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Modelling the Efficiency of the Use of Production and Investment Resources at the Regional Level: The Case of Russia

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Abstract:

Purpose: *The aim of this article is to examine the efficiency of the use of production and investment resources at the regional level in the Russian Federation.*
Design/Methodology/Approach: *The important feature of the suggested approach is to take into account the average (normative) return of sectoral resources by computing the efficiency scores of regions. Methods of agent-based modelling (ABM) were applied in the investigation using the 'gravity effects' that described the behaviour of agent-enterprises. Moreover, agent-investors regarding agent-regions are considered.*
Findings: *The key findings are: (1) There is a significant inequality and a gap between the leading regions of Russia (such as Moscow, Moscow Oblast and Saint Petersburg) and other regions. At the same time, many non-leading regions are more stable and attractive; (2) A complex classification of Russian regions based on solving four tasks, namely the 'ratio of production to labour', 'ratio of production to assets', 'ratio of investments to labour' and 'ratio of investments to assets' is an effective approach to estimate region states; (3) In the leading regions e.g., Moscow, has decreasing efficiency scores after 2014, which is probably due to the large influence of crisis phenomena on the largest Russian agglomerations in comparison with other regions; (4) The 'gravity model' explains the behaviour of economic agents and allows forecasting the number of regional enterprises and investors.*
Practical implications: *The developed method can be practically applied for other countries with non-homogeneous regional economies.*
Originality/Value: *For the first time the dynamical model of the efficiency of the use of production and investment resources at the regional level of Russia is suggested. Such model allows examining regional changes.*

Keywords: *Production and investment policy, regional economics, agent-based modelling.*

JEL Classification: *C63, E20, R11, R58.*

Paper type. *Research article.*

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1. Introduction

As is well known, the regions of Russia are characterized by a high level of heterogeneity in terms of their production and investment characteristics. Such differentiation is caused by many factors, many of which are resource characteristics, in particular, fixed assets and labour resources by branches of the economy including industry, agriculture, transport and communication, etc. All Russian regions have their own specificity that is caused by the geography, climate, history, etc. At the present time, there are 85 administrative areas in the Russian Federation, including republics, territories, autonomous areas, federal cities (e.g. Moscow and Saint Petersburg) and other regions.

There is a line of research related to the analysis of the economic state of the Russian regions (Akopov and Beklaryan, 2014; Zinovyeva *et al.*, 2016; Veselovsky *et al.*, 2017; Berezhnaya *et. al.*, 2018; Miloradov *et al.*, 2018; Voronkova *et al.*, 2018; Zelinskaya *et al.*, 2018). This research is mostly devoted to some aspects of regional economics based on statistical data. For example, the regional CGE (Common General Equilibrium Model) is discussed in a study by Akopov and Beklaryan (2014) that aimed to identify the best forms of economic policy at the regional level. This model uses system dynamics methods developed by Forrester for the first time in the middle of the 20th century (Forrester, 1958). At the present time, system dynamics methods are supported in different simulation tools such as Powersim Studio, AnyLogic, iThink, etc. These methods and tools allow the development of simulation models of regional economic systems and decision-making systems for economic planning (Beklaryan, 2018). Modern computing systems such as AnyLogic (Borshchev, 2013) support multi-method simulation modelling based on both system dynamics (SD) and agent-based modelling (ABM) developed in the 1970s (Schelling, 1971) applying them jointly within one model. This approach has many advantages for the investigation of regional economic systems because such systems are decentralized with multiple internal nonlinear relations.

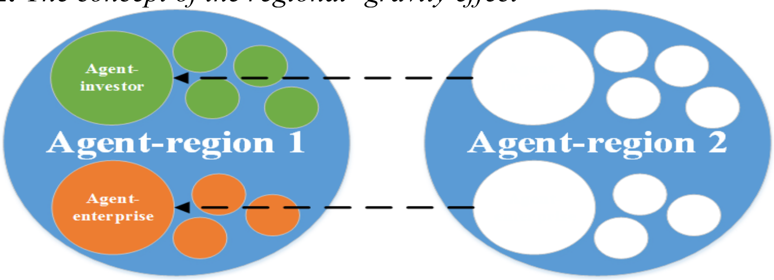
The purpose of this article is to examine production and investment characteristics at the regional level using the Russian Federation as a case study with the help of a developed simulation model. This model uses ABM methods, as well as the 'gravity effect' which explains the attraction of different agents to each other, e.g. agent-enterprises (companies) and agent-investors (organizations and individuals doing investments) to an agent-region. The attraction power for agents is directly proportional to the efficiency scores of production and investment resources used. In the results, the numbers of agents (companies and investors) forming at appropriate agent-regions can be forecast.

2. Literature Review

The research methodology is based on previous methods of system dynamics and agent-based modelling developed for regional systems (Akopov and Beklaryan, 2014; Akopov *et al.*, 2017). At the present time, ABM methods are applied for the research of regional economies (Berger, 2001; Baindur and Viegas, 2011). The importance of such methods has been described in many well-known works (Tesfatsion, 2002; Parker, 2003; Farmer and Foley, 2009; Epstein, 2012). Moreover, ABM is applicable for developing distributed optimisation methods (Akopov and Hevencev, 2013), environmental modelling (Akopov *et al.*, 2019) and designing decision-making systems (Beklaryan, 2018).

There are several well-known studies in the field of modelling regional performance characteristics (Storper, 1997; Porter, 2003; Scott and Storper, 2003). Most aim to model different performance indicators of regions for their comprehensive analysis. An exception is the class of regional computable general equilibrium models (Partridge and Rickman, 1998) in which the dynamical interaction between different economic agents is considered. Nevertheless, the influence of regional production and investment characteristics on the dynamics of enterprises and investors is still poorly understood. Therefore, there is a need to extend methods of regional modelling to include mechanisms of agent behaviour such as the 'gravity effect'. For the first time, such an effect was described in works by Tinbergen (1962) and Anderson (1979) and was used for the investigation of bilateral trade processes. In subsequent years, this method was applied to examine the migration flows between different countries. However, never before has this approach been applied to study the formation of new agents (companies and investors) in regions taking into account their production and investment characteristics. The concept of the regional 'gravity effect' is illustrated in Figure 1.

Figure 1: *The concept of the regional 'gravity effect'*



3. Research Methodology

In this model, agent-enterprises and agent-investors close in weak regions and appear in regions that are more attractive economically (Figure 1). In this work, the object of analysis is those Russian regions that possess fixed assets and labour resources. Such regions are characterized by their own economic activity whose results are the output and investments in fixed assets. The economic activity of a region is considered for five main branches of the economy:

- industry (including mining, manufacturing, production and distribution of electricity, gas and water);

- agriculture (including hunting, forestry and fishing);
- construction;
- trade (including wholesale and retail trade; repair of motor vehicles, motorcycles, household goods and personal items);
- transport and communications.

At the same time, the following tasks are considered within the suggested model:

- *'Ratio of production to labour':* the efficiency of using labour resources for the output is estimated;
- *'Ratio of production to assets':* the efficiency of using fixed assets for the output is estimated;
- *'Ratio of investments to labour':* the efficiency of using labour resources for attracting investments is estimated;
- *'Ratio of investments to assets':* the efficiency of using fixed assets for attracting investments is estimated;

Further, the abstract description of the suggested model will be presented where:

- $\tilde{T} = \{t_1,\ t_2,\ ...,\ T\}$ is the set of time moments by years, $t \in \tilde{T}$ is the model time, T is the ten-year period for the analysis of the regional economic efficiency;
- $\tilde{I} = \{i_1,\ i_2,\ ...,\ I\}$ is the set of indexes of agent-regions, I is the number of agent-regions;
- $\tilde{J} = \{j_1,\ j_2,\ ...,\ J\}$ is the set of indexes of branches of the economy, J is the number of branches of the economy;
- $\{K_{ij}(t),\ L_{ij}(t)\}$ are the fixed assets and labour resources of the j^{th}-branch of the economy $(j_i \in \tilde{J})$ in the i^{th} region $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$;
- $\{\tilde{K}_i(t),\ \tilde{L}_i(t)\}$ are summarized values (by all branches) of fixed assets and labour resources in the i^{th} region $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$;
- $\{\hat{K}_j(t),\ \hat{L}_j(t)\}$ are summarized values (by all regions) of fixed assets and labour resources of the j^{th}-branch of the economy $(j \in \tilde{J})$ at moment t $(t \in \tilde{T})$;
- $\{\frown{K}(t),\ \frown{L}(t)\}$ are summarized values (by all regions and branches of the economy) fixed assets and labour resources at moment t $(t \in \tilde{T})$;

- $\{V_{ij}(t),\ In_{ij}(t)\}$ are volumes of output and investments of the j^{th}-branch of the economy $(j \in \tilde{J})$ in the i^{th}- region $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$;
- $\{\tilde{V}_i(t),\ In_i(t)\}$ are summarized volumes (by all branches) of outputs and investments in the i^{th}-region $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$;
- $\{V_j(t),\ In_j(t)\}$ are summarized volumes (by all regions) of outputs and investments of the j^{th}-branch of the economy $(j \in \tilde{J})$ at moment t $(t \in \tilde{T})$;
- $\{\widehat{V}(t),\ In(t)\}$ are summarized volumes (by all regions and branches) of outputs and investments at moment t $(t \in \tilde{T})$;
- $\{U_{ij1}(t),\ U_{ij2}(t),\ U_{ij3}(t),\ U_{ij4}(t)\}$ are efficiency scores of j^{ths}-branches of the economy $(j \in \tilde{J})$ of i^{th}-regions $(i \in \tilde{I})$ in tasks of the '*Ratio of production to labour*', '*Ratio of investments to labour*', '*Ratio of production to assets*' and '*Ratio of investments to assets*' at moment t $(t \in \tilde{T})$;
- $\{\tilde{U}_{i1}(t),\ \tilde{U}_{i2}(t),\ \tilde{U}_{i3}(t),\ \tilde{U}_{i4}(t)\}$ are the total (for all branches) efficiency scores of i^{ths}- regions $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$.

At the same time, the following balance relations are performed for the resource characteristics of the model at each time t $(t \in \tilde{T})$:

$$\tilde{K}_i(t) = \sum_{j=1}^{J} K_{ij}(t),\ \tilde{L}_i(t) = \sum_{j=1}^{J} L_{ij}(t), \tag{1}$$

$$\hat{K}_j(t) = \sum_{i=1}^{I} K_{ij}(t),\ \hat{L}_j(t) = \sum_{i=1}^{I} L_{ij}(t), \tag{2}$$

$$\widehat{K}(t) = \sum_{i=1}^{I} \tilde{K}_i(t) = \sum_{j=1}^{J} \hat{K}_j(t),\ \widehat{L}(t) = \sum_{i=1}^{I} \tilde{L}_i(t) = \sum_{j=1}^{J} \hat{L}_j(t). \tag{3}$$

Similar balance relations are performed for the resulting characteristics of the model at each time t $(t \in \tilde{T})$:

$$\tilde{V}_i(t) = \sum_{j=1}^{J} V_{ij}(t),\ In_i(t) = \sum_{j=1}^{J} In_{ij}(t), \tag{4}$$

$$\hat{V}_j(t) = \sum_{i=1}^{I} V_{ij}(t),\ In_j(t) = \sum_{i=1}^{I} In_{ij}(t), \tag{5}$$

$$\widehat{V}(t)=\sum_{i=1}^{I}\tilde{V}_i(t)=\sum_{j=1}^{J}\hat{V}_j(t),\ In(t)=\sum_{i=1}^{I}In_i(t)=\sum_{j=1}^{J}In_j(t). \qquad (6)$$

The total efficiency scores of the i^{th}-region $(i\in\tilde{I})$ at moment t $(t\in\tilde{T})$:

$$U_{i1}(t)=\frac{1}{\tilde{L}_i}\sum_{j=1}^{J}\frac{V_{ij}(t)}{W_{j1}(t)},\ U_{i2}(t)=\frac{1}{\tilde{K}_i}\sum_{j=1}^{J}\frac{V_{ij}(t)}{W_{j2}(t)}, \qquad (7)$$

$$U_{i3}(t)=\frac{1}{\tilde{L}_i}\sum_{j=1}^{J}\frac{In_{ij}(t)}{W_{j3}(t)},\ U_{i4}(t)=\frac{1}{\tilde{K}_i}\sum_{j=1}^{J}\frac{In_{ij}(t)}{W_{j4}(t)}, \qquad (7)$$

subject to the following conditions:

$$\sum_{i=1}^{I}U_{i1}(t)K_i(t)=\widehat{K}(t),\ \sum_{i=1}^{I}U_{i2}(t)L_i(t)=\widehat{L}(t). \qquad (8)$$

At the same time, the average (normative) return of sectoral resources of the j^{th}-branch of the economy $(j\in\tilde{J})$ at moment t $(t\in\tilde{T})$:

$$W_{j1}(t)=\frac{\hat{V}_j(t)}{\sum_{i=1}^{I}L_{ij}(t)U_{i1}(t)},\ W_{j2}(t)=\frac{\hat{V}_j(t)}{\sum_{i=1}^{I}K_{ij}(t)U_{i2}(t)}, \qquad (9)$$

$$W_{j3}(t)=\frac{In_j(t)}{\sum_{i=1}^{I}L_{ij}(t)U_{i3}(t)},\ W_{j4}(t)=\frac{In_j(t)}{\sum_{i=1}^{I}K_{ij}(t)U_{i4}(t)}. \qquad (10)$$

The state of the i^{th}-region $(i\in\tilde{I})$ that characterizes the efficiency of using sectoral resources for the production and investment activity at moment t $(t\in\tilde{T})$ is defined by the following rules:

$$st_i(t)=\begin{cases}1, \text{ if I is true,}\\ 2, \text{ if II is true,}\\ 3, \text{ if III is true,}\end{cases} \qquad (12)$$

I. U_{i1}(t)>$\underline{U}_{i1}$ и U_{i2}(t)>$\underline{U}_{i2}$ и U_{i3}(t)>$\underline{U}_{i3}$ и U_{i4}(t)>$\underline{U}_{i4}$,
or $\underline{\underline{U}}_{i3}\le U_{i3}(\text{t})\le\underline{U}_{i3}$ or $\underline{\underline{U}}_{i4}\le U_{i4}(\text{t})\le\underline{U}_{i4}$,

II. $\underline{\underline{U}}_{i1}\le U_{i1}(\text{t})\le\underline{U}_{i1}$ or $\underline{\underline{U}}_{i2}\le U_{i2}(\text{t})\le\underline{U}_{i2}$,

III. U_{i1}(t)<$\underline{\underline{U}}_{i1}$ or U_{i2}(t)<$\underline{\underline{U}}_{i2}$ or U_{i3}(t)<$\underline{\underline{U}}_{i3}$ or U_{i4}(t)<$\underline{\underline{U}}_{i4}$.

Also:

- $st_i(t)\in\{1,\ 2,\ 3\}$ is the set of states of the i^{th}-region $(i\in\tilde{I})$ that characterize the efficiency of using fixed assets and labour resources for production and investment activities respectively: $st_i(t)=1$ is a positive sate, $st_i(t)=2$ is a satisfactory state, and $st_i(t)=3$ is a negative state;

- $\{\underline{U}_{i1},\ \underline{U}_{i2},\ \underline{U}_{i3},\ \underline{U}_{i4}\}$ are threshold values of efficiency scores needed for including the i^{th}-region to the cluster of regions with positive states (exogenous parameters);
- $\{\underline{\underline{U}}_{i1},\ \underline{\underline{U}}_{i2},\ \underline{\underline{U}}_{i3},\ \underline{\underline{U}}_{i4}\}$ are threshold values of efficiency scores needed for including the i^{th}-region to the cluster of regions with satisfactory states (exogenous parameters).

The forecast values of the total numbers of agent-enterprises (companies) and agent-investors (organization doing investments) in the i^{th}-region $(i \in \tilde{I})$ at moment t $(t \in \tilde{T})$ are:

$$N_{i1}(t)=\begin{cases} N_{i1}(t-1)+\sigma_1 U_{i1}(t-\tau_1)+\sigma_2 U_{i2}(t-\tau_2), \text{ if } \mathrm{st}_i(\mathrm{t})=1, \\ N_{i1}(t-1), \text{ if } \mathrm{st}_i(t)=2, \\ N_{i1}(t-1)-\sigma_1 U_{i1}(t-\tau_1)+\sigma_2 U_{i2}(t-\tau_2), \text{ if } \mathrm{st}_i(t)=3, \end{cases} \tag{11}$$

$$N_{i2}(t)=\begin{cases} N_{i2}(t-1)+\sigma_3 U_{i1}(t-\tau_1)+\sigma_4 U_{i2}(t-\tau_2), \text{ if } \mathrm{st}_i(\mathrm{t})=1, \\ N_{i2}(t-1), \text{ if } \mathrm{st}_i(t)=2, \\ N_{i2}(t-1)-\sigma_3 U_{i3}(t-\tau_1)+\sigma_4 U_{i4}(t-\tau_2), \text{ if } \mathrm{st}_i(t)=3, \end{cases} \tag{14}$$

where

$N_1(t)$ is the total number of agent-enterprises;

$N_2(t)$ is the total number of agent-investors;

$\{\sigma_1,\ \sigma_2,\ \sigma_3,\ \sigma_4\}$ are regression coefficients;

$\{\tau_1,\ \tau_2\}$ are time lags that are defined by the inertness in decision-making systems of agent-enterprises and agent-investors respectively (usually one year).

The model (1)-(14) is implemented in AnyLogic, which supports methods of agent-based modelling by allowing spatial data to be treated (Figure 2). The special iteration procedure allowing efficiency scores (7)-(8) to be completed was developed using Java, a core of AnyLogic.

4. Results

The model (1)-(14) was tested and validated using open empirical data provided by the Federal State Statistics Service of the Russian Federation[3]. The well-known method of least squares was used for the computation of the regression coefficients. At the same time, the special iteration procedure was developed and applied to compute the efficiency scores (7)-(8) by taking into account the average returns of sectoral resources (10)-(11). In Table 1, the regions are classified into three clusters

[3] *http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/en/main/*

depending on their efficiency scores for the first pair of tasks '*Ratio of production to labour*' and '*Ratio of production to assets*' in 2016.

Figure 2: *The developed regional simulation model.*

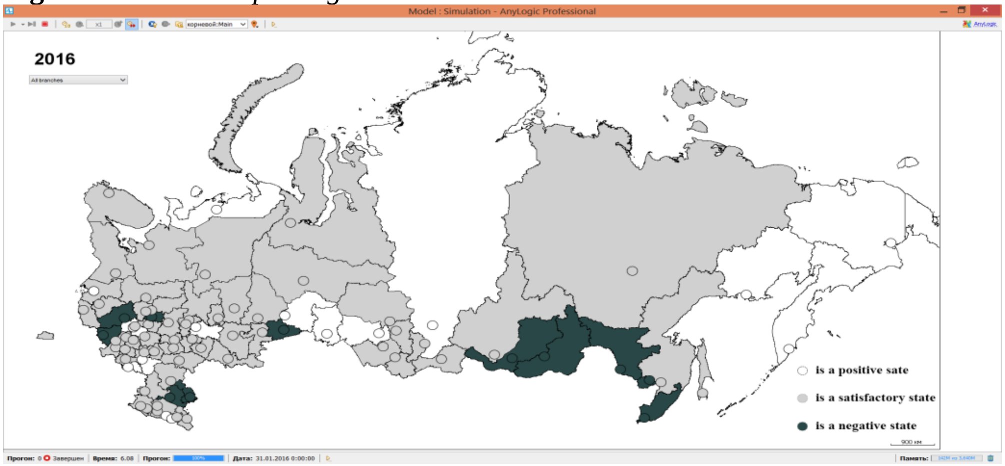


Table 1. *Classification of Russian regions by the efficiency of using resources for production activity*

	The first pair of tasks	
	Ratio of production to labour	**Ratio of production to assets**
Higher	Moscow, Magadan Oblast, Nenets Autonomous Okrug, Belgorod Oblast, Moscow Oblast, Chukotka Autonomous Okrug, Krasnoyarsk Krai, Saint-Petersburg	Moscow, Altai Krai, Omsk Oblast, The Republic of Adygea, Moscow Oblast, Belgorod Oblast, Karachay-Cherkess Republic, Kabardino-Balkar Republic, Saint-Petersburg, The Republic of Ingushetia
High	Omsk Oblast, Kamchatka Krai, Republic of North Ossetia - Alania, Voronezh Oblast, Novosibirsk Oblast, Kabardino-Balkar Republic, The Republic of Tatarstan, Tyumen Oblast, Kaliningrad Oblast, The Republic of Sakha (Yakutia), Sakhalin Oblast, Altai Krai, Khanty-Mansi Autonomous Okrug – Yugra, The Republic of Ingushetia	Voronezh Oblast, Republic of North Ossetia - Alania, Novosibirsk Oblast, Tuva, Kamchatka Krai, Krasnoyarsk Krai, The Republic of Dagestan, Kaliningrad Oblast, Vladimir Oblast, The Republic of Tatarstan, Magadan Oblast, Rostov Oblast, Ulyanovsk Oblast, Tula Oblast, Republic of Bashkortostan
Average	Tula Oblast, Republic of Bashkortostan, Rostov Oblast, The Republic of Adygea, Yamalo-Nenets Autonomous Okrug, Vladimir Oblast, Murmansk Oblast, Oryol Oblast, Udmurtia, Ulyanovsk Oblast,	Oryol Oblast, The Republic of Altai, Chechen Republic, Udmurtia, Bryansk Oblast, Kursk Oblast, Chelyabinsk Oblast, Tyumen Oblast, Tambov Oblast, The Republic of Mari El, Irkutsk Oblast,

	Irkutsk Oblast, Tuva, The Republic of Dagestan, Kursk Oblast, Chelyabinsk Oblast, Tambov Oblast, The Republic of Komi, Tomsk Oblast, Karachay-Cherkess Republic, Samara Oblast, Khabarovsk Krai, Nizhny Novgorod Oblast, The Republic of Khakassia, Leningrad Oblast, Lipetsk Oblast, The Republic of Altai, Chechen Republic, Krasnodar Krai, Orenburg Oblast, Bryansk Oblast, Kaluga Oblast, The Republic of Mari El, Sverdlovsk Oblast, Novgorod Oblast, Perm Krai, Stavropol Krai, Penza Oblast, Vologda Oblast, Yaroslavl Oblast, Republic of Karelia, Arkhangelsk Oblast, Saratov Oblast, Kemerovo Oblast, Pskov Oblast, Kostroma Oblast, Kirov Oblast, Volgograd Oblast, The Republic of Mordovia, Chuvash Republic, Ryazan Oblast	Stavropol Krai, Samara Oblast, Penza Oblast, The Republic of Khakassia, Nizhny Novgorod Oblast, Ivanovo Oblast, Krasnodar Krai, Pskov Oblast, Kaluga Oblast, Chuvash Republic, Kirov Oblast, Lipetsk Oblast, Tomsk Oblast, Yaroslavl Oblast, Khabarovsk Krai, Orenburg Oblast, The Republic of Mordovia, Novgorod Oblast, Kemerovo Oblast, Republic of Karelia, Saratov Oblast, Kostroma Oblast, Volgograd Oblast, Murmansk Oblast, Arkhangelsk Oblast, Chukotka Autonomous Okrug, Ryazan Oblast, Leningrad Oblast, Vologda Oblast, Perm Krai, Sverdlovsk Oblast, Smolensk Oblast, Primorsky Krai, Astrakhan Oblast, The Republic of Buryatia, Sakhalin Oblast
Low	Primorsky Krai, Astrakhan Oblast, Amur Oblast, Ivanovo Oblast, Smolensk Oblast, The Republic of Buryatia, Zabaykalsky Krai, Tver Oblast, Kurgan Oblast, The Republic of Kalmykia, Jewish Autonomous Oblast	Sakhalin Oblast, Khanty-Mansi Autonomous Okrug – Yugra, The Republic of Sakha (Yakutia), Amur Oblast, Zabaykalsky Krai, Tver Oblast, The Republic of Kalmykia, Kurgan Oblast, Nenets Autonomous Okrug, Jewish Autonomous Oblast, The Republic of Komi, Yamalo-Nenets Autonomous Okrug

In Table 2, the regions are classified into three clusters depending on their efficiency scores for the second pair of tasks '*Ratio of investments to labour*' and '*Ratio of investments to assets*' in 2016.

Table 2. *Classification of Russian regions by the efficiency of using resources for investment activity*

	The second pair of tasks	
	Ratio of investments to labour	**Ratio of investments to assets**
Higher	Yamalo-Nenets Autonomous Okrug, Magadan Oblast, Nenets Autonomous Okrug, The Republic of Komi, Sakhalin Oblast, The Republic of Sakha (Yakutia), Amur Oblast, Tyumen Oblast, Voronezh	Magadan Oblast, Voronezh Oblast, Karachay-Cherkess Republic, Amur Oblast, Novgorod Oblast, Tyumen Oblast, Tuva, Krasnoyarsk Krai

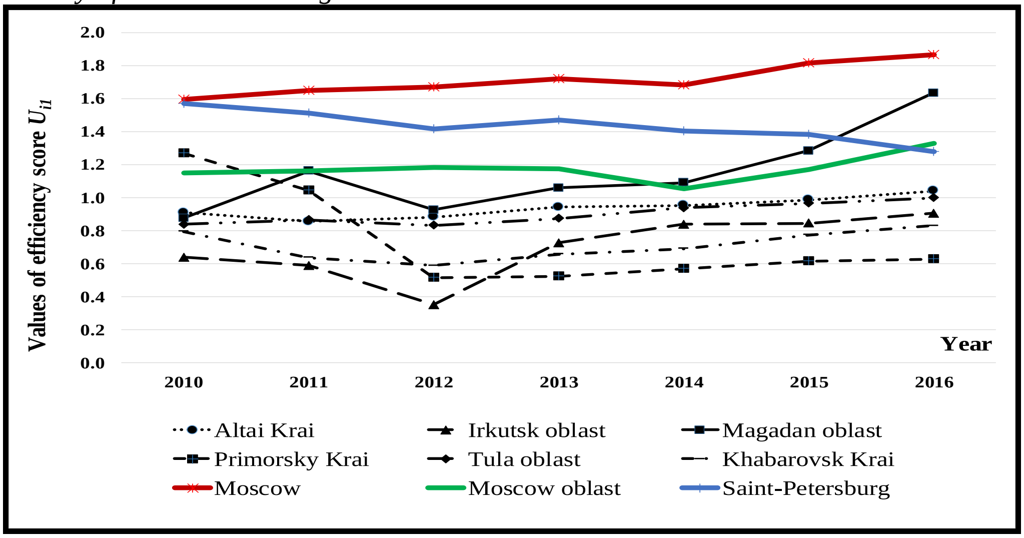
	Oblast, Khanty-Mansi Autonomous Okrug – Yugra, Novgorod Oblast, Krasnoyarsk Krai	
High	Chukotka Autonomous Okrug, Leningrad Oblast, Kaliningrad Oblast, Kamchatka Krai, Saint-Petersburg, The Republic of Tatarstan, Astrakhan Oblast, Irkutsk Oblast, Kursk Oblast, Republic of Bashkortostan, Karachay-Cherkess Republic, Tuva, Belgorod Oblast, Bryansk Oblast, Murmansk Oblast, Tomsk Oblast, Vologda Oblast, Chechen Republic, Khabarovsk Krai, Tambov Oblast, Kaluga Oblast, Moscow	Bryansk Oblast, Chechen Republic, Kursk Oblast, Republic of Bashkortostan, Rostov Oblast, Irkutsk Oblast, Sakhalin Oblast, Belgorod Oblast, The Republic of Adygea, Astrakhan Oblast, Leningrad Oblast, Omsk Oblast, Kaluga Oblast, Tambov Oblast, Tula Oblast, The Republic of Sakha (Yakutia), Samara Oblast, Moscow, Nenets Autonomous Okrug, Tomsk Oblast, Khabarovsk Krai, The Republic of Ingushetia
Average	Rostov Oblast, Tula Oblast, Samara Oblast, Perm Krai, Krasnodar Krai, Zabaykalsky Krai, Jewish Autonomous Oblast, Orenburg Oblast, Moscow Oblast, Volgograd Oblast, Lipetsk Oblast, Omsk Oblast, The Republic of Adygea, Arkhangelsk Oblast, Tver Oblast, Saratov Oblast, The Republic of Mordovia, Yaroslavl Oblast, Chelyabinsk Oblast, The Republic of Altai, Republic of North Ossetia - Alania, Kirov Oblast, Vladimir Oblast, Kemerovo Oblast, Nizhny Novgorod Oblast, Stavropol Krai	Yamalo-Nenets Autonomous Okrug, Krasnodar Krai, Moscow Oblast, Altai Krai, Khanty-Mansi Autonomous Okrug – Yugra, The Republic of Komi, Zabaykalsky Krai, Vologda Oblast, Volgograd Oblast, The Republic of Altai, Orenburg Oblast, Lipetsk Oblast, Murmansk Oblast, Vladimir Oblast, The Republic of Mordovia, Chukotka Autonomous Okrug, Perm Krai, Tver Oblast, Ulyanovsk Oblast, Saratov Oblast, Kirov Oblast, Republic of North Ossetia - Alania, Yaroslavl Oblast, Arkhangelsk Oblast, Stavropol Krai, Chelyabinsk Oblast, Kabardino-Balkar Republic, Kemerovo Oblast, Novosibirsk Oblast, Nizhny Novgorod Oblast
Low	Oryol Oblast, Republic of Karelia, Udmurtia, Ulyanovsk Oblast, Novosibirsk Oblast, Smolensk Oblast, Sverdlovsk Oblast, Kabardino-Balkar Republic, Pskov Oblast, Altai Krai, Kostroma Oblast, The Republic of Buryatia, Penza Oblast, Ryazan Oblast, The Republic of Mari El, The Republic of Ingushetia, The Republic of Khakassia,	Oryol Oblast, Jewish Autonomous Oblast, Udmurtia, Pskov Oblast, Republic of Karelia, Smolensk Oblast, Penza Oblast, Kostroma Oblast, The Republic of Mari El, The Republic of Buryatia, Ryazan Oblast, Chuvash Republic, The Republic of Khakassia, Sverdlovsk Oblast, Primorsky Krai, Ivanovo Oblast, Kurgan Oblast, The

	Primorsky Krai, Chuvash Republic, Kurgan Oblast, The Republic of Kalmykia, Ivanovo Oblast, The Republic of Dagestan	Republic of Kalmykia, The Republic of Dagestan

It should be highlighted that the leading regions (Moscow, Moscow Oblast, Saint-Petersburg) that are included in the higher cluster on using resources for production activity (Table 1) are not related to the higher cluster on using resources for investment activity (Table 2). Moreover, this demonstrates the lower stability of the dynamics of the efficiency scores compared to some other Russian regions (Altai Krai, Irkutsk Oblast, the Republic of Tatarstan).

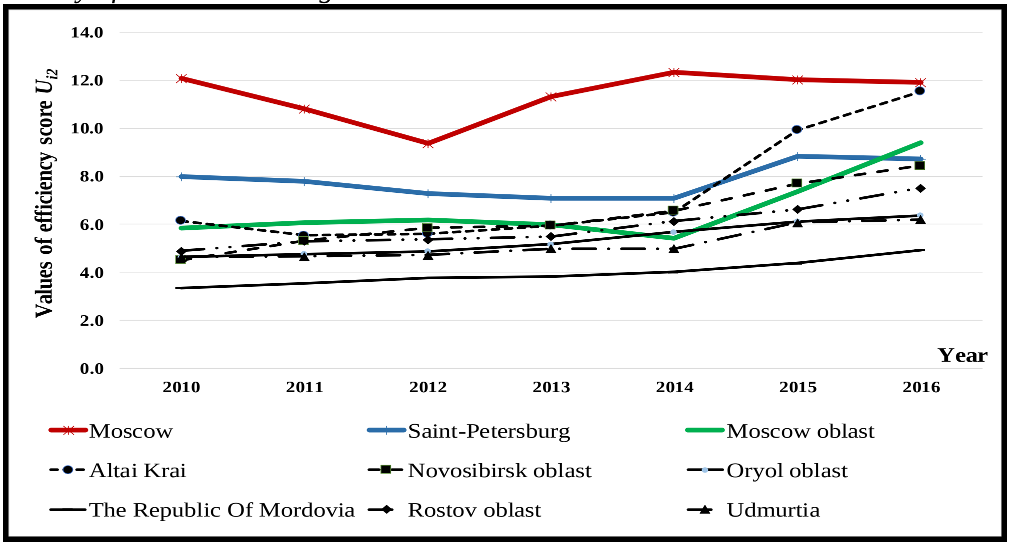
Figures 3 and 4 show estimations of the efficiency by using labour resources for some Russian regions having stable dynamics of growth from 2012 to 2016 within the first pair of tasks *'Ratio of production to labour'* and *'Ratio of production to assets'*.

Figure 3. *The dynamics of the efficiency of using labour resources in the production activity of some Russian regions*



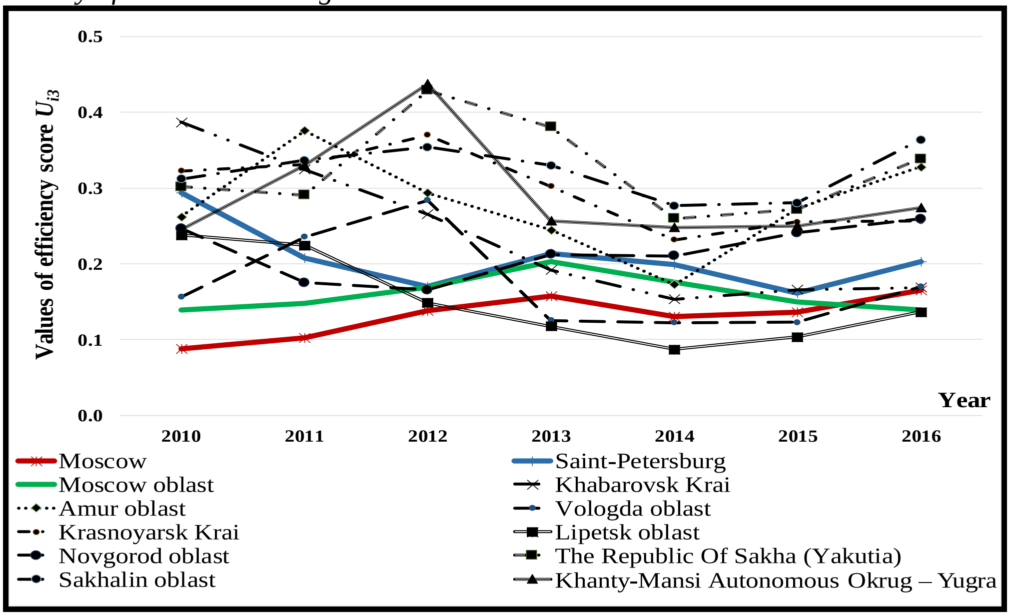
As shown in Figures 3 and 4, the majority of regions (Altai Krai, Irkutsk Oblast, the Republic of Tatarstan) that demonstrate a steady increase in the efficiency of using labour resources mainly belong to the cluster of regions with high efficiency (Table 1). In contrast, in central regions, in particular, Moscow, Moscow Oblast and St. Petersburg, decreasing efficiency scores are observed in 2014 compared to the previous year. This is probably due to the large impact of crisis phenomena on the largest Russian agglomerations in comparison with other regions of the Russian Federation. At the same time, a restoration in the positive dynamics in Moscow and Saint Petersburg is observed after 2014.

Figure 4. *The dynamics of the efficiency of using fixed assets in the production activity of some Russian regions*



Figures 5 and 6 show estimations of the efficiency of using labour resources for some regions having stable dynamics of growth from 2012 to 2016 within the second pair of tasks *'Ratio of production to assets'* and *'Ratio of investments to assets'*.

Figure 5. *The dynamics of the efficiency of using labour resources in the investment activity of some Russian regions*



It should be highlighted that a fall was observed in the dynamics of the efficiency of using labour resources in the investment activity for the majority of Russian regions during the period 2010 – 2014, with an ensuing gradual recovery (Figure 5).

Figure 6. *The dynamics of the efficiency of using fixed assets in the investment activity of some Russian regions*

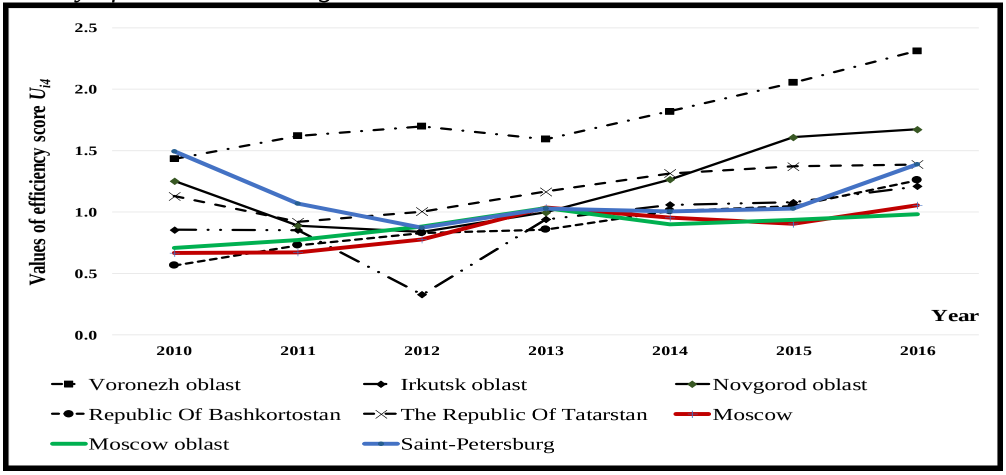
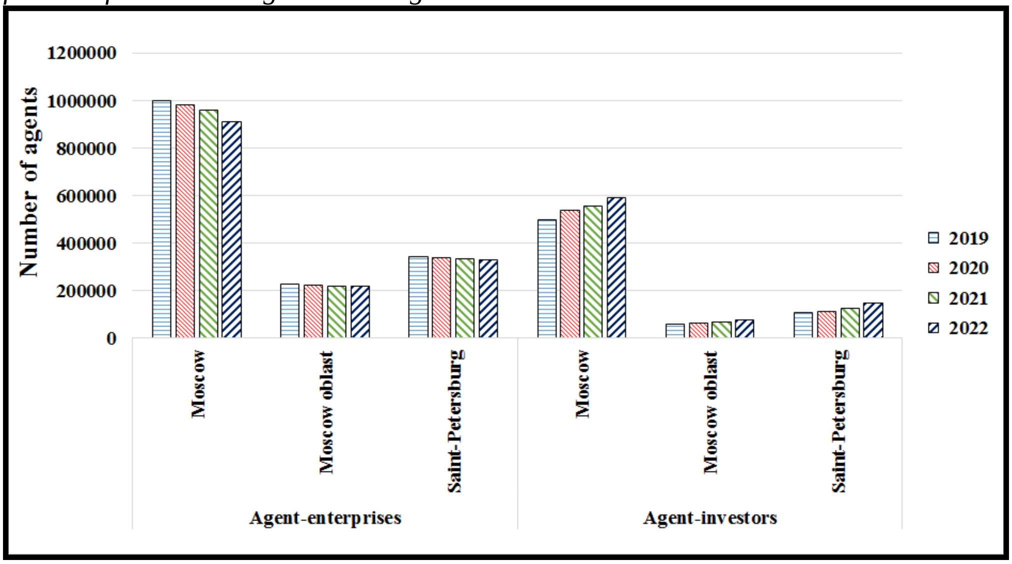


Figure 7 shows the dynamics of the total number of agent-enterprises and agent-investors forecast with the help of the developed model (1)-(14) for the leading Russian regions (i.e., regions possessing the most number of such agents) for the period 2019 – 2022, in particular, Moscow, Moscow Oblast and St. Petersburg.

Figure 7. *The dynamics of the total number of agent-enterprises and agent-investors forecast for the leading Russian regions*



As shown in Figure 7, the total number of agent-enterprises in the leading regions for the considered period decreases as expected while the total number of agent-investors demonstrates slow growth. Such dynamics are caused by increasing difficulties and barriers for Russian companies, especially for small enterprises (e.g., growing tax burden, lack of investment capital, oligopoly in Russian economy). At the same, time, the growth of the total number of agent-investors is caused by the greater attraction of assets in the leading regions in comparison with other territories.

5. Discussion

This study is based on modelling the efficiency of using production and investment resources at the regional level (1)-(14). The important feature of this approach is that it takes into account the average (normative) return of sectoral resources by computing of the efficiency scores of regions (10)-(11). It allows the strong heterogeneity of regional economies to be overcome (Beraja *et al*., 2019).

The important advantage of the suggested approach is that it provides an objective comparative assessment of the performance of using labour resources and fixed assets for the production and investment activity by all regions based on the dynamics of efficiency scores (Figures 3 – 6). It allows clustering regions according to the level of their efficiency within the four main tasks, namely the '*Ratio of production to labour*', '*Ratio of production to assets*', '*Ratio of investments to labour*' and '*Ratio of investments to assets*' (Table 1 and Table 2).

At the same time, applying methods of agent-based modelling (Akopov *et al*., 2019; Akopov *et al*., 2017; Baindur and Viegas, 2011) allows the possibilities of the analysis of the production and investment characteristics of Russian regions to be extended, in particular, to forecast the total number of enterprises and investors at the regional level (Figure 7). The agent model developed in this work can be employed to develop a decision-making system for rational management at the regional level (Akopov and Beklaryan, 2014; Beklaryan, 2018).

A limitation of the model is that it ignores other important characteristics of the regional economy, in particular, the availability of social infrastructure facilities (schools, hospitals, etc.), per capita income, inflation, transport development and several other performance indicators. Thus, this article focuses only on regional production and investment activities. Nevertheless, the method can be extended to other areas of the regional economy through including appropriate metrics.

6. Conclusion

In conclusion, it should be noted that Russian regions need a more balanced economic policy that aims to remove significant disproportions in sizes and development levels of labour resources and fixed assets at the regional level. At the present time, we observe outflows of economic agents (humans, enterprises, investors, etc.) from regions with weak economies to leading regions (Moscow and Moscow Oblast). This is due to the ‘gravity effect’ described in this article (Figure 1). Agent-enterprises and agent-investors relocate to regions with more attractive production and investment characteristics. It is possible to change the preferences of economic agents through rational management at the regional level targeting predominantly the development of remote regions instead of leading regions (Moscow, Moscow Oblast and Saint Petersburg). Moreover, many Russian regions are more efficient at using resources for production and investment activity than these leading regions (Figures 3 – 5).

The developed method and simulation model (Figure 2) can have a practical application for other countries with non-homogeneous regional economies. Moreover, it can be extended to other areas.

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