

Effective Administrative Decisions in the Investment Industrial Sphere of the Region (Case of Republic of Bashkortostan, Russia)

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Abstract—The objective of the research is to develop the hybrid economic and mathematical model allowing the state executive authorities to make effective administrative decisions in the investment industrial sphere of the region. The model is based on the application of two known methods: Cobb-Douglas production function and dynamic programming. At first the production capabilities of industrial complex branches in the region of the state are estimated. The constructibility of one general production function for several branches of an industrial complex of territorial entity of Russia is empirically estimated (based on the calculation and the analysis of indicator values of resource productivity). Then, the problem of optimum distribution of state investor's limited financial resources between the branches of industrial complex of the region is solved. The hybrid model has been tested based on the data of regional statistics for 2006-2016 evidence from the Republic of Bashkortostan, Russia. The approach, presented in the research, is universal, i.e. it can be applied for updating provisions of the state investment and industrial policy not only in any federal subject of Russia, but regions of any country in the world having federal framework.

Keywords—*hybrid economic and mathematical model; Cobb-Douglas production function; labor; capital; dynamic programming*

I. INTRODUCTION

At the present time the national economy has occurred in the turbulence zone in many respects because of the "aggressive" external environment of the affairs [17] and

particularly, sectoral sanctions against the number of the Russian economic entities limiting the access not only to the progressive technologies, but also the international financial and investment resources, introduced by the USA and EU countries. Under the circumstances, the problem of increasing the efficiency of investment and industrial policy of Russia and its subjects becomes updated.

Despite the fact that some representatives of authority and scientific and expert community have certain different views on the development prospects of national economy and efficiency of the package of measures in the field of the Russian economic policy there is a consensus regarding the key factors defining economic dynamics. Firstly, the consolidated position lies in the fact that the national economic policy and primary factors providing the development of the Russian economy for the last 15 years have no potential to lead to the sustainable growth. Secondly, the professional community has a consensus in opinion that ensuring quality and required momentum of economic growth is an impossible task without increasing the level of investment activity, first of all, of the economic entities functioning in various branches of the national industrial complex.

The Minister of Industry and Trade of the Russian Federation (RF) Denis V. Manturov has written a series of three articles devoted to the assessment of national industrial policy for the last 25 years. In the third final article of the series the objective of the research was the development of the Russian industry at the period from 2010 till present day.

Summing up the results of the conducted research he notes that "the established negative situation in industry is connected aside from the rapid deterioration in an external environment happened in 2014-2016, but with still unsolved structural problems of the Russian economy as well. Even due to the effective mechanisms created recently to support the industry their scale is too small to compensate the decrease in investment demand, capital renewals and sustainable growth of industrial production, particularly against the plurality of declared and the absence of real priorities. The significant part of expenses under the state programs of industry support is still directed not to the modernization of the enterprises (investment expenditure), but actually to the preservation of their current status. In this context the competitive national industry can be created only at simultaneous institutional reforming (with formation of the favorable investment environment) and notable ramping-up the state support with parallel setup of existing regulation instruments" [6]. The position of Ivanter V.V., the academician of the Russian Academy of Sciences (RAS), that "the Russian economy is in the state of the structural and technological disbalance characterized by disproportional distribution of production factors and financial resources" is compatible with the conclusions of the Minister of Industry and Trade of RF Manturov D.V. [19] He remarks that to remove such disproportion it is necessary the specialized structural and investment policy – a range of measures aimed at smoothing sectoral, technological and spatial disproportions complicating the interaction between economic sectors, and not removing by traditional market mechanisms. The structural and investment policy is actualized by means of focused actions for development of investment financing mechanisms to the basic capital. The initial task at choosing priorities of structural and investment policy is to define the directions for the investments providing modernization of the national economy structure as well as the formation of the appropriate financing sources and mechanisms. [19]

Considering the essential interregional gaps, primarily, high-scaled differentiation of financial opportunities of the RF territorial entities, the question of increasing the efficiency of investment and industrial policy of each region in the country has been updated. We consider that this is impossible without applying economic and mathematical modeling and modern information technologies. That has predetermined the research objective.

II. THE BRIEF REVIEW OF ECONOMIC AND MATHEMATICAL MODELS, SIMULATING THE ACTIONS OF COMPLEX SOCIAL AND ECONOMIC SYSTEMS

Nowadays the most adequate instrument of simulating the action of complex social and economic systems is the agent-based models (ABM). Their main idea of these models is to create the computing tool presenting a set of agents with a certain set of properties, and allowing to carry out simulations of the real phenomena. The fundamental difference of ABM from the object-based models consists in the activity of structural elements, each of them has not only the set of personal characteristics (resources), but the object function (interests) as well. Based on this, the responses to changes of

the external environment is simulated, affecting the sphere of interests (behaviour) [24].

The ABM had been considered in the works of the following scientists: R. Axelrod, H. Gintis, A. Kirman, G. Miles, L. Tesfatsion, J.M. Epstein. The general review of ABM is presented in the article of B. Heath [3], the review of economic ABM has been studied in the research of L. Tesfatsion [9], modeling of financial markets are described in works of M. Cristelli [10], S.H. Chen has discussed the development of the ideas which are the cornerstone of social and economic ABM [18]. In Russia the agent-based approach was developed firstly in the Central Economic and Mathematical Institute (CEMI) of RAS. Now the group of scientists headed by V.L. Makarov, the academician of RAS, [20, 22] and A.R. Bakhtizin, the corresponding member of RAS, [1] is the leader in this research area. The Institute of economy and organization of industrial production of the Siberian branch of RAS under the V.I. Suslov's guidance (the corresponding member of RAS) is developing the agent-based interindustry multiregional model (ABIMM), describing Russia multiregional economic space in combination with the outer world [25].

The general methodical approach to the identification of structural parameters, applied in the agent-based models (as well as in closely related to the computable general equilibrium model), is based on the so-called "calibration" of the model equations when actually owing to insufficiency of statistical data a number of model structural parameters is appointed expertly, i.e. the assessment of such parameters is subjective. That can lead to the decrease in validity of results of difficult social and economic systems simulation.

Also the necessity of using supercomputers by researchers – using expensive equipment and special software (mainly foreign) is the factor influenced the limiting broad application of ABM in Russia. The hybrid economic and mathematical models based on the rather inexpensive Russian information technologies can be used as an alternative to the ABM within limited financial resources. The multimodel or hybrid model is one model, but having a set of independent algorithms opposed monomodel.

In general, we should lawful to speak to two types of models having application in the macroeconomic analysis. First, it is the balance models describing the processes of formation and use of different types of natural or relative natural production resources as well as input-output balances by value. Secondly, they are factor models describing interrelations [11]: 1) economic rates and growth factors (production functions); 2) scales of consuming benefits (and services) of different types and income level of separate population groups (functions of consumer demand); 3) scales and factors of formation of foreign trade turnover indicators; 4) indicators of economic and material and financial structures of national economy, etc.

Considering the relevance of the problem of new country industrialization noted by the number of the Russian economists [2, 16] the cross-light of applying production functions (mainly Cobb-Douglas) in scientific literature and their various modifications for assessment of production

capabilities of the national economy of the country and its regions in general, and their sectors and branches as well. In this regard we will briefly describe some of such works.

In D.A. Gaynanov's research the modified Cobb-Douglas function is applied to estimate production capabilities of RF territorial entities (gross regional product (GRP) based on current prices). Besides traditional factors as: the labour (average annual number occupied in region economy) and the capital (average annual depreciate cost of the region basic funds) this function includes such indicators as expenses for technological innovations and the average monthly nominal wage of employees in the organizations of the region [5]. The last two indicators are characterized the innovative development and the living standard of the working population of the state territorial entities. As a result, based on the data for 2010-2014 the stability of model has been proved. However, this period of national economy was rather sustainable. According to scientific and expert community of the country the influence of sanctions pressure upon the Russian economy has been evident only since 2015. Therefore, we cannot draw the conclusion on supplying of requisite accuracy of the model constructed on the basis of retrospective data over 2010-2014.

CEMI of RAS developed the Computable General Equilibrium model (CGE model) of knowledge economy where arity of production function includes costs of sectors on innovative production, training employees and results of research and development (R&D). Production capabilities of manufacturing agents in CGE models are set by means of the modified Cobb-Douglas production functions, where basic funds, labour and intermediate consumption, as a rule, act as arguments [21].

Studying V.L. Makarov's research the models (modification of Cobb-Douglas production function) were constructed both considering the efficiency factors based on retrospective data for 2009-2011 and without [23]. At the same time the necessary accuracy of basic data approximation was reached due to modeling for the short-term period (one year). But it does not allow to use the received models for forecasting production capabilities of economy of the region.

In the work of G.B. Kleyner, the corresponding member of RAS, the dynamic multimodel describing a reproduction cycle of the enterprise [8] is considered. As a part of this model, along with production function, three "consumer" functions are applied (expenses, resources growth and abilities). At the same time production function reflects the dependence between enterprise income, resource level and abilities level.

All abovementioned studies at assessment of production capabilities of the national economy of the country, its sectors and branches as well as regions and economic entities calculate the productive indicator expressed in value terms, at the same time, parameters of the modified Cobb-Douglas production function remain invariable throughout all retrospective period.

N.V. Suvorov [11-14] suggests the alternative method of linear regression (AMLR). The approach is essentially different from other known ways of constructing the modified

Cobb-Douglas production function. N.V. Suvorov aptly notes that high stability formal indicators of the structural parameters average estimates do not exclude the existence of clearly defined tendencies of their values change in dynamics [13]. Therefore, according to such method, the parameters in production function are changed in time (annually), i.e. they are dynamic. Moreover, along with traditional factors the labour and the capital are included in the model as well as the indicator the "technical progress", which reflects the technological change happening both in the national economy in general, and its certain sectors and branches (including subsectors). We should also point out that indicators in the models are not absolute (monetary and natural), but relative (growth rate). All aforesaid allows to provide high precision of approximation of basic retrospective data by means of AMLR. Therefore, we can apply predictive function on the basis of preliminary identification of a tendency of parameters change of production function in dynamics. The method was successfully approved (various specifications of the modified Cobb-Douglas production function with dynamic parameters were applied) on data of official statistics of the USSR and Russia either for the national economy in general, or for its certain sectors and branches for rather long period of time

Now under the conditions of the hostile external environment of the Russian enterprises functioning also there is a relevant question of optimum distributing limited financial resources of the public investor as an effective form of supporting domestic manufacturers. As a rule, such problem is usually solved with the help of the R. Bellman's method of dynamic programming. For example, F.N. Garipov reflects in his study the problem definition using agro-industrial complex of the country [7].

Thus, the results of the review of the studies are devoted to the application of the hybrid economic and mathematical models simulating behavior of difficult social and economic systems, which are usually performed by means of modern information technologies. They can form a basis for development of information and methodical foundation of the macroeconomic analysis on the example of structural and investment policy of the Russian Federation and its territorial entities.

Further on the example of the Republic of Bashkortostan (RB) we will approve the application of multimodel as the effective instrument for making management decisions in the investment and industrial sphere of the region. Such model is implemented in two stages: at first the production capabilities of branches of an industrial complex in the Russian Federation territorial entity are estimated, and then limited financial resources of the public investor are distributed between them.

III. SUPPORTING INVESTMENT AND INDUSTRIAL POLICY EFFICIENCY IN THE RB ON THE BASES OF HYBRID MODEL APPLICATION

The first stage. Assessment of production capabilities of industrial complex branches in the RB.

The model of production capabilities of branches of the country subdivision region (P_j) of an additive type includes

determined (Y_j) and random (ε_j) components. The deterministic model component in a canonical form is described by the equation multiple nonlinear regression (a multiplicative and degree type):

$$Y_j = A_0 \cdot \prod_{i=1}^n X_i^{A_i} \quad (1)$$

where Y_j – a dependent variable (result of production activity of j of the branch of an industrial complex of the country subdivision region); A_0 – the absolute term of the regression equation; X_i – the independent (explicative) variables (production factors); A_i – regression equation parameters; n – quantity of factors.

The selected model assumes preliminary linearization (by calculating natural logarithm) and its deterministic component, i.e. transformation from view (1) into (2):

$$\ln Y_j = A'_0 + \sum_{i=1}^n A_i \cdot \ln(X_i) \quad (2)$$

In our case the deterministic component is a classical Cobb-Douglas production function. The volume of the own production shipped goods, performed works and rendered services (mln. rbl.) are used as the indicator characterizing the result of production activity of branches of the RB industrial complex. According to the classical Cobb-Douglas production function [4] the traditional production factors are: the labour (compensation of employees) (X_1) (mln. rbl.) and the capital (gross book value of basic funds) (X_2) (mln. rbl.). Both factors, as well as a productive indicator, are expressed in the current prices.

Initial information for an empirical research was taken from the data of regional statistics of the certain territorial entity of the Russian Federation – the Republic of Bashkortostan (RB) for the period from 2006 to 2016. Based on the calculation and the analysis of the resource productivity (the indicator is defined as volume of the own production shipped goods, performed works and rendered services – combined value of employees compensation and gross book value) the constructibility of one general production function for a number of branches of an industrial complex of the country subdivision region is established.

Considering a significant variation of the indicator as in a branch, and temporary section we can draw a conclusion on inexpediency of constructing one general function for a number of branches in industrial complex of the Republic of Bashkortostan. However, we have revealed the possibility of constructing particular (separate) Cobb-Douglas production functions for certain branches (food production, including drinks; tobacco; production of rubber and plastic products; metallurgical production and production of ready-made metal products; production of machinery and equipment; production of electric equipment, electronic and optical equipment and also production of vehicles and equipment) of industrial complex of the republic.

The results of calculating parameters of the models linear deterministic component for six above-mentioned branches of

the industrial complex in the Republic of Bashkortostan are presented in the table 1.

TABLE I. SPECIFICATION OF PRODUCTION CAPABILITIES MODELS OF SIX BRANCHES OF THE INDUSTRIAL COMPLEX IN RB

Parameter	Model		
	First/second	Third/ fourth	Fifth/sixth
A0'(const)	-0,178/3,403	0,496/-0,888	-2,089/1,931
A1(lnX1)	0,727/0,069	1,028/0,825	1,096/0,272
A2(lnX2)	0,502/0,694	0,150/0,465	0,301/0,665

TABLE II. RESULTS OF MODEL ASSESSMENT ON ADEQUACY AND ACCURACY

Procedure	Model		
	First/second	Third/ fourth	Fifth/sixth
Testing the equation of regression for value (acc. To the Fisher – Snedecor distribution test):			
Calculated value index (F_{calcul})	60,49/ 69,72	76,21/77,52	95,34/ 133,83
Tabulated value symbol (F_{tabul})	4,46		
Test results	F _{расч} >F _{табл}		
Interpretation of test results	equation of regression is		
Assessment of equation of regression quality (based on coefficient determination):			
Calculated index (R^2_{calcul})	0,938/ 0,946	0,950/0,951	0,960/ 0,971
Standard index (R^2_{stand})	0,9		
Testing results	R ² _{расч} >R ² _{норм}		
Interpretation of assessment results	Model allows to make accurate assessment		
Quality assessment the equation of regression (based on the calculation of the corrected coefficient determination):			
Calculated index ($R^{2\text{ck}}_{\text{calcul}}$)	0,922/ 0,932	0,938/0,939	0,950/ 0,964
Standard index ($R^{2\text{ck}}_{\text{stand}}$)	0,9		
Testing results	R ^{2ck} _{расч} >R ^{2ck} _{норм}		
Interpretation of assessment results	Model allows to make accurate assessment		
Testing the quality of selection of the theoretical equation of regression (based on the calculation of the average approximation error):			
Calculated index (E_{calcul})	0,6/0,9	0,6/0,6	0,6/0,5
Standard index (E_{standard})	5-8%		
Test results	E _{расч} >E _{норм}		
Interpretation of test results	Model allows to make accurate assessment		

To assess the adequacy and the accuracy of the models, estimating manufacturing capabilities of six branches of the industrial complex of the republic production capabilities, we have applied a number of procedures (see table 2).

The results of the correlate regression analysis (CRA) indicate the adequacy and sufficiently high accuracy degree of all models. That allows to apply them for practical purposes – firstly, to form information on the possible volume gain of shipped goods of own production, performed works and rendered services in case of additional investment to the basic capital and on compensation of employees of the enterprises functioning in various branches of the republic industrial complex.

Thus, the problem of optimum distribution of the state investment resources is solved further by the method of dynamic programming using six branches of the RB industrial complex as an example.

The second stage. Optimum distribution of financial resources of the public investor among branches of the RB industrial complex.

The computing procedure of the dynamic programming method on the basis of Bellman's principle of optimality (and the cognominal recurrence relations) besides the primary source [15] is widely covered in modern scientific literature. In particular, the same problem definition is presented in F.N. Garipov's work [7]. However, in our case distributing additional investment resources needs to be made for branches of the republic industrial complex, but not agrarian sector of the Russian economy. Let us assume that in 2016 for the purpose of state support of the industry of the RB 900 million rubles were additionally allocated. To simplify calculations we are limited to search of optimum distribution of the state investment resources between six branches of the region industrial complex. At the same time each brunch had got 0, 180, 360, 540, 720 or 900 million rubles, and of these 0/0, 130/50, 260/100, 390/150, 520/200 or 650/250 million rubles, respectively, to increase the salary level of employees and investments into basic capital.

The possible increase in volume of own production shipped goods, performed works and rendered services for each of six branches of the RB industrial complex depending on the amount of additional investments is calculated based on the earlier defined Cobb-Douglas production functions (table 3).

TABLE III. INITIAL INFORMATION FOR SOLVING THE PROBLEM OF OPTIMUM DISTRIBUTING THE STATE INVESTMENT RESOURCES AMONG BRANCHES OF THE INDUSTRIES IN THE REPUBLIC OF BASHKORTOSTAN

The volume of the allocated funds x (mln. rbl.)	Annual increase in volume of shipped goods of own production, performed works and rendered services depending on the volume of the allocated funds (mln. rbl.),		
	$f_1(x)/f_2(x)$	$f_3(x)/f_4(x)$	$f_5(x)/f_6(x)$
0	0/0	0/0	0/0
180	1167/211	1163/812	659/307
360	2332/418	2329/1626	1322/614
540	3492/622	3496/2440	1988/919
720	4650/823	4666/3255	2658/1224
900	5805/1021	5838/4071	3331/1527

In our case the distribution of investment resources providing the greatest (maximum) annual increase in volume of own production shipped goods, performed works and rendered services is considered as optimum.

Such problem is solved in two stages.

The first stage. Constrained optimization.

The maximum annual increase in volume of the shipped goods of own production, the performed works and the rendered services of the first of six branches of the republican industrial complex $F_1(x)$ in case of allocating x million rubles by the formula (3) equivalent of (4):

$$F_1(x) = \max_{0 \leq x_1 \leq x} \{f_1(x_1)\} \tag{3}$$

$$F_1(x) = f_1(x), 0 \leq x \leq 900 \tag{4}$$

Values of the function $F_1(x)$ and conditionally optimal values of volume of the funds allocated this branch x_{1opt} are presented in the table 4.

TABLE IV. CONDITIONALLY OPTIMAL VOLUME OF INVESTMENT INTO THE FIRST FROM SIX BRANCHES OF THE INDUSTRIAL COMPLEX IN RB

x	$F_1(x)$	x_{1opt}
0	0	0
180	1167	180
360	2332	360
540	3492	540
720	4650	720
900	5805	900

Further consistently the cumulative annual increase in volume of shipped goods of own production, performed works and rendered services of the first two, three, ... and all six branches of the industrial complex of the republic which have entered selection under condition of allocating x million rubles

is determined by the formula (5) which is equivalent of (6) and (7) respectively:

$$F_k(x) = \max_{0 \leq x_k \leq x} \{f_k(x_k) + F_{k-1}(x - x_k)\}, k = \overline{2, N} \quad (5)$$

$$F_2(x) = \max_{0 \leq x_2 \leq x} \{f_2(x_2) + F_1(x - x_2)\}, 0 \leq x \leq 900 \quad (6)$$

...

$$F_6(x) = \max_{0 \leq x_6 \leq x} \{f_6(x_6) + F_5(x - x_6)\}, 0 \leq x \leq 900 \quad (7)$$

Function values $F_2(x) - F_6(x)$, and conditionally optimal value of volume of investment allocated to the second-sixth branches of the republican complex $x_{2opt} - x_{6opt}$ are presented in the table 5.

TABLE V. CONDITIONALLY OPTIMAL VOLUME OF INVESTMENT INTO THE SECOND-SIXTH BRANCHES OF THE INDUSTRIAL COMPLEX IN RB

x	x ₂			F ₂ (x)	x _{2opt}
	0/180	360/540	720/900		
180	1167/211	-/-	-/-	1167	
360	2332/1379	418/-	-/-	2332	0
540	3492/2543	1586/622	-/-	3492	0
720	4650/3704	2750/1790	823/-	4650	0
900	5805/4861	3911/2954	1991/1021	5805	0
x	x ₃			F ₃ (x)	x _{3opt}
	0/180	360/540	720/900		
180	1167/1163	-/-	-/-	1167	0
360	2332/2330	2329/-	-/-	2332	0
540	3492/3495	3496/3496	-/-	3496	360, 540
720	4650/4655	4661/4663	4666/-	4666	720
900	5805/5813	5821/5828	5833/5838	5838	900
x	x ₄			F ₄ (x)	x _{4opt}
	0/180	360/540	720/900		
180	1167/812	-/-	-/-	1167	0
360	2332/1979	1626/-	-/-	2332	0
540	3496/3144	2793/2440	-/-	3496	0
720	4666/4308	3958/3607	3255/-	4666	0
900	5838/5478	5122/4772	4422/4071	5838	0
x	x ₅			F ₅ (x)	x _{5opt}
	0/180	360/540	720/900		
180	1167/659	-/-	-/-	1167	0
360	2332/1826	1322/-	-/-	2332	0
540	3496/2991	2489/1988	-/-	3496	0
720	4666/4155	3654/3155	2658/-	4666	0
900	5838/5325	4818/4320	3825/3331	5838	0
x	x ₆			F ₆ (x)	x _{6opt}
	0/180	360/540	720/900		
900	5838/4973	4110/3251	2391/1527	5838	0

Thus, the maximum cumulative annual gain of the shipped goods volume of own production of all six branches of the

republican industrial complex entering the selection of the additional 900 million rubles provided allocation will make 5838 million rubles. At the same time, it should be noted that last branch from the selection assignment is economically inexpedient.

The second stage. Unconstrained optimization.

The optimal plan of distributing additional investment resources between other five branches of the republican industrial complex included in selection is defined. From the perspective of the abovementioned intermediate calculations presented in the table 6, all additional funds should be allocated by the public investor to the third branch only. In this case the greatest of possible volume of shipped own production goods, of performed works and rendered services in six branches of the republic industrial complex will be provided. Thus, 900 million rubles are allocated by the public investor for metallurgical production and production of finished metal products, including 250 million rubles for investments into the basic capital; other funds are to higher employee's salary level. It leads to the growth of volume of shipped goods by own resources, the performed works and the rendered services on 5838 million rubles or 10,7% of the indicator value achieved in 2016.

IV. CONCLUSION

The analysis of thematic scientific literature allows to draw a firm conclusion on the necessity of increasing the efficiency of investment and industrial policy of Russia and its territorial entities. Taking into account the opinion of experts we concluded that such increase is possible by developing the effective mechanism of controlling the activity of an industrial complex, including state support (allocation of additional investments to its various branches). In its turn, it demands practical application of results of the case cross-disciplinary studies relying on the system approach and active use of economic and mathematical multimodels.

In this research to ensure the efficiency of investment and industrial policy of Bashkortostan we have developed the hybrid or the multimodel which is based on the application of two economic and mathematical methods: constructing Cobb-Douglas production function and dynamic programming. Based on the analysis of resource intensity of all segments and branches of the republican industrial complex from 2006 to 2016 we have put forward the hypothesis about the possibility of constructing one general production function for a number of branches, but according to the empirical research we have disapproved it. At the same time, we revealed the possibility of constructing particular (separate) Cobb-Douglas production function for several (six) branches of the industrial complex in Bashkortostan. Providing the additional investment into the number of branches of the republican industrial complex, varying the values of two factors in our case, the labour (compensation of employees) and the capital (gross book value of capital fund) we assessed their production capabilities. Using the method of dynamic programming we could form the optimum plan of distributing financial resources of the public investor among branches of the industrial complex in RB (providing the greatest of possible

volume gain of the shipped goods of own production, the performed works and rendered services).

Thus, the economic and mathematical multimodel will allow the profile ministry of the republic to make effective decisions on distributing limited financial resources of the public investor between various branches of the industrial complex in Bashkortostan. The approach described in the research is universal, i.e. it can be applied for updating provisions of structural and investment policy of any territorial entity of the Russian Federation.

Acknowledgment

This study was financially supported by the grant of the Russian Foundation for Basic Research (RFBR) No. 18-410-020003 "Enhancement of the investment and industrial policy efficiency in regions of Russia (the case of the Republic of Bashkortostan)".

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