

Iterated Prisoner's Dilemma and Macro-Dynamics of Transition

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Alexander Vostroknoutov,
Saint-Petersburg State University of Economics and Finance,
e-mail: aevk@online.ru
tel: +7 (812) 3456919
address:
str. Sadovaya 21,
St.Petersburg, 191023,
RUSSIA.

INTRODUCTION

After collapse of the Soviet Union, former soviet republics and countries of the Soviet block began rebuilding their economies in accordance with capitalistic market principles. But the process of transition has not been the same in all these countries. Although most of East European countries have succeeded in achieving growth, most of the former USSR republics are still in the recession.

In some papers the conclusion is drawn that the role of institutions in the process of transition was undervalued (Dewatripont and Roland, 1997). Apparently, liberalisation, decrease in state revenues and successful conquest of inflation have not been efficient enough. This can be easily seen by looking at the former Soviet republics. Therefore, the theorists have concluded that neoclassical economic theory performs well if applied to developed countries, but for the countries in transition from plan to market it failed to explain most of the output decline observed. Empirical studies (Popov, 1998) show that weakness of public institutions has stronger effect on the post-transition development than liberalisation does. For example, Vietnam, China, and to some extent Uzbekistan and Belarus are the countries where economic growth is observed even without much of liberalisation, though supported by the strong non-market institutions. At the same time, it seems that Russian liberalised economy doesn't grow. And this fact could be possibly explained by the weakening of public institutions.

Along with institutional weakness also initial conditions, an inheritance from the planned economy, could have deep impact on the transition process. Even though they cannot be directly observed, degree of economic disproportions could be a good measure for them (Popov, 1998). These disproportions, considered in comparison with the market economies of developed countries, are the differences in foreign trade balance, industry structure, defence industry etc. In the countries of Eastern Europe, where initial disproportions were not that big, recovery has already begun. On the other hand, in the countries of the former Soviet Union, whose economies had adopted the most a socialistic structure, recession is still on the agenda (Fig. 1).

Problem Definition

The aim of this paper is to create a simple evolutionary game theoretic model (following the theory described in Weibull, 1996) of a transition economy based on the assumptions of the new institutional theory (North, 1990). This approach can be useful in understanding the processes, which take place in the countries with permanently changing institutional environment like the transition countries of Eastern Europe and the former Soviet Union (see Samuelson, 1997).

Methodology

Like neoclassical theory has been developed in order to model an economy near the equilibrium, one needs a different theory with a multiple equilibrium framework in order to model an economy in the permanent institutional and structural change. The evolutionary game theory (as in Weibull, 1996) is believed to work well in the environments alike.

In evolutionary game theoretic terms we can think of an economy as a population of agents (firms), which are trying to adjust to the changing environment. Institutions define formal rules (laws), which make economic transactions

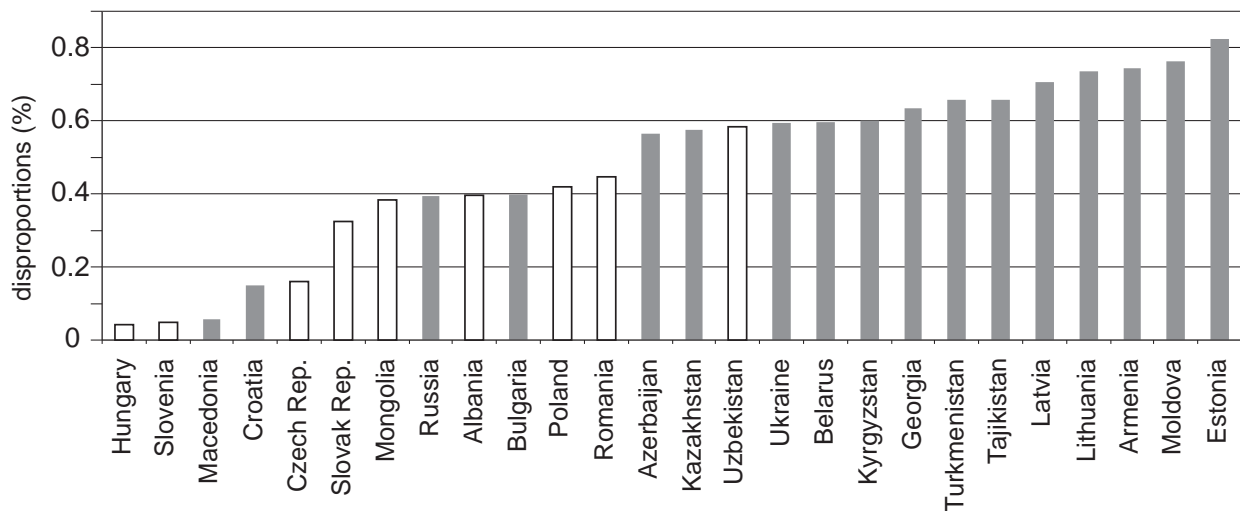


Fig. 1. Disproporitions in transition countries taken in comparison with the economies of developed countries (Popov, 1998). Light bars are countries with steady growth; dark bars are countries with steady recession. () Growth in Mongolia and Albania can be possibly explained by "advantage of underdevelopment"; (**) in Croatia and Macedonia absence of growth may take place because of the military conflicts.*

between agents enforceable. Institutions weakening entails growth of uncertainty i.e. increase in transaction costs and diminution in efficiency of the entire economy. And this is argued to be the cause of transformational recession.

Consider the population of agents which contract (play) with one another. Each agent belongs to one of the three economy sectors: 1) old sector (the one which creates disproporitions in the economy and which should be rebuilt during the transition process); 2) shadow sector (which consists of informal firms) and 3) new sector (firms that obey the laws of the market). Then, one can define the institutional environment as a function of the sizes of these three sectors. Each sector accommodates firms with a certain strategy. As the time passes, relative sector sizes change incrementally. Sectors with higher rate of return are growing because new firms enter them, sectors with lower rate of return are shrinking. This incremental process possesses a strong feature, which is important for the further analysis: path dependence.

Agents as Players

Agents (firms) play (contract) with one another. It is assumed that each agent has two *pure strategies*: either to comply with the law or not. I.e. agents are either "*honest*" and respect the law, or they are "*dishonest*" and do not follow the rules. An agent has different payoffs depending on its strategy and on the strategy of agent it plays with. These four payoffs p_o, p_{os}, p_{so}, p_s can be seen on Fig. 2:

	Official	Shadow
O	$p_o ; p_o$	$p_{os} ; p_{so}$
S	$p_{so} ; p_{os}$	$p_s ; p_s$

Fig. 2. Payoff matrix (Row; Col)

- Both agents play officially and get payoff p_o (agents, both complying with the law get high payoff);
- Both agents play in the "shadow" and get payoffs p_s (two shadow agents get low payoff);

3. One agent plays officially, another agent plays in a shadow. The former gets payoff p_{os} , the latter gets payoff p_{so} (shadow player gets super-profit, agent playing officially gets nothing, $p_{os} = 0$).

Two conditions are assumed to hold: $p_{os} < p_s < p_o < p_{so}$ and $p_{os} + p_{so} < 2p_o$. The payoff of “honest” agent dealing with “dishonest” should be less than payoff of dishonest agent dealing with the one alike ($0 = p_{os} < p_s$); payoffs from contracting officially should be greater than payoffs from contracting informally ($p_s < p_o$); and payoff of dishonest agent who is “cheating” the honest one should be greater than payoff got by each agent in the game with two official players ($p_o < p_{so}$). The game with such constraints is called Prisoner’s Dilemma (Fudenberg, Tirole, 1998).

Firms’ Strategies

Thus, it is a pure strategy that defines agents’ choice of either being “honest” or “dishonest” in each concrete case. In a course of time agents play with one another more than once. Such kind of game is usually called Iterated Prisoner’s Dilemma. Agent (a firm) can either use only pure strategy (i.e. play only officially or informally all the time) or choose its behaviour according to the games it has already played. Each agent remembers the history of games it has played with each other agent. For example, agent can play officially with agents, which played with it officially before, and informally with ones, which played informally in the past (Tit-for-Tat strategy).

The number of iterations in this game is not known to the agents. So, infinite number of strategies can be realized in this environment. But we need only three strategies (we have only three different sectors). Thus, we consider the following structure.

Firms from the old sector always play official pure strategy. It means that whomever they deal with they always comply with the law. Firms of the shadow sector regardless of their counteragent’s strategy always use pure shadow strategy. And firms of the new sector play Tit-for-Tat, i.e., playing with each their counteragent, they simply repeat its previous move (but being honest in their nature the first move they make in each game is an official one). Looking at the payoff matrix (Fig. 2) it can be seen that, when a firm from the old sector plays with a firm from the shadow sector, the former loses in all games played by these two firms and gets payoff p_{os} in each game, while shadow sector firm always gets maximum payoff p_{so} in each game. When a new firm plays with an old one, both get payoff p_o in all games played by them because, repeating official moves of old sector firm, new sector firm also plays officially. If a new firm plays with a shadow firm, then, playing officially the first time, new firm loses the first game to this shadow firm, but later on, mimicking the behaviour of this shadow firm, the new firm gets the same payoff p_s in each game, as this shadow firm does. In the series of games of two old firms, both old firms get payoff p_o in each game; in the series of games of two new firms, both new firms get payoff p_o in each game; and in the series of games of two shadow firms, both shadow firms get payoff p_s .

Mechanism of Evolution and Macroeconomic Indicators

In the real economy in the long-run the proportions of sectors change. This happens because in the sectors with higher rate of return more new firms emerge. This process in game theoretic setting is modelled as replicator dynamics.

The simplest approach to analysing such environment seems to be a computer simulation for this economy. To do that, we follow the standard tournament procedure and generate agent's interactions at the each time step. Replicator dynamics of the whole system is generated following the standard procedure explained for example in Weibull (1995).

In each tournament all the firms (agents) make a series of contracts with all other firms. Agents remember the history of games played with other agents only within one tournament period. In the end of the tournament the average

rate of return is calculated in each sector. Then, the share of each sector in economy changes proportionally to the current rate of return in this sector. Finally, the tournament is repeated, but with new recalculated shares of sectors in the economy.

GDP can be approximated here as a sum of profits of all the firms in economy. The ratio of the size of an old sector to the size of a new sector defines the disproportions coefficient. So, in the process of evolution we are able to keep track of macroeconomic indicator dynamics.

Path Dependence and Evolution

Referring back to the statement of the problem, it is worthwhile to ask if the model answers the main question: Which conditions could transformational recession be overcome under? Within the scope of the model the answer lies in the analysis of steady states. A simple analysis of dynamics shows that which steady state is reached depends on initial conditions (namely, on initial disproportions).

To demonstrate how initial conditions influence equilibrium selection, let us consider several particular cases of the model. Imagine that the size of an old sector is zero. Institutional environment consists of *one* firm in the new sector and many firms in the shadow sector. Playing only with shadow sector firms, new sector firm loses (in time average) because of its “honest” first move. Thus, during the evolution process this firm will die out. And, evidently, there exists a steady state where all firms are playing “dishonestly” or in a shadow, getting low profits. This means that Pareto-dominated equilibrium is reached, and the situation definitely excludes the possibility of growth.

Let us consider another example. In the economy, which consists entirely of the shadow firms, *several* new sector firms appear. Losing to the shadow sector firms, new sector firms, at the same time, are able to get higher profits from cooperating among themselves. And these profits are greater than profits of the shadow sector firms ($p_s < p_o$). Thus, we can argue for the existence of a threshold. If the ratio of the number of new sector firms to the number of

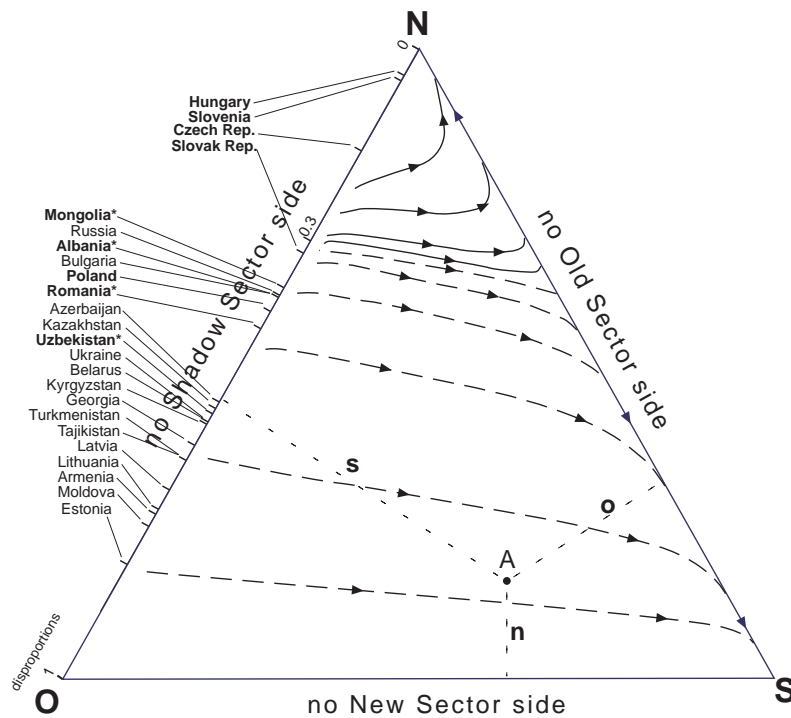


Fig. 3. Evolution paths. On the scale on the left countries are positioned according to the sizes of disproportions in their economies. In the countries, marked with bold, in the period between 1989 and 1996 the growth started, in all others there is no growth. (*) - Data is not precise (Mongolia and Albania, for example, face the “advantage of underdevelopment”)

shadow sector firms exceeds some critical level then the rate of return in the new sector, raised by mutual cooperation, will be greater than the rate of return of the shadow sector. In this situation, expansion of the new sector is observed along with shrink of the shadow sector. As a result, a (Pareto-dominant) steady state exists where all firms are playing officially (and therefore socially efficiently), getting high profits. So, we obtain the steady state, which is reached after overcoming the transformational recession. In this state only new sector is present and planned economy is fully transformed into the market one.

Two cases shown above are just two possible ways of development, which lead to different steady states. All possible paths are presented on the graph (Fig. 3). Each point inside the triangle represents structure of economy. For example, for point A the sizes of the new, shadow and old sectors are n , s and o respectively. Curves inside the triangle are the possible ways of development dependent on the starting conditions. Considering the examples above, it could be understood that depending on the starting conditions evolution leads to one of the two steady states: either only shadow sector remains or only new one does. These steady states correspond to points **N** and **S** on Fig. 3. Point **O** corresponds to the unstable equilibrium where only old sector is present (being invaded by the firm of any other type equilibrium breaks). So, once begun in any point of the triangle, path will end in either point **N** or point **S**. The model allows determining all the paths of the possible development and corresponding steady states.

Results

The model described above has been implemented as computer program. It models an economy represented by agents possessing three types of strategies corresponding to three sectors. Starting shares of sectors in the economy can be initially defined. Each of these states is presented by a point on Fig. 3. The program models populational dynamics of the economy.

The transition is assumed to start from shadow sector being almost zero. I.e. all the paths of dynamics begin on the side **ON** of the triangle. Each point on **ON** is characterised by the ratio of the old sector to the new sector. As

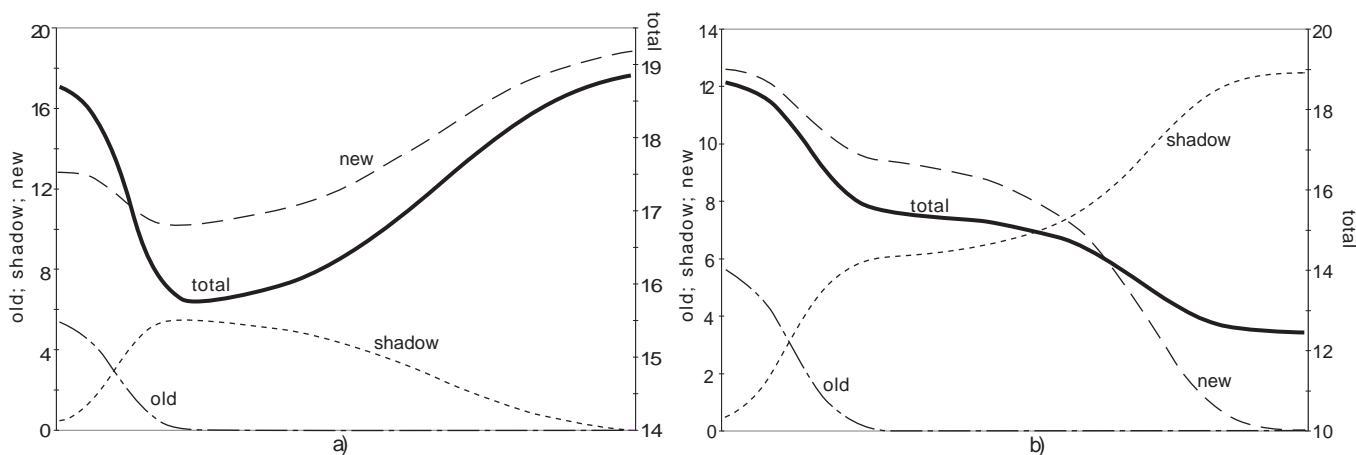


Fig. 4. Two types of transition dynamics: a) transition to growth; b) stable recession.

mentioned above, this ratio mirrors the disproportions coefficient. We have the data on disproportions and GDP in the transition countries economies (Fig. 1). These data make it possible to estimate the disproportions coefficient. It was found to be $Q_0 = 0.3$. Therefore, starting conditions with disproportions less than Q_0 lead to the stable growth and steady state in the point **N**, while starting conditions with disproportions more than Q_0 result in no growth and steady state in the point **S**. By changing matrix payoffs (but not breaking the conditions imposed) we can adjust our model in accordance with the real data.

So, we have two paths of development for the transition countries. Countries of the first type are ones, which have started to grow after the transformational recession (Hungary, Check Republic, Slovakia). Second type countries are the ones, which have not (Russia and the former USSR republics). Typical dynamics are shown on Fig. 4.

Conclusions

Despite of simplicity, the model has shown to mimic the real transition dynamics. This is argued to show the crucial role of institutional factors in the transition process. It is important that dynamics is determined by the starting conditions of the transition period and, therefore, path dependence.

It can be asserted that the presence of the institutions to enforce the contracts is the most important factor of economic growth during transition. Let us notice now that Russia happened to be among countries, which will suffer further recession, according to the model. How can we break this tendency? One of the ways is to influence the situation exogenously. It could be, for example, investments from abroad. But this is problematic at the moment. Another possibility is to strengthen the institutions by means of regular government reforms. We see that growth can be observed in the countries (Vietnam, China) with strong institutions regardless of big disproportions in their economies. Also it is possible to strengthen the contract enforcement in one or several industries and provide these industries with investments, in order to create conditions appropriate for growth. In the case of improvement in the main industries, one can expect that the entire economy will follow the trend.

The approach used could be enlarged to model this situation. In this case agents should contract not with all other agents, but only with limited number of their neighbours (spatially). By observing the behaviour of such enlarged model the new conclusions on dynamics of growth could be made.

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