METHODS OF ANALYSIS OF THE PROCESSES OF COMPETITION AND COOPERATION OF HIGHER EDUCATIONAL INSTITUTIONS IN THE MODERN ECONOMIC SITUATION

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Abstract

Growing marketization is one of the main tendencies of the modern sphere of education. Therefore the role of markets, competition, private initiative and cooperation in case of achieving economic and social goals is becoming more and more important. The paper focuses on game theory modeling of interaction between universities for researching the trends and peculiarities of higher education development.

As a result the cooperative model of university reform is developed. The characteristic function is based on estimation of conventional units of university admission determined with consideration of the demand and supply structure of qualified labour market. The latter suggests an approach to the characteristic function construction in monetary terms based on modeling and forecasting the regional demand for professionals with higher education. The cooperative model is analyzed with the range of solution concepts including the Shapley value, the Core and the Nucleolus. The obtained results can be used to develop solutions within the general framework of the state policy on supporting higher education institutions at the regional level.

Keywords: higher education; game theory; cooperative games; university cooperation

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Introduction

It is quite obvious that human capital is an integral part of a country's wealth; it is also the base for the global competitiveness of any modern state; and either university or higher education in general is one the essential parts of the human capital. Higher education system in Russian Federation is facing serious challenges. First of all there is a growing gap between the quality and structure of university education and the needs of real national and regional economies. Another thing is that growing marketization is one of the main tendencies of the modern sphere of education in general. At the same time Russian government is strengthening the requirements to quality and structure of vocational and higher education. Considering reduction of the resource base of the universities due to continuing economic recession the above leads to intensification of competition and the increase of role of cooperation in case of achieving educational institutions' economic and social goals and provides opportunities to apply cooperative game theory to universities management.

Cooperation of educational institutions may become an efficient instrument for matching the education sphere outcomes with the economic needs and improving the quality of university education. The paper focuses on game-theoretic modelling of educational institutions interaction for researching the trends and peculiarities of development of the economy of higher

education. The methodology of the research is based on the game theory methods and analytical methods.

The paper consists of three chapters. The first one includes the literature review including the review of traditional approaches to the economic analysis of education in general and higher education in particular. The second chapter contains the cooperative game theory model of the higher education institutions (universities) interaction. The third chapter is devoted to the consideration of the applied aspects of the game-theoretic model.

Literature review

The efforts to define and evaluate the role and impact of education to the economy have been made since the emergence of economic science as an autonomous body of knowledge. Throughout the last two and a half centuries economic understanding of education in general and higher education in particular have been usually based on determining its dimensions. In this case education is considered as the source of benefits at the individual and the social levels. The former is easily illustrated by means of the idea formulated by Adam Smith (1977) that the wages for the skilled labour replaces the expenses of the education, with at least the ordinary profits of an equally valuable capital. The logic of the latter can be explained particularly by mentioning the dependence of economic growth, political stability and social welfare of the region on the level of its population's education (See, e.g. Teixeira and Dill, 2011).

An outgrowth of this line of investigation is the theory of human capital among the founding fathers of which are Jacob Mincer, Gary S. Becker and Theodore W. Schultz. Within this theory education is considered as one of the main directions of investment in human capital which includes human's knowledge, skills, health, or values (Becker, 1994). Hence, the development of approaches to economic evaluation of investments in people becomes promising field of research (See, e.g. Rouse, 2010). The theory of human capital includes interpretation of education both as individual (when it is determined as a factor of personal wealth (Becker, 1994)) and social (when it is understood as a factor of economic growth (See, e.g. Mincer, 1981)) value. Thus, the roots of the idea of education as an individual service and/or public good can be found.

The natural consequence of understanding education as a service is the consideration of the system of education, especially the system of vocational and higher education, as a market. Thus, market model is one of the basic models of economic agents' interaction within the system of education. It defines the participants as buyers (applicants and students) and sellers (educational institutions) of educational services (See, e.g. Mogaji, 2016). The early base of this model is market mechanism of social choice that effectively distributes goods and services through rational utility-maximizing behaviour of individuals. Then the idea of market itself and its application to education (higher education) becomes more and more complicated with the evolution of economic theory. For example, John S. Mill (1885) pointed out market failures particularly in case of education.

However it should be noted that education as a market is rather peculiar. The thing is not only in the existence of externalities and market failures caused by them. First of all the system of education in general and higher education in particular is highly regulated in most countries, especially in Russia. Moreover the subject of transaction is not defined clearly: it can be a service of education (ability to follow several courses), an educational good (a set of skills and knowledge), an official document (diploma or certificate) and so on. Furthermore the result of education process is highly dependent on the actors' will, availability and efforts so that psychological factors become significant. These specific characteristics are partly considered in the institutional theory (See, e.g. Heinz-Dieter and Rowan, 2006 or Muscio et al. 2016).

Actually the role and place of education in the socio-economic system is usually defined through its functions. For example, according to OECD Thematic Review on tertiary education,

four major missions of tertiary education contribution to social and economic development are mentioned (OECD, 2008):

- the human capital formation (primarily through teaching);
- the building of knowledge bases (primarily through research and knowledge development);
- the dissemination and use of knowledge (primarily through interactions with knowledge users); and
- the maintenance of knowledge (inter-generational storage and transmission of knowledge).

The simplest definition of vocational education can be formulated as an element linking the economy needs for qualified labour force and capabilities and wishes of individuals. In case of higher education the role of research hub is added to the basic functions of vocational education in general.

Turning now directly to modelling and analysis of higher education development in economic context, main blocks of approaches can be highlighted:

- Socio-economic efficiency analysis or evaluation of social and economic effect and efficiency of investments in education (considering education as a factor of social wealth).
- Individual efficiency analysis or evaluation of individual economic effect of investments in education (considering education as a factor of personal wealth).
- Financial analysis or defining different models of higher educational institutions' financing, calculation their financial efficiency etc.
- General analysis or analysis of interaction between higher education and labour market in general (identifying the main problems of graduates' employment etc).
- Quantitative analysis or analysis and modelling of the mutual dynamics of higher education and the labour market.
- Qualitative analysis or the study of the qualitative correspondence between the supply and demand for professionals with higher education, the identification of indicators characterizing the quality of students' training in universities.
- Structural analysis or analysis of interaction between the elements of the system «higher education – labour market», modelling of information exchange between agents, considering management impacts etc.

The cooperative model of university interaction

Cooperative approach to game-theoretic analysis implies that players can coordinate their actions and unite in different coalitions. The function that associates with every coalition the utility (payoff) that the players of this coalition provide acting together is called the characteristic function. The strategic aspect or the search for optimal actions of players within the coalition and therefore the question of the origin of the characteristic function usually is not involved directly in the study of cooperative game theory. However it is extremely interesting for the economic applications of specific cooperative models and their practical implementation.

A cooperative game in characteristic function form is given by the set of players $I = \{1, \dots, n\}$ and the characteristic function $v: 2^I \to \mathbb{R}$. Coalitions are the elements of a nonempty subset $S \subset I$. The coalition I that consists of all the players is called the grand coalition. In the case under consideration it is assumed that the utility of the players is transferable, that means it is measured on one scale and can be transferred from one player to another without losses and restrictions. The vector $x \in \mathbb{R}^n$ of the game (I, v) which components determine utilities each member of the grand coalition gains if the coalition is formed is called an imputation. The

imputation should satisfy conditions of individual rationality and collective rationality. The first condition assumes that as a result of distributing the grand coalition payoff, each player should receive no less utility than he can obtain by himself autonomously without joining any coalitions

$$x_i \geq v(\{i\}),\ i \in \{1,..,n\}. \quad (1)$$

In accordance with the second condition, the payoff of the grand coalition I must be fully distributed among its participants

$$x(I) = x_1 + x_2 + \cdots + x_n = v(\{I\}). \quad (2)$$

The vector that satisfies only the second condition is called the pre-imputation.

In the conditions of economic recession and principle changes in the technology of the educational process, competition between universities inevitably intensifies. This competition can take a variety of forms. In particular, it can be both a competition for the entrant's base, and for funding from the state budget. To date, there are no specific practical mechanisms for the establishment of agreements between universities. However, this does not mean that there are no objective trends that encourage universities to agree on their policies and form associations. Also, as coalition outcomes, we can treat the consequences of possible solutions for merging universities, adopted at the state or municipal level.

These arguments lead us to the idea of describing the system of separate universities' (s.c. *relatively isolated university group*, RIUG) interaction in the form of a cooperative game with transferable utility. In the next discussion, for the symbol of this model it is proposed to use the name *cooperative game-theoretic model of universities' interaction*.

Within the framework of this model, sets S are understood as potential coalitions (associations) of universities, I – full set of universities in RIUG.

The values of the characteristic function $v(S)$ reflect the results (utility, consequences) of the association for the coalitions of universities S.

The characteristic function is based on estimation of conventional units of university admission determined with consideration of the demand and supply structure of qualified labour market. Therefore the educational institutions receive supreme payoff when the vocational-qualification structure of labour force with higher education in the region is balanced. Determine the base admission capacity for each educational program of each university as 1 unit. Then it is necessary to specify marginal contribution of the university for estimating each coalition's payoff $v(\{i\})$ considering that the educational institutions can balance the structure of admission only in cooperation.

To analyze the proposed model of the university interaction classical concepts of cooperative game solutions can be applied. Such solutions receive a natural meaningful interpretation. Namely, to which share of the allocated resource they can objectively claim in the case of the achievement of a full (within the framework of RIUG) an agreement. Also, the shares specified by the solution imputation can be interpreted as generally acceptable, rational decisions of the state management (coordination) institution.

Speaking about the classical concepts of the solution of cooperative games, we primarily mean such solutions as Shapley value, Core, Nucleolus.

We recall that the *Shapley value* is in accordance with formula

$$\Phi_i(v) = \sum_{S:i\notin S} \frac{s!\cdot(n-s-1)!}{n!} \cdot [v(\{S \cup i\}) - v(\{S\})], \quad (3)$$

where

$\Phi_i(v)$ – the share which player i gets in the frame of imputation defined as solutions;

s – number of players of coalition S;

n – total number of players;

$v(\{S \cup i\}) - v(\{S\})$ – the contribution of the player (participant) i in case of his joining to coalition S.

As is known, the principal advantages of this decision, proposed by L. Shepli in 1953, is that it is the only solution simultaneously satisfying the next requirements (axioms):

- The axiom of efficiency (according to this axiom total value of grand coalition's payoff $v(\{I\})$ should be distributed).
- The axiom of dummy player (according to this axiom the players who make no contribution to the grand coalition's payoff should receive nothing).
- The axiom of symmetry (according to this axiom the players who make the same contribution should receive the same utility).
- The axiom of additivity (according to this axiom the value should be additive over the set of all games).

At the same time, we must note that, despite the natural and transparent «economic sense» nature of the listed axioms, they usually can`t be easily applied to the case of competition between universities. For example, in practice, the shares and claims of universities can depend significantly on their «names», which contradicts the axiom of symmetry.

The solution concept known as set of the not dominated imputations or *Core* suggests that the imputations satisfy not only conditions of individual rationality and group rationality but the condition of coalitional rationality also:

$$x(S) = \sum_{i \in S} x_i \geq v(\{S\}). \quad (4)$$

The principal advantage of the Core (from the point of view of the university interaction model) is that none of the potential associations of participants can object to the shares belonging to it.

The fundamental drawbacks of the Core, as a solution to the cooperative game, are its potential emptiness, or, on the contrary, too large size (ambiguity). These defects are absent from *Nucleolus* – solution based on the problem of lexicographic minimization of the maximum excess. We recall that excess of the coalition S for distribution vector x defines as

$$e(S, x) = v(\{S\}) - x(S), \quad (5)$$

where $x(S) = \sum_{i \in S} x_i$.

Excess is a measure of the discontent of the coalition. Thus, Nucleolus as a solution, focused on minimizing the complaints of the most dissatisfied (offended) coalition, can be associated with the policy of maintaining all the members of the RIUG (including the weakest).

Applied aspects of the cooperative game-theoretic model of universities' interaction

Consider the game with transferable utility where players are three educational institutions of one region: (1) university-leader or large state university, (2) a smaller and more specialized institution of higher education or academy and (3) small private university. The situation described is rather close to the real one in Russian Federation where the number of the main educational institutions of one region is rather small[1].

Suppose that the universities' educational programs can be integrated into Technical Sciences (engineering), Economics & Business and Social sciences & Humanities. In this way the first educational institution implements all of them. The second one prepares only «economists» and «engineers». The third university provides Economic & Business educational program and Social Sciences & Humanities.

The characteristic function of 3-participant universities' cooperative interaction model is represented in the table 1.

Table 1. **The characteristic function for 3-paticipant model**

[1] When exclude Moscow and Saint-Petersburg it is nearly 3-5 main universities for one region; see Russian Federation Federal State Statistics Service, www.gks.ru

Educational program	Coalition, S						
	{1}	{2}	{3}	{1,2}	{1,3}	{2,3}	{1,2,3}
Economics & Business	1	1	1	3	3	3	5
Social sciences & Humanities	1	—	1	1	3	1	5
Technical sciences (engineering)	1	1	-	3	1	1	5
Characteristic function $v(\{S\})$	**3**	**2**	**2**	**7**	**7**	**5**	**15**

Source: simulation of real data

The Shapley value for this game is:

$$\Phi_1(v) = 6;\ \Phi_2(v) = 4{,}5;\ \Phi_3(v) = 4{,}5.$$

The solution found can be interpreted as admission capacities of the universities proportionate to which the educational market of the region is divided in grand coalition. Draw attention that the amounts that the players get in the total grand coalition payoff according to the Shapley value of this model is higher than the individual payoffs.

It should be also noted that alterative solution concepts provide slightly different results. For example, the core of this game is non-empty and rather big (fig. 1).

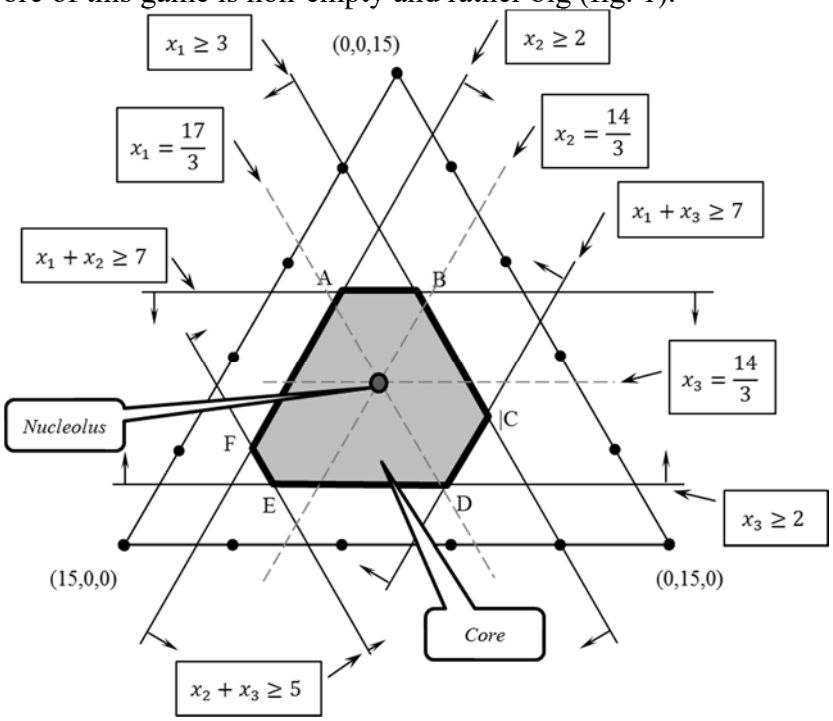

Fig. 1. **Characteristic function (including the core and the nucleolus)**

Thus when determining the Core of the game the following conditions are taken into account:

- The condition of group rationality that determines the set of allocations $x(\{I\}) = x_1 + x_2 + x_3 = v(\{I\}) = 15$.
- The conditions of individual rationality: $x_1 \geq 3;\ x_2 \geq 2; x_3 \geq 2$.
- The conditions of coalition rationality: $x_1 + x_2 \geq 7; x_1 + x_3 \geq 7; x_2 + x_3 \geq 5$.

As it is shown on figure 1, the Core of the game is described by a set of points:
A (5;2;8); B (3;4;8); C (3;8;4); D (5;8;2); E (10;3;2); F (10;2;3).

The calculations representing the imputations values that corresponds the nucleolus are shown in the table 2.

Table 2. **Final calculations of the nucleolus**

	Coalition						
	{1}	{2}	{3}	{1,2}	{1,3}	{2,3}	{1,2,3}
v(S)	3	2	2	7	7	5	15
x(S)	5,667	4,667	4,667	10,333	10,333	9,333	15

	Coalition						
	{1}	{2}	{3}	{1,2}	{1,3}	{2,3}	{1,2,3}
$e(S,x)$	-2,667	-2,667	-2,667	-3,333	-3,333	-4,333	0

Source: the author's calculations

In this situation the Nucleolus does not significantly differ from the Shapley value:

$$N(v) = (5{,}7;\ 4{,}7;\ 4{,}7).$$

It is obvious that the differences mentioned earlier are determined only by starting point of the analysis and there is no sense in giving absolute priority to any solution concept. Moreover in case of the model under discussion the variation between the solutions is within background information error range. The research based on comparison of different solution concepts (the Shapley value, the core, the kernel, the nucleolus) results with the real terms of engagement of the universities seems more useful and informative. The situations where there are no coalitions in the higher education market should not be excluded too. In this case the models proposed may help to define and estimate objective and subjective causes of the situation and the possible ways of its evolution.

One of the main issues of cooperative game theory application is construction of characteristic function in monetary values or any other real, not just conventional units. In the situation considered above the major factor maximizing payoff of the educational institutions is balance of the vocational-qualification structure of labour force. In this way the answer to the question mentioned earlier for the concrete region can be found by the evaluation of marginal demand for professionals with higher education in this very region in 2 or 4 years (term of apprenticeship of students in the master's and bachelor's programs).

Average cost rate for the year of taking each educational program is evaluated on base of costs of studying in universities of Vologda region in the year 2014. Then average cost rate for Economics & Business educational programs is nearly 71 977 roubles, for Technical sciences (engineering) programs is 82 899 roubles, for Social sciences & Humanities programs is 89 298 roubles. Thus, when considering total grand coalition payoff receiving when the vocational-qualification structure of labour force with higher education in the region is balanced as total income, it amounts to 1850.9 mln. roubles (48.76 mln USD) for the period 2014–2016. So that the Shapley value when applying the game theory model considered above is estimated as following:

$\Phi_1(v) = 740{,}3$ mln roubles (19.5 mln USD);

$\Phi_2(v) = \Phi_3(v) = 555{,}3$ mln roubles (14.63 mln USD).

In this situation the nucleolus solution is (mln USD):

$$N(v) = (18{,}42;\ 15{,}17;\ 15{,}17).$$

All things considered, the solutions found and the approach developed may be of use for justification and forecasting of the interaction between universities and evaluation the payoffs in case of different types of cooperation.

Conclusions

The simplest definition of vocational education can be formulated as an element linking the economy needs for qualified labour force and capabilities and wishes of individuals. In case of higher education the role of research hub is added to the basic functions of vocational education in general. Higher education is one the essential parts of the human capital that is the base for the global competitiveness.

The analysis of human capital and patterns of higher education development in the regions of Russian Federation with the emphasis on the university education and its interaction with the regional labour market indicate certain contradictions for employment of university graduates due to the presence of a number of objective and subjective factors. An objective discrepancy between the factors of labour market demand and supply formation is the first basis for the above contradictions. The next exogenous cause of imbalance is the presence of a lag

associated with the time necessary for education process. These objective and exogenous (in relation to the integrated system of education and labour market) factors determine the need in effective and efficient analytical and management tools. Reduction of the resource base of the universities due to continuing economic recession, growing marketization and restricting government requirements to quality and structure of vocational and higher education leads to intensification of competition and the increase of role of cooperation in case of achieving educational institutions' economic and social goals. The above provides opportunities to apply cooperative game theory to universities management.

As a result of the research the cooperative model of university reform is developed. The characteristic function is based on estimation of conventional units of university admission determined with consideration of the demand and supply structure of qualified labour market. The latter suggests an approach to construction of the characteristic function in monetary terms based on modelling and forecasting the regional demand for professionals with higher education using statistics and econometrics. The cooperative model is analyzed with the range of solution concepts including the Shapley value, the Core and the Nucleolus.

All things considered, the solutions and approaches proposed may be of use for justification and forecasting of interaction between universities as well as for evaluation of the payoffs in different types of cooperation.

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