Evolution of Agents Behavior in the Labor Market

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Abstract The paper studies imbalance of labor supply and labor demand relative to qualifications. Every person faces a problem of choosing a right path for his future career. On the other hand, employers have a dilemma either to hire insufficient qualified personnel in a particular field and train until he or she reaches required level of qualification, or seek an opportunity to hire skilled personnel. We model these choices trough the evolutionary game theory approach.

Keywords: labor market, qualification, evolution.

1. Introduction

One of the leading resources of Russian economic internal growth in modern conditions is the labor force. Currently the focus is on the problem of the economic growth in Russia associated with the energy dependency, whereas the problems connected with the dependence of the Russian economic system on the cost and quality of the labor force, unfairly in the shadows. The study of the reasons for the current state of the labor market is definitely important applied problems as well. However, the problem of explaining patterns of the labor market evolution is more significant on the theoretical level in the long term.

Urgent problem of the Russian economy is the lack of qualified personnel and imbalance of labor supply and labor demand relative to qualifications. Thus, there is excess of labor demand over its supply for the market of rare and needed professions, which causes the price of labor assignment by the candidates themselves. For the low-skilled labor market it can be observed the reverse situation. An enormous low-skilled labor supply leads to the situation where employers dictate most of the conditions.

Every person faces a problem of choosing a right path for his future career. In most of the cases decisions about profession and the quality of education are made based on the imperfect information and incorrect definition of objectives. Employees make decisions based not on the market indicators of demand and wages, but on the basis of subjective factors. In other words, candidates take into account not quantitative but qualitative indicators.

On the other hand, employers have a dilemma either to hire insufficient qualified personnel in a particular field and train until he or she reaches required level of qualification, or seek an opportunity to hire skilled personnel. In this case, firms should be guided by the motives for the optimization of personnel costs. Therefore, the objective of employers is the choice of their behavior, based on current market conditions and adequate quantitative assessment of possible alternatives.

Described problems reveal the need to study the behavior of agents in the labor market in order to find an equilibrium strategy in the long term. It is worth noting that the labor market agents also play one of the major roles in this area of Russian economy. Their recruiting strategy based on the appropriate quantitative indicators through their access to information could be an integral part of the process of equilibrium achieving.

2. The model

The labor market can be divided into three sectors according to the level of personnel qualification: low-skilled, skilled and highly skilled. Each of these sectors has different sets of rules and conditions. Selection of an optimal strategy for responding to the behavior of other similar participants can facilitate a potential conflict of interests for both employers and candidates. Conflict character of participants' behavior stipulates the use of mathematical tools of game theory to the labor market study.

Each candidate has an alternative of either accept a job offer, which meets his current qualifications, or look for a job which will offer him or her an opportunity of getting trained by qualified personnel and in the long run give possibility of a career growth. Therefore, employees have two appropriate strategies: to hire already qualified personnel or to spend money on training non-qualified personnel.

We introduce further notations for the set $Z_w = \{l, s, h\}$ of possible workers' pure strategies, and notations for the average wage according to three distinguished sectors: w^l, w^s, w^h for the low-skilled, skilled and highly skilled workforce, respectively, $0 < w^l < w^s < w^h$ at that. In terms of labor demand the set $Z_e = \{q, t\}$ of employers' pure strategies includes two alternatives: to hire qualified or to train unqualified personnel correspondingly. Assume the cost of meeting the skilled and highly skilled level to be equal to c^s and c^h, respectively, for both employees and employers, and $0 < c^s < c^h$.

Let us consider firstly low-skilled labor market where is no need to train employees. Here and further we assume that in non-crisis economic environment, individuals will not compete for employment in the market with the need for minor qualification then he or she has. Then in terms of employees the payoffs $u_w^l(z_w)$ could be described as

$$u_w^l(z_w) = \begin{cases} w^l, & z_w = l, \\ 0, & z_w \in \{s, h\} \end{cases}$$

Obviously, the solution of this game according to Nash equilibrium (NE) is the strategy l. Otherwise, in crisis economic environment all of the payoffs $u_w^l(z_w)$ in this evolution game could be equal to w^l regardless of the strategies. This case, however, is of interest in neither the theoretical nor the practical point of view. A similar situation is in the game in terms of employers, where there is no need for any qualification level and, therefore, all of the payoffs $u_e^l(z_e)$ are designated as

$$u_e^l\left(z_e\right) = f\left(z_w\right) - w^l,$$

where $f\left(z_w\right)$ is the effect from the employee with type z_w work, $0 < f\left(l\right) < f\left(s\right) < f(h)$ at that. Here we assume $z_w = l$ in non-crisis economic environment. The invariance of wages in low-skilled labor market is determined by the excess of labor supply over labor demand, as mentioned above.

For modeling the games in the skilled and highly skilled labor markets it is necessary to introduce a parameter of propensity to education for workers $0 \leqslant \theta^w \leqslant 1$ and parameter of propensity to training for employers $0 \leqslant \theta^e \leqslant 1$. These parameters can be interpreted as the probability of interest coincidence for the players of different types. Thus, in the skilled labor market the payoffs $u_w^s\left(z_w\right)$ in terms of employees could be described as

$$u_w^s\left(z_w\right) = \begin{cases} w^l\theta^e, \quad z_w = l, \\ \left(w^s - c^s\right)\left(1 - \theta^e\right), \quad z_w = s, \\ 0, \quad z_w = h. \end{cases}$$

It can be seen that there is exists dependence of the evolutionarily stable strategies on the training propensity parameter. Thus, strategy l is NE if

$$\theta^e > \frac{w^s - c^s}{w^l + w^s - c^s}$$

and strategy s is NE if

$$\theta^e < \frac{w^s - c^s}{w^l + w^s - c^s}$$

Otherwise, NE is determined by the mixed strategies l and s with training propensity parameter

$$\theta^e = \frac{w^s - c^s}{w^l + w^s - c^s}$$

In terms of employers skilled labor market could be defined by the payoffs $u_e^s\left(z_e\right)$ as follow

$$u_e^s\left(z_e\right) = \begin{cases} \left(f\left(s\right) - w^s\right)\left(1 - \theta^w\right), \quad z_e = q, \\ \left(f\left(l\right) - w^l - c^s\right)\theta^w, \quad z_e = t. \end{cases}$$

NE here is defined by the strategy q if

$$\theta^w > \frac{f\left(s\right) - w^s}{f\left(s\right) - w^s + f\left(l\right) - w^l - c^s}$$

and by the strategy t if

$$\theta^w < \frac{f\left(s\right) - w^s}{f\left(s\right) - w^s + f\left(l\right) - w^l - c^s}$$

NE is determined by the mixed feasible strategies with education propensity parameter

$$\theta^w = \frac{f(s) - w^s}{f(s) - w^s + f(l) - w^l - c^s}$$

Considering further the highly skilled market it is worth noting that the low-skilled employee is unlikely to be hired here. In this case the evolutionary game in terms of employees is defined by the payoffs $u_w^h(z_w)$ as

$$u_w^h(z_w) = \begin{cases} 0, & z_w = l, \\ (w^s - c^s)\theta^e, & z_w = s, \\ (w^h - c^h)(1 - \theta^e), & z_w = h. \end{cases}$$

Moreover, the average wage w^h is dictated largely by the employees due to excess of labor demand over labor supply, at least in accordance with the current state of the labor market. NE for workers in the highly skilled labor market is the strategy s if

$$\theta^e > \frac{w^h - c^h}{w^s - c^s + w^h - c^h}$$

and the strategy h if

$$\theta^e < \frac{w^h - c^h}{w^s - c^s + w^h - c^h}$$

As before, NE is determined by the mixed strategies s and h with training propensity parameter

$$\theta^e = \frac{w^h - c^h}{w^s - c^s + w^h - c^h}$$

The opposite situation may occur in the entrepreneurial activity, for example, and cause the existence of other stable strategies. But price formation in this kind of employment market has another rules and conditions then we are aimed to consider here.

Finally the highly skilled market in terms of employers is defined by the payoffs $u_e^s(z_e)$ as follow

$$u_e^s(z_e) = \begin{cases} (f(h) - w^h)(1 - \theta^w), & z_e = q, \\ (f(s) - w^s - c^h + c^s)\theta^w, & z_e = t \end{cases}$$

NE here is specified by the strategy q if

$$\theta^w < \frac{f(h) - w^h}{f(s) - w^s + c^s + f(h) - w^h - c^h}$$

and by the strategy t if

$$\theta^w > \frac{f(h) - w^h}{f(s) - w^s + c^s + f(h) - w^h - c^h}$$

NE is specified by the mixed feasible strategies with education propensity parameter

$$\theta^w = \frac{f(h) - w^h}{f(s) - w^s + c^s + f(h) - w^h - c^h}$$

At the same time each of employees as well as each of employers takes a decision in favor of only one employer and only one employee respectively. Here it is possible to consider the situation where employers compete with each other for the same employee, and employees compete for the same employer, in turn. The opportunity to choose two players randomly from the population is available in the evolutionary game theory.

Since availability of training candidates can improve their skills and employers can improve the skills of their workers. Employers also can evolve by gaining experience of hiring new employees under conditions of turnover. Training and development are the crucial factors in the evolutionary game theory. Thus, propensity for trainings can be considered as one of the main factors which determines an evolutionarily stable strategy (ESS, (Maynard Smith, 1982)) in the game theory model for both employees and employers.

The main difference in the evolutionary models building is dependence of each player's gains upon a type of the opposing player. If competitors have the same strategy, the gain goes to some one of them with equal probability. Here the above assumption that individuals will not compete for employment in the market with the need for minor qualification then he or she has remains. The zero gain of overqualified employee in this case can be interpreted as employers' projections about stuff turnover growth.

Let us return to the low-skilled labor market first. The payoff matrix in terms of employees could be described as shown in the Table 1. ESS here coincides with NE of this game and is obviously the same situation $(l,\ l)$. The employers do not take any decision as well.

Table 1: Low-skilled labor market: the payoff matrix in terms of employees

	l	s	h
l	$\left(\frac{w^l}{2}; \frac{w^l}{2}\right)$	$(w^l; -c^s)$	$(w^l; -c^h)$
s	$(-c^s; w^l)$	$(\frac{w^l}{2} - c^s; \frac{w^l}{2} - c^s)$	$(w^l - c^s; -c^h)$
h	$(-c^h; w^l)$	$(-c^h; w^l - c^s)$	$(\frac{w^l}{2} - c^h; \frac{w^l}{2} - c^h)$

In the skilled employment market the game is determined as shown in the Table 2. The amount of NE's in pure strategies in this game depends on the propensity parameter θ^e *It can be shown that there are no other cases.*:

$$NE: \begin{cases} (s,s), \quad \theta^e \leqslant \dfrac{w^s - c^s}{2w^l} \\ (s,s);(l,l), \quad \dfrac{2w^s - w^l + 2c^s}{2w^s} \leqslant \theta^e \leqslant \dfrac{w^s - c^s}{2w^l} \\ (l,l), \quad \dfrac{2w^s - w^l + 2c^s}{2w^s} < \theta^e \end{cases}$$

NE in mixed strategies here is nothing more but the vector $(\theta^w; 1 - \theta^w; 0)$:

$$(\theta^w; 1-\theta^w; 0) = \left(\frac{w^s - 2c^s - 2w^l\theta^e}{(1-2\theta^e)(w^l - w^s)}; \frac{w^l - 2w^s(1-\theta^e) + 2c^s}{(1-2\theta^e)(w^l - w^s)}; 0\right)$$

Table 2: Skilled labor market: the payoff matrix in terms of employees

	l	s	h
l	$\left(\frac{w^l}{2}; \frac{w^l}{2}\right)$	$\left(w^l\theta^e; w^s(1-\theta^e) - c^s\right)$	$\left(w^l; -c^h\right)$
s	$\left(w^s(1-\theta^e) - c^s; w^l\theta^e\right)$	$\left(\frac{w^s}{2} - c^s; \frac{w^s}{2} - c^s\right)$	$\left(w^s - c^s; -c^h\right)$
h	$\left(-c^h; w^l\right)$	$\left(-c^h; w^s - c^s\right)$	$\left(\frac{w^s}{2} - c^h; \frac{w^s}{2} - c^h\right)$

In terms of ESS it means that in the skilled employment market the strategy s is optimal if:

$$\begin{cases} (1-2\theta^e)\left(w^l - w^s\right) < 0 \\ w^s - 2c^s - 2w^l\theta^e < 0 \\ \theta^w < \dfrac{w^s - 2c^s - 2w^l\theta^e}{(1-2\theta^e)(w^l - w^s)} \end{cases}$$

or

$$\begin{cases} (1-2\theta^e)\left(w^l - w^s\right) > 0 \\ \\ \theta^w > \dfrac{w^s - 2c^s - 2w^l\theta^e}{(1-2\theta^e)(w^l - w^s)} \end{cases}$$

then $\theta^w \to 0$. Otherwise, if:

$$\begin{cases} (1-2\theta^e)\left(w^l - w^s\right) < 0 \\ \\ \theta^w > \dfrac{w^s - 2c^s - 2w^l\theta^e}{(1-2\theta^e)(w^l - w^s)} \end{cases}$$

or

$$\begin{cases} (1-2\theta^e)\left(w^l - w^s\right) > 0 \\ w^s - 2c^s - 2w^l\theta^e > 0 \\ \theta^w < \dfrac{w^s - 2c^s - 2w^l\theta^e}{(1-2\theta^e)(w^l - w^s)} \end{cases}$$

then $\theta^w \to 1$ and strategy l is ESS.

ESS for the game in the terms of employers (Table 3) coincides with its game' NE. Evolutionary games in the terms of employees and employers for all other types of markets are presented.

Table 3: Skilled labor market: the payoff matrix in terms of employers

	q	t
q	$\left(\frac{f(s)-w^s}{2}; \frac{f(s)-w^s}{2}\right)$	$\left(\left(f\left(s\right)-w^s\right)\left(1-\theta^w\right); \left(f\left(l\right)-w^l-c^s\right)\theta^w\right)$
t	$\left(\left(f\left(l\right)-w^l-c^s\right)\theta^w; \left(f\left(s\right)-w^s\right)\left(1-\theta^w\right)\right)$	$\left(\frac{f(l)-w^l-c^s}{2}; \frac{f(l)-w^l-c^s}{2}\right)$

Table 4: High-skilled labor market: the payoff matrix in terms of employees

	l	s	h
l	$\left(\frac{w^l}{2}; \frac{w^l}{2}\right)$	$\left(0; w^s-c^s\right)$	$\left(0; w^h-c^h\right)$
s	$\left(w^s-c^s; 0\right)$	$\left(\frac{w^s}{2}-c^s; \frac{w^s}{2}-c^s\right)$	$\left(w^s\theta^e-c^s; w^h\left(1-\theta^e\right)-c^h\right)$
h	$\left(w^h-c^h; 0\right)$	$\left(w^h\left(1-\theta^e\right)-c^h; w^s\theta^e-c^s\right)$	$\left(\frac{w^h}{2}-c^h; \frac{w^h}{2}-c^h\right)$

Table 5: High-skilled labor market: the payoff matrix in terms of employers

	q	t
q	$\left(\frac{f(h)-w^h}{2}; \frac{f(h)-w^h}{2}\right)$	$\left(\left(f\left(h\right)-w^h\right)\left(1-\theta^w\right); \left(f\left(s\right)-w^s-c^h+c^s\right)\theta^w\right)$
t	$\left(\left(f\left(s\right)-w^s-c^h+c^s\right)\theta^w; \left(f\left(h\right)-w^h\right)\left(1-\theta^w\right)\right)$	$\left(\frac{f(s)-w^s-c^h+c^s}{2}; \frac{f(s)-w^s-c^h+c^s}{2}\right)$

Introduced propensity parameters in these employment market models play the role of the population shares and do determine the process of equilibrium establishing in all types of labor market for both types of players. Therefore, their ratio to the particular professions is of special interest.

3. Conclusion

One of the main results of such evolutionary games is the necessity for player to be guided by the unavailable information about the incentives of the opposite type players. The solution to this lack of information is the involvement of recruitment agencies that possess such data. Identified ESS's dependence on the propensity parameters, that is next conclusion, should be taken into account in this instance.

For practical application of this model, it is necessary to consider certain occupations for each of the sectors. Derived evolutionarily stable strategies determine the equilibrium behavior of the labor market with certain allowable intervals for the model parameters.

As a further development, we propose to introduce into the model additional parameters that affect the behavior of economic agents in the labor market, such as work experience. There are some occupations, in which more relevant is to get practical experience rather than to receive theorize education, and vice versa.

References

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