economies could have been affected more strongly by the consequences of the introduction of restrictive measures due to the spread of the coronavirus pandemic in 2020–2021 and the economic difficulties associated with the introduction of large-scale sanctions against Russia by Western countries in 2022.

Table 7. Agglomeration share in the total regional value and city-core share in the agglomeration as a whole by indicators of goods shipment and investment in fixed capital (without small businesses).

Agglomeration name	Indicator	Goods shipped *			Volume of investments in fixed assets **				
		2015	2022	2022 to 2014, +/− p.p.	2010	2015	2022	2022 to 2010, +/− p.p.	2022 to 2015, +/− p.p.
Arkhangelsk	Agglomeration share ***, %	66.9	65.7	−1.2	57.1	67.9	66.4	9.3	−1.5
	Core share ****, %	41.2	40.5	−0.7	74.6	48.7	67.2	−7.4	18.4
Vologda	Agglomeration share, %	18.3	16.1	−2.2	38.6	20.2	30.0	−8.6	9.8
	Core share, %	76.5	73.6	−2.9	78.0	73.6	69.4	−8.5	−4.1
Kaluga	Agglomeration share, %	60.2	41.9	−18.4	69.3	66.0	39.2	−30.0	−26.8
	Core share, %	91.6	74.7	-16.9	96.5	92.7	85.6	−10.9	−7.1
Norilsk	Agglomeration share, %	37.2	34.4	−2.7	13.6	28.7	49.6	36.0	20.9
	Core share, %	97.0	88.2	−8.8	73.1	75.2	66.0	−7.1	−9.2
Surgut	Agglomeration share, %	49.8	48.3	−1.5	58.4	47.3	45.6	−12.8	−1.7
	Core share, %	29.9	29.1	−0.8	13.9	12.1	7.3	−6.6	−4.8
Tambov	Agglomeration share, %	61.3	56.5	−-4.8	50.5	47.7	49.6	−1.0	1.8
	Core share, %	72.1	57.3	−14.8	47.1	61.7	67.1	20.1	5.5

Continued on next page

Agglomeration name	Indicator	Goods shipped *			Volume of investments in fixed assets **				
		2015	2022	2022 to 2014, +/− p.p.	2010	2015	2022	2022 to 2010, +/− p.p.	2022 to 2015, +/− p.p.
Khanty-Mansiysk	Agglomeration share, %	8.8	10.5	1.7	11.1	14.7	21.1	10.0	6.4
	Core share, %	8.5	9.7	1.2	26.4	11.9	13.2	−13.2	1.3
Yuzhno-Sakhalinsk	Agglomeration share, %	70.3	55.0	−15.3	12.5	73.1	76.7	64.3	3.6
	Core share, %	95.6	27.2	-68.5	80.5	98.0	95.7	15.3	−2.3

Note: * Indicator: "Goods of own production shipped and works and services performed by own forces (without small businesses)". ** Indicator: "Volume of investments in fixed assets made by organizations located in the territory of the municipality (without small businesses)". *** Agglomeration share in the value of the indicator for the RF constituent entity as a whole %; **** Agglomeration core city share in the indicator value for the agglomeration as a whole %.

The study of dependencies between the values of socio-economic development indicators in the agglomeration core and in its other municipalities for 2010–2022 using the correlation analysis method allowed us to draw the following conclusions:

- in terms of population dynamics, high direct correlation is observed only in a small number of pairs (4 out of 25; Table 8) "agglomeration core" – "other agglomeration municipality" (Vologda and Vologda District, Arkhangelsk and Novodvinsk, Arkhangelsk and Severodvinsk, and Surgut and Surgut District).

- in terms of the dynamics of the natural population growth rate, a high direct relationship is observed in the overwhelming majority of agglomerations' pairs of municipalities; this is due to the fact that the processes of natural population reproduction are stable and long-lasting in most municipalities of the region; At the same time, these agglomerations mainly attract young population, which determines approximately the same reproductive demographic processes in these territories. It should be noted that all municipalities of the Surgut and Norilsk agglomerations experienced natural population growth over the entire analyzed period.

- high direct correlation is observed in less than half of the pairs of municipalities in terms of the dynamics of the indicator of product shipments per 1 inhabitant (10 out of 25; Table 8) (all 3 pairs of municipalities of Vologda agglomeration, 1 out of 3 pairs of municipalities of Arkhangelsk agglomeration, 3 out of 6 pairs of municipalities of Tambov agglomeration, 2 out of 3 pairs of Yuzhno-Sakhalinsk agglomeration, and the only pair of Norilsk agglomeration).

- in terms of the dynamics of the volume of investments in fixed capital per 1 inhabitant, a high direct correlation is observed only in 4 pairs of agglomeration municipalities (Vologda and Gryazovets District, Vologda and Sokolsky District, Khanty-Mansiysk and Khanty-Mansiysk District, and Norilsk and Taimyrsky District), which is due, on the one hand, to the different specialization and economic structure of all agglomeration municipalities and, consequently, the objectively different investment cycles; On the other hand, it is indicative of poor conjugation of reproduction processes between agglomeration municipalities.

- in terms of the dynamics of the volume of local budget revenues per 1 inhabitant, a high direct correlation is observed in the vast majority of pairs (19 out of 25) of agglomeration municipalities, which is due to the intergovernmental fiscal relations of the principle of equalization of fiscal

capacity of municipalities in the region by transferring subsidies to municipalities from the budget of the constituent entities of the Russian Federation in the system. The absence of correlation on this indicator for 6 pairs of municipalities is due to the use of different approaches to the organization of intergovernmental fiscal relations in the regions and redistribution of powers between the region and municipalities.

Table 8. Correlation coefficients between the values of socio-economic development indicators in the core city and the values of indicators in other municipalities of the agglomeration for the period 2010–2022.

Pairs of municipalities of urban agglomerations	NP	Cng	Shipment	VI	LB revenues
Vologda UO - Vologodsky MD	0.872	0.750	0.931	0.628	0.892
Vologda UO - Gryazovetsky MD	−0.487	0.769	0.930	0.843	0.862
Vologda UO - Sokolsky MD	−0.300	0.876	0.938	0.901	0.896
Arkhangelsk UO - Novodvinsk UO	0.882	0.962	0.894	0.169	0.906
Arkhangelsk UO - Severodvinsk UO	0.938	0.961	0.559	0.424	0.912
Arkhangelsk UO - Primorsky MD	−0.803	0.987	0.556	0.353	0.765
Tambov UO - Kotovst UO	−0.649	0.959	0.586	0.292	0.742
Tambov UO - Rasskazovo UO	−0.413	0.933	0.798	0.194	0.763
Tambov UO - Tambovsky MD	−0.309	0.948	0.813	0.002	0.429
Tambov UO - Rasskazovsky MD	−0.733	0.836	0.605	−0.226	0.891
Tambov UO - Znamensky MD	−0.702	0.768	0.797	0.276	0.332
Tambov UO - Sampursky MD	−0.839	0.782	−0.592	0.066	0.666
Kaluga UO - Babyninsky MD	−0.472	0.769	0.584	0.587	0.872
Kaluga UO - Dzerzhinsky MD	−0.628	0.798	0.486	0.340	0.964
Kaluga UO - Peremyshlsky MD	0.083	0.698	0.507	0.034	0.959
Kaluga UO - Ferzikovsky MD	0.549	0.839	0.438	0.324	−0.100
Yuzhno-Sakhalinsk UO - Korsakov UO	−0.134	0.687	0.759	0.358	0.964
Yuzhno-Sakhalinsk UO - Aniva UO	0.327	0.592	0.783	0.402	0.979
Yuzhno-Sakhalinsk UO - Dolinsk UO	−0.146	0.540	−0.650	0.275	0.822
Khanty-Mansiysk UO - Khanty-Mansiysky MD	−0.497	0.934	0.567	0.734	0.446
Surgut UO - Nefteyugansk UO	0.669	0.952	0.534	0.143	0.709
Surgut UO - Pyt-Yakh UO	−0.862	0.945	0.576	0.103	0.513
Surgut UO - Surgutsky MD	0.950	0.958	0.442	0.646	0.836
Surgut UO - Nefteyugansky MD	0.656	0.863	0.503	0.510	0.725
Norilsk UO - Taimyrsky Dolgano-Nenets MD	−0.434	0.802	0.861	0.980	0.827

Note: Designations in the table: NP—number of permanent population at the end of the year, Cng—coefficient of natural population growth, Shipment—shipped goods of own production, works and services performed by own forces (without small businesses), VI—volume of investments in fixed capital (without small businesses) per 1 inhabitant, and LB revenues—local budget revenues per 1 inhabitant.

Stage 3. Assessing the influence of the studied second-tier urban agglomerations on the processes of formation of intra-regional socio-economic inequality.

The analysis of the Theil index values dynamics shows that the inequality among the municipalities of the Vologda Oblast in terms of product shipment has increased and the inequality in

terms of investment has decreased (Table 9). In the Arkhangelsk Oblast, the trends are also quite different (the value of inequality in terms of product shipment in 2022 is higher than in 2014, but lower than in 2015 and 2021; in terms of investment volume, on the contrary, the value of inequality in 2022 is lower than in 2010, but higher than in 2015 and 2021).

Table 9. Theil index values by indicators of goods shipment and investment in fixed assets in the Arkhangelsk and Vologda Oblasts (without small businesses).

RF constituent entity	Indicator	Shipped goods and services per 1 inhabitant*				Volume of investments in fixed capital per 1 inhabitant**			
		2014	2015	2021	2022	2010	2015	2021	2022
Arkhangelsk Oblast	IT	0.296	0.394	0.369	0.341	0.351	0.220	0.208	0.255
	ITinterg	0.106	0.083	0.052	0.053	0.058	0.073	0.021	0.029
	ITinterg share, %	35.7	21.0	14.1	15.5	16.7	33.2	9.9	11.5
Vologda Oblast	IT	0.425	0.491	0.572	0.567	0.179	0.382	0.264	0.160
	ITinterg	0.323	0.383	0.436	0.441	0.074	0.289	0.115	0.099
	ITinterg share, %	76.0	78.0	76.2	77.8	41.3	75.6	43.6	62.1

Note: IT—Theil index, ITinterg—intergroup Theil index, ITinterg share—share of intergroup Theil index in the total value of Theil index. ** Indicator of "Goods shipped and works and services performed by own forces (without small businesses)". ** Indicator of "Volume of investments in fixed assets made by organizations located in the territory of the municipality (without small businesses)".

Considering the dynamics of the Theil index in terms of intragroup and intergroup inequality will allow us to draw a conclusion about the influence of urban agglomerations on the formation and strengthening of socio-economic differentiation at the intra-regional level. Thus, in the Vologda Oblast, the structure of inequality is dominated by intergroup inequality for almost all years: Cherepovets agglomeration (a group of territories of the Oblast) makes a significant contribution to the formation of intergroup inequality in terms of shipment and investment, but Vologda agglomeration does not make a significant contribution to the formation of inequality. In the Arkhangelsk Oblast, on the contrary, intra-regional inequality prevails, i.e., in many groups of territories identified by periphery, there are one or two municipalities significantly outperforming the rest of the territories of this group by the indicators under consideration. In addition, Arkhangelsk agglomeration makes a significant contribution to the formation of intergroup inequality by shipment, but does not make a significant contribution to other types of inequality.

5. Conclusions

The study on socio-economic processes occurring in the second-tier agglomerations is currently an urgent, but extremely undeveloped issue not only in Russia, but also abroad. In this regard, the assessment of the impact of these processes on the production and diffusion of agglomeration effects to the periphery and the formation of regional socio-economic inequality remains unexplored for science and practice. These circumstances have determined the high significance of the presented work.

To study the specifics of agglomeration processes around a number of large and largest Russian cities, we developed and tested the author's methodological approach, which has scientific novelty, as

far as it considers urban agglomeration as an open and developing system with a spatial dimension. The advantages of this approach in comparison with the existing ones in science are the following:

1. it allows us to identify not only the scale of agglomeration's development as a socio-economic system, but also to assess the degree of its internal integration by analyzing the direction and degree of co-development of the core and satellite zone; agglomeration's impact on regional inequality;

2. it is based on a publicly available information base, which provides an opportunity to replicate it quite easily in use;

3. it allows us to make correct interregional comparisons when assessing the peculiarities of development of Russian urban agglomerations, including those at different levels of hierarchy.

At the same time, a certain disadvantage of this methodological approach is the use of official statistical data on satellite municipalities as a whole, since in Russia, agglomerations are currently not subject to statistical accounting.

Based on the results of this methodological approach approbation, the following features of the development of the studied Russian second-tier urban agglomerations were revealed:

1. These agglomerations have a rather underdeveloped settlement network of the satellite zone; at the same time, the share of the core city in the total population and in a number of other socio-economic indicators of the agglomeration is further increasing (this is especially pronounced in case of those agglomerations where the satellite zone includes large rural areas). All this indicates the growth of centripetal tendencies and strengthening of the core city's position at the expense of the satellite zone resources. In the future, this may be a factor limiting the development of such agglomerations as integrated socio-economic systems and growth centers of regional and macro-regional scale.

2. The key manifestation of agglomeration processes is the concentration of a significant share of the region-wide volume of production, investment, and population in such second-tier agglomerations; these processes often act as factors contributing to the growth of intra-regional socio-economic differentiation. At the same time, it should be noted that agglomerations have a different impact on intra-regional inequality: For example, the Arkhangelsk agglomeration is the only key industrial center of the region and makes a significant contribution to the formation of intergroup and intragroup inequality; At the same time, the Vologda agglomeration does not significantly influence the formation of inequality, as far as the Cherepovets agglomeration, which is the industrial "capital" of the region, and it is formed in the region as well.

3. Explicitly agglomeration processes and effects spread from the core city only to the nearest satellite zone; this is manifested in the convergence and certain positive synchronization of these territories' growth rates in terms of key socio-economic indicators; Weak integration, with the core of other municipalities of the satellite zone, leads to the fact that they either do not experience these positive effects or have to put up with the negative ones related to their milking (primarily human resources) by the central city; shrinking differences between agglomeration municipalities in key social and a number of other indicators (average monthly wages, amount of local budget revenues per 1 inhabitant) are primarily related to the equalizing priorities of federal and regional policy, rather than due to the real integration of markets and diffusion of positive effects. These results correlate with the findings of Chinese scientists (Wang et al., 2022), obtained in the case of a number of Chinese second- and third-tier agglomerations, where it was shown that the real scale of integration processes within the agglomeration in practice turns out to be much smaller than the boundaries of these agglomerations normatively established by the authorities.

4. Calculations have shown that among Russian second-tier agglomerations, a number of northern and arctic agglomerations (for example, Surgut and partly Arkhangelsk agglomerations) have a greater potential for development due to a fairly high level of development of urban settlements in their satellite zone and the location of large industrial enterprises with effective specialization, complementary to the economy of their core with consistency of investment cycles of the core and satellite zone; at the same time, such agglomerations are embedded in national and global value chains.

At further stages of this study, we will additionally consider the specifics and features of agglomeration processes within the 8 studied urban agglomerations of Russia for a longer period (2000–2022):

•   in the economic sphere (dynamics of innovation activity; the number of registered organizations per 1,000 inhabitants, including nonprofit organizations, and individual entrepreneurs; dynamics of the number of employees of organizations per 1 sq. km of territory and 1,000 inhabitants, etc.);

•   in the social sphere (dynamics of the demographic load indicator, social infrastructure facilities, morbidity of the population, unemployment rate, tension in the labor market, etc.);

•   in the infrastructural sphere (concentration of engineering infrastructure facilities, dynamics of the street and road network density, housing affordability ratio, housing availability, housing stock improvement indicators, etc.).

In addition, we plan to develop and test a methodological toolkit for assessing agglomeration effects at the micro- (enterprise level) and meso-levels (the level of municipalities included in the agglomerations) in these 8 agglomerations. We are going to assess the state and identify problems and promising areas for the development of integration socio-economic ties within the agglomerations on the basis of a questionnaire survey of all municipalities' heads included in the studied agglomerations.

All this will make it possible to substantiate the organizational and economic mechanism for managing the development of second-tier urban agglomerations as a single management object, providing for the organization of management of expectations of various groups of stakeholders, formation and use of inter-municipal property, determination of the legal status and powers of the administrative center of agglomeration, approaches to coordinating the activities of local government, business community and nonprofit sector in the processes of agglomeration development, and approaches to the possible transfer of municipal powers to inter-municipal structures and other municipalities—the participants of the agglomeration.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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