Computer Simulation of Social Partnership in the System of Continuing Professional Education

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Abstract
A game-theoretic model of social partnership in the system of continuing professional education is proposed. Some results of the model identification and investigation based on simulation modeling are considered. A comparative analysis of egoistic and cooperative approaches to the social partner-ship is conducted.
Keywords: social partnership, continuing professional education, simulation modeling, identification, dynamic games.

1 Introduction

A system of professional education should be flexible enough to prepare qualified and competitive specialists capable to improve their knowledge and skills in the changing environment. One of the important mechanisms providing the solution of this problem is social partnership that allows for the cooperation of employers, universities, and students. Traditionally, social partnership is considered in conformity with relations between workers, employers, and trade unions[1]. A wider view is presented in[2]. Social partnership relations also exist in the system of higher education. In order to be successful in these partnerships, agents must look carefully at how they are influenced by factors such as race, class, gender, age, culture, histories and other differences[3]. Unequal power relations prevailing in such partnerships affect the ability to share information, solve problems and form honest relationships. The most complex social challenges - such as post-secondary access and success for under-represented students, diversification of the workforce, poverty, environmental degradation, and global health - exceed the problem-solving capacity of single organizations or societal sectors. Social partnership provides colleges and universities, corporations, government agencies, non-profits, and other organizations with a model for how to effectively address these and other pressing social issues through strong, effective collaboration[4].

There are only a few papers that contribute to the mathematical modeling of the problems of social partnership. D. Talman and Z. Yang[5] propose a general model of partnership formation. Let a number of agents want to conduct some activities. They may act alone or seek a partner for cooperation and need in the latter case to consider with whom to cooperate and how to share the profit in a cooperative or competitive environment. Necessary and sufficient conditions under which an equilibrium exists are given. In[6] the Cobb-Douglas production function is used to measure synergy effects of a Public Social Private Partnership project. The microeconomic approach opens up a possibility for allocating the synergy effects to partners according to a cooperative principle of optimality. Analysis of a social partnership among a complex network of stakeholder organizations is fulfilled in[7]. M. Diaconu and A. Pandelica examine the partnership relationship between economic academic and business environment and propose a series of measures regarding how this relationship can shape the modern university[8]. The authors of[9] propose a synergy model of a smart tri-partite partnership among polytechnics - industry - students in the industrial training program in Malaysia.

Social partnership in continuing professional education is a specific system of joint activities of the education system agents characterized by trust, common objectives and values, and providing highly qualified, competitive, and mobile specialists for the labor market. The main research hypothesis is that social partnership permits to increase a level of professional competence of the students.

It seems natural to use the formalism of differential games for description of social partnership relationships[10]. Due to the high complexity of the differential game model the techniques of simulation modeling are applied for its investigation[11]. Some previous results of the authors' approach in social systems modeling are presented in[12, 13].

2 A General Description of the Model

In the proposed model social partnership relations among employers, students, and university are considered. The payoff functions are as follows:

$$
\begin{aligned}
J_P &= \sum_{t=0}^{T} g_P(u_P(t), u_B(t), u_C(t), x(t)) \to \max, \quad u_P(t) \in U_P \\
J_B &= \sum_{t=0}^{T} g_B(u_P(t), u_B(t), u_C(t), x(t)) \to \max, \quad u_B(t) \in U_B \\
J_C &= \sum_{t=0}^{T} g_C(u_P(t), u_B(t), u_C(t), x(t)) \to \max, \quad u_C(t) \in U_C
\end{aligned} \tag{1}
$$

where $N = P, B, C$ is a set of players, namely: - employer; - university; - student.

The systems dynamics are given by the equation

$$
x(t+1) = x(t) + f(x(t), u_P(t), u_B(t), u_C(t)), \quad x(0) = x_0 \tag{2}
$$

Here $u_p(t)$, $u_b(t)$, $u_c(t)$ are strategies of the players describing their efforts directed to the development of social partnership relations; U_p, U_B, U_C - domains of feasible strategies; J_P, J_B, J_C - payoff functionals of the players; g_P, g_B, g_C - instantaneous payoff functions; $P = \{P_1, \dots, P_r\}$ - a finite set of employers; - university (only one is considered); $C = \{C_1, \dots, C_S\}$ - a finite set of students; = 4 (period = 5 years).

The strategies determine a share of the annual budget assigned by a player to the needs of continuing professional education (CPE): $u_{Pi}(t)$ - a share of the annual budget assigned to CPE programs by an employer, $U_{Pi} = [0, 1]$; u_Cj(t) - a share of the annual budget assigned to CPE programs by a student, $U_{cj} = [0, 1]$; u_B(t) - a share of the annual budget assigned to CPE programs by the university, $U_B = [0, 1]$.

In the current investigation five employers and ten students are considered. The strategies of generalized players in any moment of time are calculated as an arithmetic mean of the strategies of those agents, namely:

Strategy of P (Employer):

$$u_P(t) = \frac{1}{r}\sum_{i=1}^{r} u_{P_i}(t); u_P(t) \in U_P, \mathrm{r} = 5 \tag{3}$$

Strategy of (Student)

$$u_C(t) = \frac{1}{s}\sum_{j=1}^{s} u_{C_j}(t); u_C(t) \in U_C, \mathrm{s} = 10 \tag{4}$$

Strategy of (University):

$$u_B(t); u_B(t) \in U_B \tag{5}$$

The state variable of the model considered as a time function x(t) characterizes a quantitative factor which determines relations in the social partnership system; $f - a$ function of the system dynamics depending on the players strategies.

It is assumed that the function of system dynamics increases in respect of all arguments (the efforts of players positively influence to the results of social partnership). To give the system dynamics the modified Verhulst-Pearl model is used, i.e. f is taken in the form

$$f(x(t), u_P(t), u_B(t), u_C(t)) = h(u_P(t), u_B(t), u_C(t))x(t)(1 - \frac{x(t)}{K}) \tag{6}$$

where K - maximal feasible value of the state variable in the given conditions; h - function of impact of the players' strategies, namely:

$$h(u_P(t), u_B(t), u_C(t)) = \sum_{i=1}^{3} a_i u_i(t); a_i \geq 0; \sum_{i=1}^{3} a_i = 1; i = P, B, C; \tag{7}$$

a_i - relative weights of the strategies.

For the estimation of the relative weights the following considerations are used. The sum of the weights is equal to 1, and all weights are positive. The most important influence is made by students as key agents of the CPE system. The two other weights are approximately equal to each other and dont differ from the former weight (students) too significantly. So, the weights are chosen as follows (Table 1):

Table 1 Relative weights of the strategies (a_i)

Relative weight i	Employer	University	Student
a_i	0.3	0.3	0.4

Accordingly to the research hypothesis it is rational to consider two variants of parameterization of the payoff functions.

1) Egoistic approach. Speaking about the real situation in the CPE system it is natural to suppose that g_i decreases on u_i and increases on other arguments (“ free-rider principle ”). This variant determines an egoistic approach when all players save their personal efforts.

Thus, a problem of coordination of private (efforts saving) and common (social partnership development) interests in the CPE system arises. In this case the payoff functions are parameterized as follows:

$$g_i(u_P(t), u_B(t), u_C(t), x(t)) = \frac{b_j u_j(t) + b_k u_k(t) + b_x x(t)}{1 + b_i u_i(t)}; i, j, k = P, B, C \quad (8)$$

b_i - relative weights of the strategies.

2) Cooperative approach. This parameterization describes a desirable (ideal) state of the relationships of social partnership in the CPE system when its elements voluntarily and consciously contribute to the development of social partnership relationships. This variant defines a cooperative approach when payoff functions become increasing on all arguments:

$$\begin{aligned} &g_i(u_P(t), u_B(t), u_C(t), x(t)) \\ &= b^i_P u_P(t) + b^i_B u_B(t) + b^i_C u_C(t) + b^i_x x(t), i = P, B, C \end{aligned} \quad (9)$$

${b_j}^i$ - a relative value of the factor for the player i (i=P, B, C; j=P, B, C, x).

3 Identification of the Model

Suppose that the state variable $x(t)$ characterizes a level of professional training of the students. For the estimation of the initial training level a known approach proposed by Donald Kirkpatrick[14] is used. D.Kirkpatrick has developed a model of evaluation of the training effectiveness which considers four levels:

1) Reaction: to what degree participants react favorably to the training. For the estimation the results of sociological polls conducted among students of the Southern Federal University are used.

2) Learning: to what degree participants acquire the intended knowledge, skills, attitudes, confidence and commitment based on their participation in a training event. Here the data about the students progress together with data characterizing the material base of education are considered.

3) Behavior: to what degree participants apply what they learned during training when they are back on the job. The results of polls conducted among employers in the Rostov region are used.

4) Results: to what degree targeted outcomes occur as a result of the training event and subsequent reinforcement. The data of polls among employers on the topic "A level of professional knowledge and skills of the graduates" are used.

Therefore, an initial value of the professional training level is evaluated by an evident formula

$$x_0 = \frac{1}{4}\sum_{i=1}^{4} x_i \tag{10}$$

To determine the values of x_i the results of polls are interpreted as follows. The answers "Satisfied", "Rather satisfied", "High" and "Very high" are treated as satisfaction and their values for a question are added. The answer "I dont know" means that the respondent may have either positive or negative opinion. Supposing their ratio as 1:1, the value is taken equal to 1/2 in this case. The summing up gives an array of the values of x_i as follows: $x = [0.911; 0.823; 0.559; 0.617]$. Also, the maximal feasible value of the state variable in the given conditions is taken equal to $K = 1$.

The relative weights are identified accordingly to the following reasoning.

1) Egoistic approach. This approach supposes an economy of the personal efforts ("free-rider problem"). The principal role belongs to the Student whose efforts and professional training are of crucial importance. Nevertheless, other players are important too. The next is University as the training base and then Employer who determines the requirements on a labor market. If this approach is chosen then the players are more interested in resource economy than in the improvement of professional training. The respective relative weights of influence factors b_i are presented in Table 2.

2) Cooperative approach.

Student. The aim of partnership for the Student is knowledge acquisition and improved professional training. Respectively, the factor of professional level is the principal one for the Student and it has the biggest value. The factor of personal

Table 2 Relative weights of influence factors (b_i)

Relative weight	Employer	University	Student	Professional level
b_i	0.25	0.3	0.4	0.1

Table 3 Relative values of the factor j for the player i, ($b^i_j, i = P, B, C; j = P, B, C, x$)

Relative values ${b_j}^i$	Employer	University	Student	Professional level
Employer	2/8	1/8	2/8	3/8
University	1/8	3/8	2/8	2/8
Student	1/7	1/7	2/7	3/7

effort is evaluated a bit smaller. The two other factors (significance of University and Employer) are equal and have minimal values.

University. The University gives a maximal value to the significance of its efforts because they provide a base for the professional training. The significance of Student and professional level are evaluated by the University with equal and a bit smaller values. At last, the minimal value goes to the Employer who is as a rule not very active participant of the training process.

Employer. This player is interested above all in the professional level of the potential employees, and efforts of the Student and his own receive equal values. The last place belongs to the University because its training programs rarely satisfy the Employers needs completely.

The relative values of the factors are presented in Table 3.

4 Planning and Implementation of the Computer Simulation Experiments

The model investigation was conducted by computer simulation on the base of scenario method [11]. The scenarios are formed according to plausible behavior patterns of the players. For simplicity the arithmetic mean strategies are described. It is supposed that for all scenarios for any moment of time the values of strategies are equal: $u_P(t) = u_C(t) = u_B(t) = u_O(t)$, $t = 0, ..., 4$. Six scenarios are considered:

1) Maximal (max) one corresponds to the maximal possible financing when the whole budget of a player is assigned for training: $u_O(t) = 1$;

2) Medium (med) one assigns a half of the budget for training: $u_O(t) = 0.5$;

3) Minimal (min) allows for training only a small part of the budget: $u_O(t) = 0.2$;

4) Absence of financing (abs) is clear: $u_O(t) = 0$;

5) Decreasing of financing (dec) means that initially an eminent part of the

players budget is assigned for training but then the share decreases to a small value, namely: $u_O(t) = 0.8 - 0.15t$;

6) Increasing of financing (inc) describes the opposite strategies: $u_O(t) = 0.2 + 0.15t$.

Thus, in the former four scenarios the strategies are constant in time, while in the fifth and sixth scenarios the shares of financing are time-dependent.

5 Processing and analysis of the modeling results

The processing of modeling data includes a comparative analysis of the graphs of state variable and payoff functionals for different scenarios. The graphs of the Employer's payoff functional for different scenarios are shown in Fig.1-Fig.2. The functional $J1_p(t)$ corresponds to the egoistic approach, and $J2_p(t)$ to the cooperative one.

As it could be expected, the best results are achieved for the maximal scenario

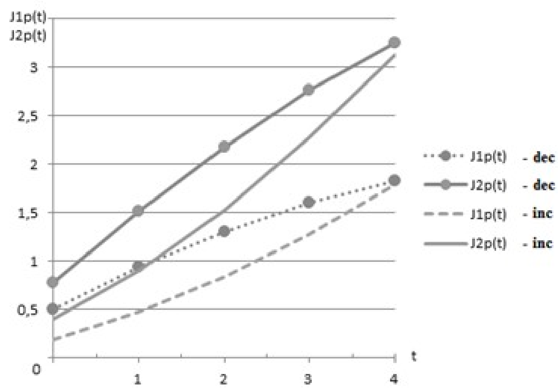

Fig.1 Comparison of graphs of the employers payoff functional for the scenarios "dec" and "inc"

, and the worst results for the minimal one. The values of payoff functionals and state variable decrease in the following order of scenarios: maximal, decreasing, medium, increasing, minimal, absence.

In Fig.3 it is shown the comparative dynamics of the state variable (professional level) respec-tively to the six scenarios. The dynamics are described by the Verhulst-Pearl function.

Let's notice that for the decreasing scenario the values of payoff functionals are initially big but then they decrease in time, and for the increasing scenario the picture is opposite. It means that if the players make an eminent contribution from the very beginning then they can create a good base which allows for a certain decreasing in the future, and the level of development of social partnership

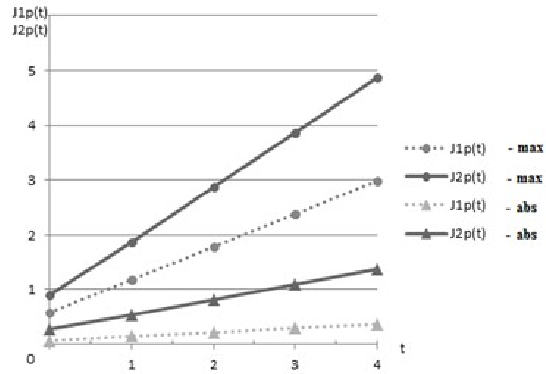

Fig.2 Comparison of graphs of the employers payoff functional for the scenarios "max" and "abs"

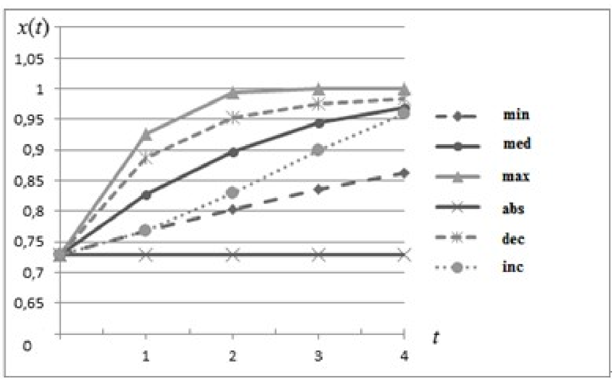

Fig.3 Comparison of graphs of the state variable for different scenarios

will be still satisfactory.

The comparative analysis shows that all players win from the social partnership. However, for any specific scenario the payoff functional of a player can achieve both maximal and minimal value in respect to the payoffs of other players depending on the players strategy. So, the strategic choice is critical for a player.

For two variants of payoff functionals (egoistic and cooperative approach) a comparison of the payoffs is fulfilled. A difference between the approaches is clearly observable in time. The difference grows when financing increases, and the comparison demonstrates advantages of a higher level of the social integration. In the case of cooperation payoffs are greater than in the case of egoism: for the Employer in 3.75 times (absence of financing) and 1.64 times (maximal scenario); for the Student in 4.29 and in 2.04 times for the same scenarios respectively; for the University in 2.5 times (absence of financing) and in 1.76 times (medium scenario).

6 Conclusions

In the paper a mathematical model of the social partnership in the CPE system is built using differential games techniques and investigated by computer simulation. The model identification is made on the base of sociological polls conducted in the Southern Federal University and Rostov region (Russia).

One of the main results is a confirmation of the thesis concerning necessity to join efforts of the subjects of social partnership. In this case all considered scenarios lead to better results than in the egoistic approach. It is clear that more financing allows for more convincible results.

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