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GAME THEORY MODEL OF STATE INVESTMENT INTO TERRITORIES OF ADVANCED DEVELOPMENT IN THE REGIONS OF MINERAL RESOURCES SPECIALIZATION

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Historically developed and non-compliant with modern conditions, the structure of industry placement and related inequality in economic development of certain territories are additional negative factors that hinder economic development of the country. Hence, the search for new organizational forms and methods of territorial development, facilitation of industrial growth in regions with mineral resources specialization become more and more relevant. Another no less important issue is justification of economic feasibility of using such tools and assessment of critical consequences of their application. Suggested by the authors, game theory model of state investment into territories of advanced development describes the method of limited resources distribution and becomes an instrument to assess the feasibility of investment into creation of advanced development territories under the conditions of insufficient information and actions of specific interest groups. Application of the suggested game theory model of state investment into creation of advanced development territories allows to forecast behavior of program participants, to model consequences of management decisions both for government structures and separate program participants.

Key words: territories of advanced development, investment, regions of mineral resources specialization, interest groups, game theory model, stakeholders

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Introduction. Current situation in Russia is characterized by low rates of economic growth, which is especially visible compared to early and mid 2000s, when the rates of GDP growth in Russia reached 8.2 % in 2006 and 8.5 % in 2007, whereas in the last years they hit bottom ground with their negative values of –2.8 % in 2015 and –0.2 % in 2016, and in 2017 amounted to 1.5 %.* The situation only gets worse due to existing limitations on external sources of growth, primarily caused by international sanctions. One more negative factor is a flawed structure and industry placement, related inequality in economic development of certain territories and disproportionate contribution of different Russian regions into GDP. According to statistical data on absolute gross regional product (GRP), in 2016 the leader among subjects of Russian Federation was Moscow – 14 299 billion rubles, then by a significant margin Moscow Oblast – 3 565 billion rubles and Saint-Petersburg – 3 742 billion rubles* However, GRP per capita looks different: regions with mineral resources specialization clearly play the leading role. The first on the list is Yamalo-Nenets Autonomous Okrug (YNAO) – 3 670 257 rub per person, the second is Khanty-Mansi Autonomous Okrug Yugra – 1 852 318 rub per person, Sakhalin Oblast – 1 575 642 rub per person, Chukotka Autonomous Okrug – 1 323 201 rub per person.* Despite the fact that the key contribution into high results of leading regions is made by mineral resources extraction (Khanty-Mansi Autonomous Okrug – 66.1 %, YNAO – 54.5 %, Sakhalin Oblast – 54.0 %, and 50.1 % in Chukotka Autonomous Okrug), the share of processing industries is very modest: 2.0; 1.8; 2.8 and 0,4 % respectively.* It should be noted that the main source of GRP in the mentioned cases is extraction and transportation of raw materials, whereas equipment and technical resources of Russian industrial plants lag behind compared to similar facilities in other countries. E.g., refinery yield in Russia amounts to 71 % (67 % in 1990), whereas in China it reaches 85 %, in European countries 92 % and in the USA 95 %. The average Nelson complexity index (NCI) for Russian plants is only 4.5 compared to the world average of 6.7 and 9.5 in the US [24]. Specific weight of innovative products (services) in the

* Federal State Statistics Service. Official website [Electronic source]. URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/accounts/# (access date 30.08.2018).

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total amount of production for oil processing industry in 2010 was only 3.9 %. According to the government report «On the state and use of mineral resources of Russian Federation in 2015»*, the share of processed natural gas is also quite small and has very low growth rates: in 2015 only 45 % (i.e. less than half) of extracted «wet» gas. In 2015 manganese ore extraction in Russia amounted to only 9 thousand tons and no processing was done, extraction and processing of silicate ores have also been practically stopped. The limiting factor is the absence of cost-effective technologies, the need for large investments into construction of processing facilities and investors' doubts regarding the demand for such products on the internal market. It should be emphasized that the share of innovative products in the total amount of dispatched goods and rendered services was 7.9 % in 2015, compared to 8.9 % in 2013**.

Hence, all the above mentioned factors dictate the necessity to create mechanisms of sustainable industrial development in the regions with mineral resources specialization by means of deeper processing and the search for internal reserves by using internal sources of development. This is why the search for new organizational forms and methods of territorial development to intensify industrial growth of regions with mineral resources specialization is a critically important task. At the same time, this objective puts forward one of the most challenging economic problems.

Territories of advanced (socio-economic) development (TAD) as a new type of territorial entities in Russian Federation were created under the Federal law from 29 December 2014 No. 473-FZ «On the territories of advanced socio-economic development in the Russian Federation». Together with the zones of territorial development and special economic zones, TADs attract special attention as a key mechanism facilitating economic growth in the system of public administration in the regions of mineral resources specialization. Each of the mentioned forms has its advantages, disadvantages and main development objectives. So, for special economic zones (SEZ), the objective is development of processing and high technology industries, tourism, health and resort facilities, port and transport infrastructure, technological development. Being conductive to industrial growth, SEZs have some impact on socio-economic development of the region [10], but never consider it their main goal. In this respect they are different from zones of territorial development (ZTDs), which imply complex acceleration of socio-economic development [11]. Meanwhile, the problems of complex socio-economic development of the regions with mineral resources specialization are a hot topic both for scientific and business communities [20, 21, 23, 28].

Being an acceleration source of international turnover of commodities, investment raising, technology and information exchange, SEZs are usually created in economically underdeveloped regions; their selection criteria can include unemployment rates and average income per capita [22]. Generalized analysis of the global practice of SEZ creation and operation reveals their controversial impact on regional development [26]. An important factor, enabling the implementation of long-term programs of complex socio-economic development of Russian regions, is a balanced partnership of public and private sectors with the state, serving as a key regulator of functioning for special territories [7].

Critical assessment of different methods to calculate the efficiency of Russian special zones of all types has revealed that the greatest drawback is the absence of indicators [8]:

* Government report «On the state and use of mineral resources of Russian Federation in 2015 [Electronic source]. URL: http://www.mnr.gov.ru/regulatory/list.php?part=1257 (access date 30.08.2018).

** Release of Innovative Products by Industrial Plants. Higher School of Economics. Institute for Statistical Studies and Economics of Knowledge. Iss. 25.01.2017. URL: http://www.issek.hse.ru/data/2017/01/25/1113618301/ NTI_N_37_25012017.pdf].

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• demonstrating consequences for direct participants (residents) of special economic zones;

• showing the impact on regional economy (total macroeconomic effect from creation and functioning of special economic zones).

The reasons of low investment attractiveness of Russian SEZs have been highlighted on numerous occasions [2, 18], suggested improvements included:

• changes in the management structure and delegation of certain functions to the regional level;

• changes in financing structure to activate the mechanisms of public-private partnership.

A new instrument of innovative development for separate regions and national economy as a whole is the creation of territories of advanced development. TADs cannot be formed inside special economic zones or zones of territorial development, nor can they include any. Unlike SEZ or ZTD, TAD is created for a specific investor.

According to Federal Law N 473-FZ «On the territories of advanced socio-economic development in the Russian Federation», TAD can be created for a period up to 70 years with an opportunity to prolong the term by a decree of Russian Government. In addition, there is a fixed list of economic activities that have a special legal status and a minimal amount of investment for TAD residents, as well as minimal requirements to the level of applied technologies, production methods and equipment, if needed. An agreement signed between competent public authority and a municipal entity, where TAD is formed, defines:

• liabilities of the parties regarding transfer of authority in administration and disposal of public or municipal property, funding (including sources) of construction, reconstruction and exploitation of infrastructure facilities;

• property rights on the constructed facilities after TAD ceases to exist.

A managing entity in the form of public joint stock company is created for the administration of advanced development territory, 100% of its capital belongs to the state. The company has the widest possible range of competences: territory development, infrastructure maintenance, provision of services including accounting, legal and customs services, technical connection to common user networks etc. Inefficiency of special economic zones is often pointed out, and SEZs are compared to TADs with their separate concept of socio-economic development supported by infrastructure projects, which allows to justify feasibility of their use under current conditions in Russia [9, 25].

It is economically feasible to align TAD formation with the specifics of investment projects, which will allow [1] to assess the efficiency of separate territory development projects and to carry out targeted development programs. The authors of [6] analyze an innovative scenario of regional development in case of TAD creation and note that growth areas should be created in order to enhance the differences and to polarize economic space, not to even it out. Therefore it is crucial to pay attention to payoff and loss allocation among key stakeholders of the territories. Moreover, creation of TADs has an influence on all aspects of life in the region, and in case of positive feedback from external stakeholders, including the state, it can increase social activity of companies in the region [29].

Literature review demonstrated that main focus areas of scientific studies are associated with separate aspects of TAD existence, e.g., issues of housing construction [16], formation of a managing system meeting new requirements [13], activation of entrepreneurship in separate industries [3]. A lot of studies are dedicated to the growth of small and medium business associated with TAD creation [5, 12].

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Despite this clear scientific interest to the problem, very few publications address justification of TAD investment costs, or assess the payoffs of separate stakeholders (including the state). There is research [17], which offers to attract anchor residents with a share of investment 5 % and more by means of creating favorable conditions for their economic activities. Authors associate creation of such conditions with infrastructure development financed from federal budget. However, the efficiency of such investments is not assessed. Publication [14] presents results of enterprise reorganization by means of creating financial accounting centers, defines the terms of reducing TAD company's loss ratio, suggests how to calculate a bonus of financial accounting centers depending on business profitability. Paper [19] offers a methodology to assess periodicity of financial risks using analysis of econometric multiregression models for TADs. The method allows to assess financial risks and financial stability of companies both on TAD and regional levels. Study [27] presents a game theory model which determines investors' behavior. Comparative results for three and more investors are demonstrated.

Nevertheless, despite a clearly visible interest in this problem, the feasibility of investment expenses on TAD creation, as well as assessment of separate stakeholder payoffs (including the state) have not been examined properly, which determines the timely character of current research.

Problem statement. As already stated above, efficient functioning of TADs is only possible in case of justified intervention of the state into spontaneous economic processes, which leads to redistribution of resources and stakeholders' opportunities and finally to redistribution of income among separate groups of economic agents. As TADs are created for individual investors whose interests can be interrelated, there is a big chance of lobby groups formation. Therefore, the aim of this research is a distribution method for limited resources and rationality assessment of TAD subsidies under conditions of insufficient information and operation of different interest groups. The main objective is to assess consequences and to justify redistribution criteria.

As demonstrated in [4], TAD creation is viable, when the following criteria are met:

• stimulation of economic growth instead of overcoming territory depression;

• existence of projects that increase depth and complexity of raw materials processing and generate significant added value;

• projects should have an export component in the mid-term;

• projects should meet the criteria for efficiency and practicability;

• close cooperation between federal and local authorities.

Let us formulate the problem as follows. The government shall decide whether to subsidize TAD in the region ($\overline{S} = S > 0$) or not ($\overline{S} = 0$), where $\overline{S}$ – decision made by the state, i.e. $\overline{S} \in \{0, S\}$. With a probability $\alpha > 1/2$ there is no need in such allocation of funds. Let us define a variable reflecting the situation in the region as $\widetilde{S}$. If TAD in the region does not need subsidizing, $\widetilde{S} = 0$, otherwise $\widetilde{S} = S > 0$.

Let us identify the symbols used in the model:

• $\widetilde{S}$ – actual amount of required subsidy on TAD creation;

• $\overline{S}$ – amount of TAD subsidy allocated by the state;

• α – probability that there is no need to allocate the subsidy;

• $\overline{L}$ – funds spent on lobby work to obtain a state subsidy;

• C_1 – state expenses on region examination, in case it takes place after the lobby;

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• C_2 – state expenses on region examination, in case there is no lobby;

• $\pi_L = X\overline{S} - L$ – payoff (profit) of special interest groups (lobby), where X – size of special interest group;

• $\pi_P = -(\overline{S} - \widetilde{S})^2 - C$ – payoff (profit) of the state;

• θ_0 – probability that the interest group chooses to spend $\overline{L} = L$ on the lobby, if $\widetilde{S} = 0$;

• θ_S – probability that the interest group chooses to spend $\overline{L} = L$ on the lobby, if $\widetilde{S} = S > 0$;

• γ – probability that the government examines TAD after the lobby (the group of interest chooses $\overline{L} = L$);

• δ – probability that the government examines TAD without the lobby (the group of interest chooses $\overline{L} = 0$);

• $\beta(L)$ – the probability that the state allocates a subsidy $\overline{S} = S > 0$, without checking the lobby $\overline{L} = L$;

• $\beta(0)$ – the probability that the state allocates a subsidy $\overline{S} = S > 0$, without checking the absence of lobby $\overline{L} = 0$;

• P_L – posterior state estimation that the subsidy is not allocated $\widetilde{S} = 0$ after the lobby signal $\overline{L} = L$;

• P_0 – posterior state estimation that the subsidy is not allocated $\widetilde{S} = 0$ after the signal of lobby absence $\overline{L} = 0$.

Hereafter for better visual representation the authors will either repeat this legend or, when necessary, introduce new designations.

An interest group (potential investors, regional and municipal authorities etc.) in any case has a concern in the positive decision of the state.

Full information whether the subsidy is actually needed is only known to the interest group, the state relies on the α value. The game procedure is the following [15]:

1. Primarily, on a random basis it is decided whether the subsidy $\widetilde{S}$ is needed or not. The interest group sees the move.

2. The interest group can choose to lobby $\overline{L} = L > 0$ or not to lobby the subsidy $\overline{L} = 0$, i.e. $\overline{L} \in \{0, L\}$. The state sees the move.

3. The state can examine the region. In case of positive decision, examination costs are $C_1 > 0$ if it happens after the lobby, and $C_2 > C_1$, if there is no lobby. I.e. $C \in \{0, C_1\}$ after the lobby and $C \in \{0, C_2\}$, if $\overline{L} = 0$.

4. The state decides whether to subsidize TAD creation or not.

5. Players' payoffs are distributed in the following way:

• the special interest group receives $\pi_L = X\overline{S} - L$, where X – size of the special interest group;

• the state receives $\pi_P = -(\overline{S} - \widetilde{S})^2 - C$, considering that $XS > L$.

Methodology. Let us introduce additional designations. We will specify $\theta_0(\theta_S)$ as a probability with which the special interest group chooses $\overline{L} = L$, if $\widetilde{S} = 0$ ($\widetilde{S} = S > 0$); γ is the probability that the state chooses to examine the region after the interest group has chosen $\overline{L} = L$, and δ is the probability that the state chooses to examine the region in case there is no signal, i.e. after $\overline{L} = 0$.

The probability that the state chooses $\overline{S} = S > 0$, without checking the signal $\overline{L} = L$, is denoted as $\beta(L)$, the probability that the state chooses $\overline{S} = S > 0$, without checking the signal $\overline{L} = 0$, is denoted as $\beta(0)$.

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Posterior state estimation that $\widetilde{S}=0$, after the signal $\overline{L}=L$ has been received, is referred to as P_L, posterior state estimation that $\widetilde{S}=0$, after the signal $\overline{L}=0$ has been received, is, respectively, P_0. Bayes rule can be formulated as follows:

$$P_L=\Pr(\widetilde{S}=0|\overline{L}=L)=\frac{\Pr(\overline{L}=L|\widetilde{S}=0)\Pr(\widetilde{S}=0)}{\Pr(\overline{L}=L|\widetilde{S}=0)\Pr(\widetilde{S}=0)+\Pr(\overline{L}=L|\widetilde{S}=S)\Pr(\widetilde{S}=S)};$$

$$P_0=\Pr(\widetilde{S}=0|\overline{L}=0)=\frac{\Pr(\overline{L}=0|\widetilde{S}=0)\Pr(\widetilde{S}=0)}{\Pr(\overline{L}=0|\widetilde{S}=0)\Pr(\widetilde{S}=0)+\Pr(\overline{L}=0|\widetilde{S}=S)\Pr(\widetilde{S}=S)}.$$

Plugging the above mentioned values, we obtain:

$$P_L=\frac{\alpha\theta_0}{\alpha\theta_0+(1-\alpha)\theta_S} \text{ and } P_0=\frac{\alpha(1-\theta_0)}{\alpha(1-\theta_0)+(1-\alpha)(1-\theta_S)}.$$

Game analysis starts from terminal nodes. The last move is made by the state. Let us consider a situation when the state makes a decision after the interest group has chosen $\overline{L}=L$. If it chooses examination $\overline{L}=L$, its payoff is $[-C_1]$. If it does not examine and chooses $\overline{S}=0$, its payoff is $[-(1-P_L)S^2]$, in case it does not examine and chooses $\overline{S}=0$, its payoff is $[-P_LS^2]$.

Therefore, if the state does not examine the situation after the signal $\overline{L}=L$, its payoff is $[-S^2\min\{P_L,(1-P_L)\}]$.

If $[-C_1<-S^2\min\{P_L,(1-P_L)\}]$, the state will never examine the situation after it receives the signal $\overline{L}=L$, then $\gamma=0$.

When we analyze the last two options, in the former case we get $\gamma\in[0,1]$, if $[-C_1=-S^2\min\{P_L,(1-P_L)\}]$, in the latter case $\gamma=1$, if $[-C_1>-S^2\min\{P_L,(1-P_L)\}]$.

It should be noted that because $\min\{P_L,(1-P_L)\}\le 1/2$, the probability that the state will choose the examination is $\gamma=0$ if $[-C_1<-1/2\,S^2]$, i.e. if $C_1>1/2\,S^2$.

In a similar way let us analyze the situation when the state makes its decision after the interest group has chosen $\overline{L}=0$:

• the probability that the state is going to examine if the signal is absent $\delta=0$, if $[-C_2<-S^2\min\{P_0,(1-P_0)\}]$;

• $\delta\in(0,1)$, if $[-C_2=-S^2\min\{P_0,(1-P_0)\}]$;

• $\delta=1$, if $[-C_2>-S^2\min\{P_0,(1-P_0)\}]$.

And if $C_2>1/2\,S^2$, then $\delta=0$.

Let us compare state payoffs in the situation, when the interest group chooses $\overline{L}=L$, and the government does not initiate examination. If the government chooses $\overline{S}=S$, than its payoff equals $[-P_LS^2]$, and if $\overline{S}=0$, then the payoff is respectively $[-(1-P_L)S^2]$. If $-P_LS^2<-(1-P_L)S^2$, i.e. $P_L>1/2$, then $\beta(L)=0$. If $P_L<1/2$, then $\beta(L)=1$, and if $P_L=1/2$, then $\beta(L)\in[0,1]$.

In a similar way let us analyze the situation when the interest group chooses $\overline{L}=0$, and the government did not examine situation in the industry:

• the probability that the government allocates a subsidy without examination $\beta(0)=0$, if $P_0>1/2$;

• $\beta(0)\in(0,1)$, if $P_0=1/2$;

• $\beta(0)=1$, if $P_0<1/2$.

Now let us analyze the interest group behavior. If the group chooses $\overline{L}=L$ and if $\widetilde{S}=0$, then the group payoff equals $(1-\gamma)\beta(L)SX-L$, if $\widetilde{S}=S$, then the payoff is $\gamma SX+(1-\gamma)\beta(L)SX-L$.

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Similarly, if the interest group chooses $\overline{L}=0$ and if $\widetilde{S}=0$, then its payoff equals $(1-\delta)\beta(0)SX$, if $\widetilde{S}=S$, then the group wins $\delta SX+(1-\delta)\beta(0)SX$.

At $\theta_0=0$, if $\theta_S>0$, then according to Bayes rule we get $P_L=0$. Then $\min\{P_L,1-P_L\}=0$ and consequently $[-C_1<0]$ and $\gamma=0$. As $P_L=0<1/2$, then $\beta(L)=1$.

In order for the possibility that the interest group chooses $\overline{L}=L$, if $\widetilde{S}=0$, to be zero, as we have assumed (i.e. $\theta_0=0$), it must be true that $(1-\delta)\beta(0)SX\geq SX-L$. In order for $\theta_S>0$ to hold, it should be true that $\delta SX+(1-\delta)\beta(0)SX\leq SX-L$. This inequation fails at $\delta>0$. If $\delta=0$, then $\beta(0)SX=SX-L$, from which $\beta(0)=1-L/SX$. Thus, $\beta(0)\in(0,1)$ and $P_0=1/2$.

On the other hand, if $\theta_0=0<\theta_S$, then according to Bayes rule

$$P_0=\frac{\alpha(1-\theta_0)}{\alpha(1-\theta_0)+(1-\alpha)(1-\theta_S)}=\frac{\alpha}{\alpha+(1-\alpha)(1-\theta_S)}>\frac{\alpha}{\alpha+(1-\alpha)(1-0)}=\alpha.$$

In other words, $P_0>\alpha>1/2$ and the equation $P_0=1/2$ fails. Therefore, the probability that the interest group chooses $\overline{L}=L$, if $\widetilde{S}=0$, should also be zero: $\theta_S=0$. As $\theta_S=\theta_0=0$, then $P_0=\alpha$.

This implies that $\delta=1$, if $C_2<(1-\alpha)S^2$, and that $\delta=0$ and $\beta(0)=0$, если $C_2>(1-\alpha)S^2$. In case $C_2=(1-\alpha)S^2$, then probability δ can assume any value $\delta\in(0,1)$. Having selected probability value off the equilibrium path $P_L=1$, we will obtain $\beta(L)=0$. Then in both cases of $\widetilde{S}=0$ and $\widetilde{S}=S$ the interest group will have no incentive to diverge regardless of δ value.

Thus, three types of equilibrium have been found. Let us denote them as E_1 (at $C_1>1/2S^2$); E_2 (at $C_2=(1-\alpha)S^2$); E_3 (at $C_2<(1-\alpha)S^2$). Equilibrium strategies for E_1: $\theta_0=\theta_S=0$; $\delta=0$, $\beta(0)=0$. Equilibrium strategies for E_2: $\theta_0=\theta_S=0$; $\delta\in(0,1)$, $\beta(0)=0$. Equilibrium strategies for E_3: $\theta_0=\theta_S=0$; $\delta=1$, $\beta(0)=0$.

Now let us assume $\theta_0>0$. As the selection of $\overline{L}=0$ will guarantee at least zero profitability for the interest group, then $\gamma<1$, $\beta(L)>0$, and consequently $P_L\leq 1/2$ and $P_L\leq C_1/S^2$. From the Bayes rule we can derive that $\theta_0<\theta_S$. From the inequality $\theta_0<\theta_S$ follows that $P_0>1/2$, from which $\beta(0)=0$. As $0<\theta_0<1$, then $(1-\gamma)\beta(L)SX-L=0$, in other words $(1-\gamma)\beta(L)=L/SX$. If $0<\theta_0<\theta_S$, then $\gamma\geq\delta$, and $\theta_S<1$ is only true in case $\gamma=\delta$.

Let us assume that in addition to $\theta_0>0$, $\theta_S<1$. Let us consider that $0<\gamma=\delta<1$. In such case $P_0=1-C_2/S^2$ and $P_L=C_1/S^2$ (as $P_0>\alpha$, then $C_2<(1-\alpha)S^2$). According to Bayes rule, the following equations have to be satisfied:

$$\theta_0=\frac{C_1(S^2(1-\alpha)-C_2)}{\alpha S^2(S^2-C_1-C_2)};$$

$$\theta_S=\frac{(S^2-C_1)(S^2(1-\alpha)-C_2)}{(1-\alpha)S^2(S^2-C_1-C_2)}.$$

In order for $0<\theta_0<\theta_S<1$, the following parameter limitations have to be true: $C_1<\alpha S^2$ and $C_2<(1-\alpha)S^2$. From the ratios $C_1\leq C_2$, $\alpha>1/2$ and $C_2<(1-\alpha)S^2$ follows that $C_1<1/2S^2$ and consequently $\beta(L)=1$. Hence, we can conclude that $\gamma=\delta=1-L/SX$. It defines one more type of equilibrium E_4:

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$$\theta_0 = \frac{C_1(S^2(1-\alpha)-C_2)}{\alpha S^2(S^2-C_1-C_2)};\ \theta_S = \frac{(S^2-C_1)(S^2(1-\alpha)-C_2)}{(1-\alpha)S^2(S^2-C_1-C_2)};\ \gamma=\delta=1-L/SX,\ \beta(0)=0,\ \beta(L)=1.$$

Now let us consider that $\theta_S<1$, but, unlike before, $\gamma=\delta=0$. Then $\beta(L)=L/SX$. From $0<\beta(L)<1$ follows that $P_L=1/2$. If $P_L=1/2$, then $\gamma=0$ only if $C_1\geq 1/2S^2$. In such case, as $C_1\leq C_2$, the equality δ=0 is also true.

As $P_L=1/2$, then $\theta_0=(1-\alpha)\theta_S/\alpha$, where θ_S can take on any value from the interval $0<\theta_S<1$. Thus, we come to a new type of equilibrium E_5:

$$\theta_0=(1-\alpha)\theta_S/\alpha;\ 0<\theta_S<1;\ \gamma=\delta=0;\ \beta(0)=0;\ \beta(L)=L/SX.$$

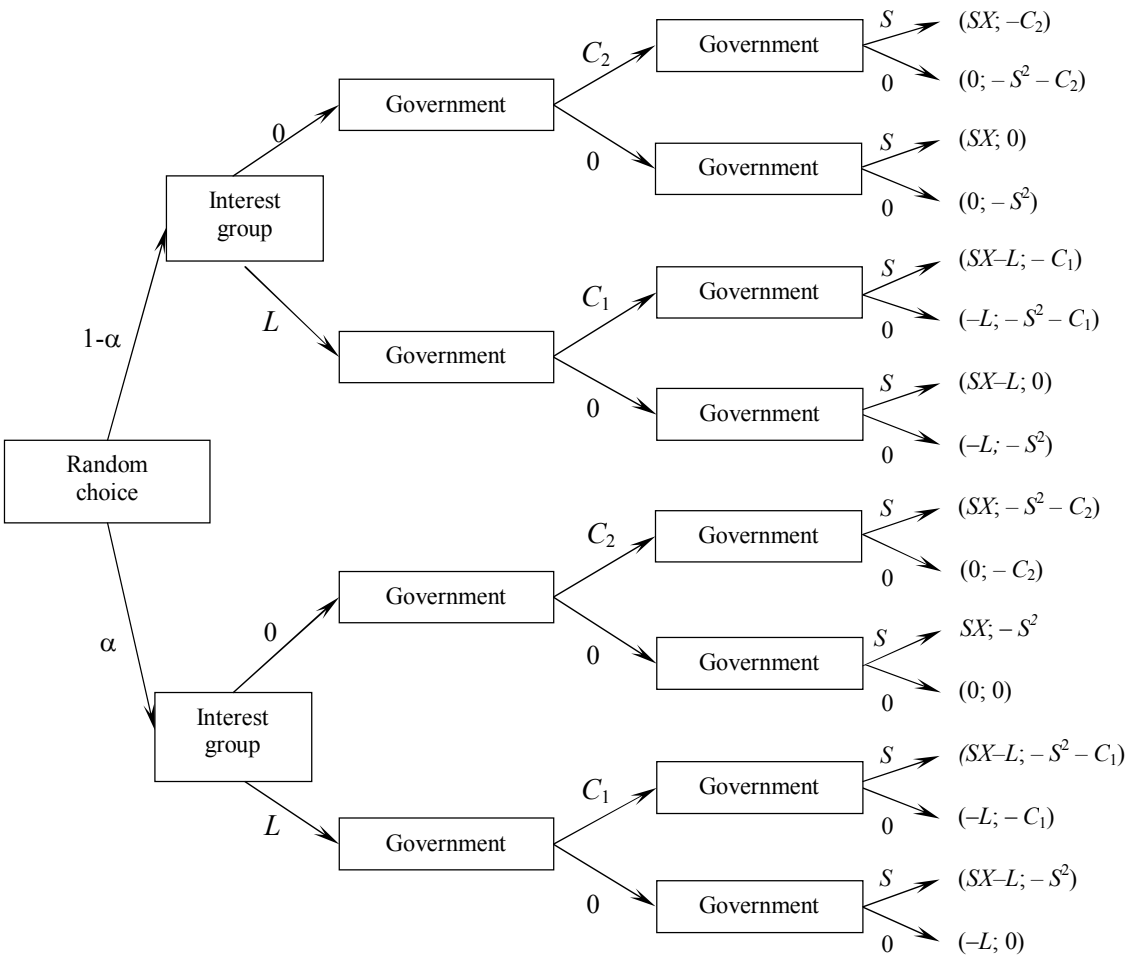
The last case to consider is $0<\theta_0<1$ and $\theta_S=1$. Then $P_0=1$, from which follows that $\delta=\beta(0)=0$ and $(1-\gamma)\beta(L)=L/SX$. Now the equation $0<\gamma<1$ implies that $P_L=C_1/S^2$, whereas $0<\beta(L)<1$ means that $P_L=1/2$. If$C_1<S^2/2$, then $\beta(L)=1$; $P_L=C_1/S^2$ and $\gamma=1-L/SX$.

As $P_L=C_1/S^2$, then $\theta_0=\dfrac{(1-\alpha)C_1}{\alpha(S^2-C_1)}$.

In other words, we have constructed a new type of equilibrium E_6:

$$\theta_0=(1-\alpha)/\alpha,\ 0<\theta_S\leq 1,\ \gamma=\delta=0,\ \beta(0)=0,\ \beta(L)=L/SX.$$

An expanded form of the game with possible outcomes and payoffs is presented in the Figure.



Expanded form of the game theory model

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Discussion: authors' opinion and studies. Testing of the model, suggested by the authors, proved its feasibility and applicability for the task of supporting management decisions on creating territories of advanced development. The model allows to forecast behavior of program participants, to model consequences of management decisions both for government structures and separate program participants. Same as for all other game theory models, insufficiency of data serves as a limiting factor. However, if this insufficiency applies to less than critically important information, then it is feasible to analyze similar (comparable) situations taking into account correcting differences. Nevertheless, the model allows to define important factors that require consideration before making the decision.

Conclusion. Territories of advanced development are an effective tool of industrialization for the regions with mineral resources specialization. They facilitate investment raising due to maintaining the balance of interests between parties involved in the process. The search for this balance and feasibility assessment of TAD creation and state support are complex problems, the best way to solve which is by using mathematical modeling. The game theory model described in this paper can be used to analyze and draw conclusions on the feasibility of TAD development in the Russian Arctic. The model also allows to evaluate the payoff distribution in case of positive decision, which is necessary for understanding and complex assessment of socio-economic consequences of the decision. The model can also be used by the government to evaluate the amounts of funding which can be allocated to reach separate goals. Hence, the suggested model can be of interest for both public and private structures analyzing TAD feasibility.

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