Nash – Disequilibrium, Random Decisions and Imbalance of Society: Is it Relevant to Ukraine?

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Abstract:
Ukrainian society is undergoing rapid transformational changes. The authors attempted to identify the main behavioral strategies before the war as well as possible changes in the following years. Attempting to recognize the most prevalent behavior in society, the interaction and attitude of students during the exam were taken into consideration. The student group includes representatives of various regions in proportionate numbers. The research is based on the simulation of the interaction of different groups in society by means of game theory and programming. The study proposes using Schumpeter market disturbances and 'Nash disequilibrium' to invigorate the current ineffective system. It has been shown that pre-war Ukrainian society exhibited a very high level of collusion. The interim conclusions were tested using Axelrod's tournament algorithms and strategies. A simulation of the cooperative equilibrium in the Ukrainian society during the pre-war period was demonstrated. The study also contains important predictions about the changes in the institutional environment in the aftermath of the war in Ukraine.

Keywords: Ukrainian society, case study, mathematical modeling, Nash disequilibrium, Axelrod tournament

Introduction

As of 1991, the majority of the population in Ukraine could be described as Soviet people, i.e., a specific form of ethnic and cultural community that is primarily identified with the USSR. As an overall reflection of the *homo sovieticus* psychological type, Soviet people were characterized by specific psycho-physical features, first of all by paternalism. In 1991, the majority of Ukrainians were not only unprepared for market reforms but also avoided active engagement in social and political life. In this context, Dolishnij (2006, p. 115) remarked that "successful reforms in economy in general and the development of an efficient administrative system at the national and regional levels are impossible without the development of a civil society." In the present, we can state that Ukrainian society is characterized by the post-communist syndrome that is a specific pattern of individual symptoms: cognitions, attitudes, and behaviors developed during communist totalitarianism that persists during the period of transition to democracy (Klicperová 1997). The post-communist syndrome is manifested by:

- passivity (withdrawal, depression, helplessness, and collectivism), which prevents the individual from the development and use of his or her full abilities;

- naiveté: rigid persistence of old simplistic ideologies; responsiveness to superficial populist solutions; uncritical pliability to nationalistic and demagogic appeals; in extreme cases, joining in obedient aggression and acts of violence.

Therefore, considering historical and current features of the Ukrainian society, we would like to reveal the main behavioral strategies by analyzing the interactions among students during the exam, in realistic conditions, using mathematical models. The authors also propose models for the interaction between the main strategies in the Ukrainian society on the basis of the tournament of Axelrod, and make predictions about both the outcome of the conflict and main behavior strategies in the Ukrainian society following its end.

This study proposes the following hypotheses:

Hypothesis 1. The level of collusion in students groups (reflecting the society) is significantly high and this type of collusion is not rational.

Hypothesis 2. A mathematical kind of thinking eliminates or minimizes ineffective collusion.

Hypothesis 3. Highly decisive and creative strategies of the Axelrod tournament are going to be the most influential players in post-war Ukraine.

Hypothesis 4. The Prisoner's dilemma is not an adequate tool for describing the Ukrainian society.

1. *Theoretical background and literature review*

Axelrod and Hamilton (1981) described the evolutionary emergence of cooperation, emphasizing that "cooperation can get started by even a small cluster of individuals who are prepared to reciprocate cooperation" and "the shadow of the future is important enough to make this reciprocity stable." The cooperation and interaction between different actors can be analyzed by methods of the traditional microeconomics or macroeconomics (Blanchard & Johnson, 2017). But not far ago such approach was developed by researchers in the field of institutional economics, game theory (Gibbons, 1992; Friedman, 1990) and behavioral economics (Fudenberg & Maskin, 1986; Steuart, 1993; Thaler, 2015; Zafirovski, 2003).

Students group in the stressful environment (e.g., an exam) could become a good basis for the analysis of social interaction mechanisms. A thorough description of variables for analysis of such interaction was made by Webb (1982). He focused on the role of student's experience in small group interaction and singled out such input factors as giving help, receiving help, off-task activity, passive behavior and two mechanisms of bridging interaction (directly affecting and mediating variables).

Gillies et al. (2008) revealed that "reflection on individual learning processes takes some time, but it is a very efficient way for teachers to get feedback on what to change in their teaching – and it helps learners to establish competencies of self-regulation". They also proposed to change the methods of assessment.

What methods might be employed to conduct such an evaluation? Bilotkach (2006, pp. 31–49) examined the problem of tax evasion by enterprises through underreporting activity based on the equilibrium of the game between a businessman and an imperfectly monitored supervising official. The next scientific research, "Analysis of Institutions Interaction in the Ukrainian Economy" (2019), contains the proposition of the simple problem solving of the interaction between quasi-state authorities and related oligarchic groups, as well as other oligarchic groups without such sustainable support or some middle-sized enterprises without fixed property rights. The main idea was to solve this problem based on a competition game. In this case for modern Europe, competition is the opposite of cooperation. This is the traditional case of zero-sum game because the payoff of one player is equal to the losses of the other. Competition is the most important thing in such games because the players' interests are diametrically opposed.

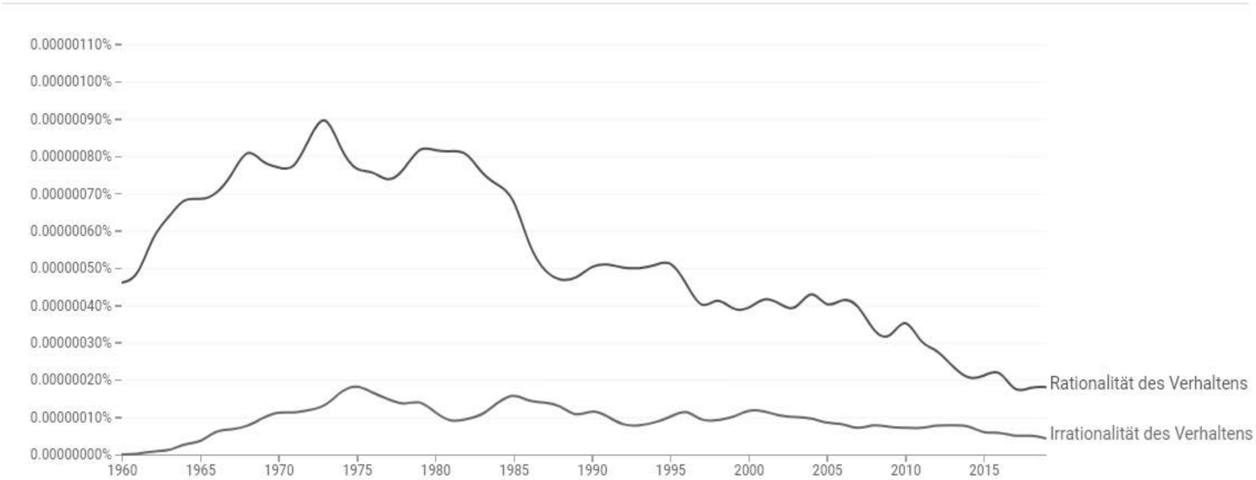
The Nash folk theorem states that essentially any payoff can be obtained as a Nash Equilibrium when players are patient enough, but such strategies may not be subgame-perfect, implying that they may not be rational in human nature (see: Fudenberg & Maskin 1986, pp. 533–554). Simultaneously, we are discussing rational players, which is a highly implausible initial postulation when analyzing human nature. For example, the model of repeated games proposed by Bilotkach has shown the absence of such rationality in the research community. The same opinion is reflected by Thaler (2015) who was awarded the Nobel Memorial Prize in Economic Sciences for his work on behavioral economics and has made the core analysis of this problem. Unlike the field of classical economics, where decision-making is based on cold-headed logic, behavioral economics allows for irrational actions and attempts to understand why this might be the case.

In general, rational behavior is defined by a necessary, natural, or logical association or adaptation between goals and means, as the Pareto's concept of logical action or Weber's types of social action suggests (Boudon, 1982). Using Ngram, we could examine a research interest in the issues of rationality and irrationality of behavior in English and German-language sources (Fig. 1, Fig. 2).

Figure 1. Interest for the irrationality in behavior (English – language sources)

Source: https://books.google.com/ngrams

Figure 2. Interest for the irrationality in behaviour (German-language sources)



Source: https://books.google.com/ngrams

This study is mainly based on the theories of R. Hall Varian, presented in the textbook "Microeconomics", who combines the tools and methods of game theory, institutional economics, mathematical analysis, innovation, and behavioral economics (Varian, 2010). Among other scientists, the issue of institutional interactions was analyzed by V. Bilotkach, J.W. Friedman, R. Gibbons, S. J. Grossman, O. D. Hart, C. Hurtado, J. H. Moore, and J. E. Stiglitz. Besides, the professor of Political Science, Robert Axelrod, has proposed a tournament based on The Prisoner's Dilemma (1980), prompting the analysis of hundreds of different strategies. In the modern version of the game, the Python code allows us to perform such calculations more quickly and efficiently.

Lee Ch. and Lee Ch-H. (2023) underline that in human civilization, people cooperate with one another "even when it logically makes more sense to do otherwise at the time". They looked at the prisoner's dilemma issue from a different angle, concentrating on the performance of the group as a whole. The goal was to maximize the group's overall benefit, regardless of how each player performed.

Thus, the authors believe that the toolkit proposed by classical games (Prisoner's Dilemma, Chicken Game, etc.) is perfectly complemented by the interactions of strategies based on the Axelrod tournament. This initial approach enables us to foresee outcomes of the war and the main strategies of the Ukrainian society after it is over. The presence of such powerful players as Backstabber and Stalker in society, in our opinion, created the prerequisites for the remarkable examples of strength and courage of the Ukrainian people we observe now.

Karhina, Ghazinour, Ng, & Eriksson (2017) argue that social capital transforms during military conflict with changes happening both in cognitive and structural components. Authors pay attention on changes occurring in bonding social capital, where new formation such as brotherhood, emerges and replaces previous bonding ties with family and friends. New forms of social capital are generated through the existence of voluntary services, and these networks provide essential social support in times of military conflict. Perceived support softens negative emotional responses to traumatic events. In line with the stress-buffering model, the results reveal that the formation of new social capital in times of military conflict may protect against the negative mental health effects of these experiences.

2. *Methodology and data sources*

The data concerning student participation in the entry examinations was obtained autonomously. The students were evaluated on their ability to think mathematically, graphically, and intuitively. The ability to cooperate is manifested in the combination of several factors: a longer period of communication with the group, understanding the inefficiency of the group's decision (based on a clear analysis given by the lecturer), but the refusal to make a personal decision because the group decided otherwise.

The study contains a range of methods of game theory and economic-mathematical modeling. A variety of linear and logistic regression models were constructed to assess relationships between factors. When it comes to discrete variables, only soft correlation estimates were calculated. Some estimates are based on regression analysis, taking into account the problem of continuity of variables. Besides, the results of sociological surveys of GFK Ukraine on the values of citizens were used for the final assessment (Committee of Entrepreneurs of Lviv Oblast, 2006). In addition, the Axelrod Tournament (2015) was used for analyzing the strategies of individual social groups. A wide range of strategies allows us to implement an effective search for the nearest behavioral model. It was noticed the possibility of creating individual strategy and integrating it into the common Python code. The Python packages axelrod, matplotlib.pyplot, nashpy, and numpy have been used in the coding process.

3. Game theory models and results of the study

For analyzing the behavior of society, we organize a case study among students of the University (3 groups each of approx. 20 students) during the exam in 2019 with the aim of revealing most popular strategies. It was believed that the student group could be a close representation of the community or society.

With the aim of imparting the proposed vision, the lecturer encourages students to participate in an investment game. The investments in our case are the exam points. The possible maximum is 100 points. The student has the opportunity to invest in his exam 10 points. The points don't play an important role in this analysis, but they represent the analogy to the transfer of a right to take management decisions (like ownership rights), as in the case of elections. The game includes three stages (i.e. attempts) during which the rules are changed.

At the first stage, according to the lecturer, if students do not agree to take part in the game, they will pass the exam according to the general rules, but if they agree, they will get:

- additional 30 points, if more than 90% of students agree to participate in the game (i.e., to invest);
- (–15) points if less than 90% of students agree to participate.

The lecturer decided to talk with each student separately. What are the benefits of joining the game? On the one hand, it is assumed that human generally chooses the easier way to obtain something, and on the other hand, students do not know that the rules of the game could be changed on the next stages.

Generally, we redistribute our students into 2 groups: (***m***) students and (***k–m***) students that separately are able to make own decision but within groups they take the position of majority. The behavior of each individual immediately affects the entire system. The repetitive game will create the possibility for everyone to join a group that decides on the common interests (as in cases of the majority and the opposition). We're talking about repeatability, since every student has a right to take three attempts on each exam, and every subsequent exam has elements similar to the previous.

3.1 Solution of the game

It is assumed that ***k*** represents the overall quantity of students. The case no. 1 (Table 1) reflects the situation when $\mathbf{0{,}1*k \leq m \leq 0.9*k}$. At some point, these groups begin to work together (they have their leaders, frames, a type of behavior inside and outside the group, etc.). Accordingly, our payoff matrix takes the form presented in Table 1 (the case no. 1). In this case we obtain two Nash equilibriums. The first one reflects the decision 'to invest' by two groups: [m*30; (k–m)*30], while the second one – 'not to invest' both of them [0; 0]. So, in the first equilibrium – all students obtain 30 points, while in the second one – 0 points. If the Group (M) decides 'to invest', while the Group (K–M) decides 'not to invest,' then we obtain the result: [–m*15; 0]. Simultaneously, if the Group (M) decides 'not to invest,' while the Group (K–M) decides 'to invest,' the result is: [0; –(k–m)*15]. So, the last two options reflect the loss of 15 points for one group and 0 points for another group of students (Table 1).

Table 1. The game solution for the first stage of the exam

The case no.1 (the first stage)

		Group (K–M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*30; (k–m)*30	m*(–15); 0
	Not to invest	0; (k–m)*(–15)	0; 0

Source: own elaboration

The case no. 2 (the first stage)

		Group (K–M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*30; (k–m)*30	m*(–15); 0
	Not to invest	0; (k–m)*30	0; 0

Source: own elaboration

The case no. 3 (the first stage)

		Group (K–M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*30; (k–m)*30	30*m; 0
	Not to invest	0; (k–m)*(–15)	0; 0

Source: own elaboration

Assuming that **m < 0.1*k** we obtain the following payoff matrix (the case no. 2, Table 1). If the Group (K–M) decides 'to invest,' while the Group (M) decides 'not to invest,' the result is: [0; (k–m)*30], so the Group (K–M) obtains 30 points, while the Group (M) – 0 points. The other cells reflect the same results as previously in the case no. 1.

The case no. 3 (Tab. 1) presents a situation when **m > 0.9*k**. As in the previous two cases the equilibrium reflects the cell [m*30; (k–m)*30]. If the Group (M) decides 'to invest,' while the Group (K–M) – 'not to invest,' the first one obtains 30 points, while the other – 0 points (i.e., the cell [30*m; 0]). In the opposite situation, if Group (K–M) decides 'to invest,' while the Group (M) decides 'not to invest,' the first one obtain 0 points, while the second one loss 15 points (i.e. the cell [0; (k–m)*(–15)]).

Consequently, the only equilibrium in these three cases is the decision by two groups 'to invest.' So, the only good solution for the first exam is to participate in the game. In practice, students chose a strategy for participation in a game during their first exam without understanding the results of the solution. It was a common decision and no one made a step to stand out. It is noteworthy that the exam was on a completely different topic, unrelated to game theory. Besides, all students collect their points according to their own abilities (Appendix 1).

For the second day of the exam the lecturer changes rules of the game. Should the student decide to participate in the game, he has the potential to obtain:

- additional 30 points, if less than 90% of the students agree to participate (i.e. 'to invest');
- 15 points, if more than 90% agree to participate in the game.

Table 2 presents payoff matrix for three cases (the case no.1 [0.1*k ≤ m ≤0 .9*k], the case no. 2 [m < 0.1*k] and the case no. 3 [m > 0.9*k]).

In the first case, if two groups decide 'to invest' – all students loss 15 points. If one group decides 'to invest,' while the other 'not to invest' – one of them gets 30 points, while the other 0 points (i.e. the following cells: [m*30; 0]; [0; (k–m)*30]). If two groups decide 'not to invest' – all students have 0 points. In the second case we have the same situation except of the cell [0; (–15)*(k–m)].

If the Group (K–M) decides 'to invest,' while the Group (M) decides 'not to invest,' the first one loses 15 points, while the second one has 0 points. In the third case, if the Group (K–M) decides 'not to invest,' while the Group (M) decides 'to invest,' then the first one loses 15 points, while the second one has 0 points. So, in all three cases the best solution for all students is 'not to participate' in the game.

Table 2. The game solution for the second day of the exam

The case no. 1 (the second stage)

		Group (K – M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*(–15); (k–m)*(–15)	m*30; 0
	Not to invest	0; (k–m)*30	0; 0

Source: own elaboration

The case no. 2 (the second stage)

		Group (K – M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*(–15); (k–m)*(–15)	m*30; 0
	Not to invest	0; (–15)*(k–m)	0; 0

Source: own elaboration

The case no. 3 (the second stage)

		Group (K – M)	
		Invest	*Not to invest*
Group (M)	*Invest*	m*(–15); (k–m)*(–15)	m*(–15); 0
	Not to invest	0; 30*(k–m)	0; 0

Source: own elaboration

During the second day of the exam four students having an understanding of the game solution decided 'not to participate.' Meanwhile, the majority of the group has made the same choice without understanding, so their behavior was not sensible.

For the third day it was proposed the following solution:

If you agree to play game with the probability *p* you will get (Table 3, 4):

Table 3. Choice with taking into account the probability

45*m*p – 15*m; 45*(k–m)*p –15*(k–m)	–45*m*p+30*m; 0
0; –45*(k–m)*p + 30*(k–m)	0; 0

Source: own research

Table 4. Choices for different probability levels

In case 1/3<p<2/3		**In case p>2/3**		**In case p<1/3**	
>0; >0	>0; 0	>0; >0	<0; 0	<0; <0	>0; 0
0; >0	0; 0	0; <0	0; 0	0; >0	0; 0

Notes: equilibrium positions are underlined
Students were requested to solve the dilemma under the given condition: 1/3<p<2/3.
Source: own elaboration

The current state of affairs reflects the usual situation in Ukrainian society, where the rules of the game are changing while it is still in progress (for example for the entrepreneurs during their business activity). In case of *Folk theorem* adaptation in our analysis the payoff matrix could be changed during the game not once. In fact, the possibility of the game rules being modified is significantly more than 1/3. In two other situations, we cannot anticipate the probable result of the Folk theory, because the subgame is divided into two different solutions and requires a mixed equilibrium system.

The initial difficulty was that the combined effort of the entire student group did not result in a conclusion regarding the problem solution. It was just a gesture of solidarity in the group. Thus, the researchers of the study comprehended the significance of hypothesis 1.

The questions were the next: *Why would you agree to the game if you can't handle the issue? Is it a tendency to make emotional decisions rather than rational ones?* The lecturer accepted that playing the game was a feature of selfish interest defense disability.

The answer of groups was 'to participate.' Following a brief debate, some students were able to modify their decisions with little difficulty. Some of them changed their position during the game, but only as a distinction between their own position and the general position, which was not sufficiently supported.

Thus, we accumulate the following student results data base:

- Graph – ability to think graphically;
- Math – ability to think mathematically;
- Intuit – ability to think intuitively;
- Col_pos – increasing time to collude and to discuss problem with others;
- Thinking speedily – speed of decisions (answers) preparing;
- Part_g – agree or disagree to participate in the game;
- Expected points – expected score on the base of own answers by student;
- Res_pr – part of the points depends on the group behavior, decision, knowledge on the base of connectivity of student and his group;
- Passed – result of exam (passed or not).

So, what are the factors influenced for the "Expectation points"? (Table 5).

Table 5. Influence factors for the Expectation points

	Dependent variable "**Expectation points**"					
Factors	**Graph**	**Math**	**Intuit**	**Col_pos**	**Res_pr**	**Part_g**
2 groups with one day period between exams Adjusted R^2=0,49; F = 6,65	0,23 (2,5*)	0,47 (4,9)	0,15 (1,6)	-0,12 (-1,2)	0,28 (2,9)	-0,09 (-1,12)
3 groups with 5 days period between 2nd and 3d exam additionally Adjusted R^2=0,74; F = 28,4	0,15↓ (1,8*)	0,53↑ (6,6)	0,24↑ (3,1)	-0,28↓ (-0,36)	0,1↓ (1,3)	0,14↑ (2,08)

** - t-statistics*
Source: own elaboration

By using the model "Logit" we try to determine the most influencing factors for the variable "Passed" in case of two and three groups (Table 6).

Table 6. Influence factors for the "Passed"

Factors	Dependent variable "**Passed**"			
	Mathematically	**Graphically**	**Intuitively**	**Constant**
2 groups with one day period between exams Cox&Snell R Square=0,57	Not used in model	5,05 (0,03**; 4,3*)	5,69 (0,017; 5,6*)	-3,2 (0,08; 6,9*)
3 groups with 5 days period to 3rd exam Cox&Snell R Square=0,55	Not used in model	6,083 (0,003; 8,8)	4,2 (0,005; 7,8)	-2,9 (0,001; 11,7)
3 groups with 5 days period to 3rd exam Cox&Snell R Square=0,599	**2,18 (0,045; 4,03)**	6,06 (0,008; 7,04)	4,09 (0,018; 5,56)	-3,5 (11,2; 0,001)

* - Wald-statistics, ** - Significance level

Source: own elaboration

Taking into consideration the appearance in the medium-term perspective the factor 'ability to think mathematically' we can suppose the appearance of rationality in the student choice (Table 7).

Table 7. Influence factors for the "participation in the game" (for third exam)

Dep. Var. 'Participation in the game.'						
Const	**Math**	**Col_pos**	**Res_pr**	**Graph**	**Intuit**	**Exp_p**
-2,266*	1,34	2,3	-0,028	-0,216	-2,2	0,123
2,932**	2,3	3,8	0,2	0,048	3,5	3,8
0,087***	0,122	0,049	0,651	0,826	0,06	0,045

Nagelkerke R Square=0,249. Percentage correct = 87,7%

* - B – coefficient; ** - Wald estimation; *** - Significance level (for the row)

Source: own elaboration

Thus, it can be conclusively stated that 'thinking mathematically' has been significantly altered during the 3rd exam (Table 6, 7, 8).

Table 8. Participation in the game and thinking mathematically

Factors	**Participation in the game (disability for the rational choice)**		
	Mathematically (type of thinking)	Collusion possibility (increasing time and improved conditions to collude)	Reservation price (ability for the team working)
2 groups with one day period between exams adj. R^2= 0,172; F = 3,42	-0,324 (-2,05*)	0,385 (2,04*)	0,195 (1,04*)

Notes: * - t-statistics
Source: own elaboration

So, it is obvious that our hypothesis 2 can only be verified in the short-term, but maybe it's only a characteristic of the present Ukrainian society.

Let us mention the "Beautiful mind" with a narrative of John Nash biography. Without any doubt mathematics is a science, which draws necessary conclusion. Mathematics is a way to settle in the mind of human a habit of reasoning (Fatima, 2017). Does the mathematical reasoning become an opposition to the not rational collusion? We can confirm this statement through the analysis of the 3rd exam's outcomes. As shown by the described models, mathematical reasoning is a way to the rationality (See also: Fatima, 2017).

Might mathematics be implemented as a tool to combat corruption? Yes, if the collusion is not a result of rational behavior. And in the same direction the decreasing of the period of communication with officials promotes the same result if the collusion is not rational.

Accordingly, upholding the exploration of mathematical strategies not only in the fundamental discipline, but its designation as a required subject of examination for admission to higher education is an instrument of state progress, an integral component of national security. Our next concern is the analysis of two possibilities. To start with, we shall look into the data of two groups: those apprised of the exam's conditions ahead of and during the test, and the other with an added day to prepare.

3.2 Folk theorem compliance

To ensure we are in compliance with the Folk theorem, it may be advisable to contemplate the ensuring result once both groups have concluded their exams (Table 9).

Table 9. Problem of rational choice

		Subgroup 1	
		Participate	*Don't participate*
Subgroup 2	*Participate*	-0,42*; -0,42	-0,42; 0,64
	Don't participate	0,64**; -0,42	0,77***; 0,77

Notes: * - COR (Expected point; Game participation), ** - COR (Thinking intuitively, Game participation), *** - COR (Thinking mathematically, Game participation). There is a pronounced disparity between utilizing intuition unaccompanied by thorough mathematical backing and mathematical proof that is clear to all. In light of our prior investigation, it is evident that the apprehension to collaborate sans rationale is directly proportional to a mathematical mindset. It was solely an intuitive response that drove the majority of students to engage in a collusive act during the second exam. And it was not a Nash equilibrium outcome. This behavior was not supported by mathematical reasoning.
Source: own research

It is not feasible to employ the correct methodology or attain this outcome for the third selection. Thus, logit regression coefficients are the exclusive method of computation applicable to the payoff matrix in this situation.

The 3rd group's exam could lead to the following outcome (Table 10).

Table 10. The Nash Equilibrium in accordance with the prevailing intuition

		Subgroup 1	
		Participate	*Don't participate*
Subgroup 2	*Participate*	0,123*; 0,123	0,123; 1,34
	Don't participate	1,34**; 0,123	-2,2***; -2,2 OR -0,216; -0,216

Notes: we use in this case *b*-coefficients of *Logit* – matrix for the * - exp_p, ** - math, *** - intuit OR graph. Students know from the previous experience that the most prudent mathematical choice is 'not to participate.'
Source: own elaboration

This solution does not include a review of the current game problem. Students analyze the experience of other groups during previous stages but don't try to solve the problem separately on the basis of the condition of the current task. So, we can suspect that negative expectations prevailed and this fact influenced the choice of group. This matrix summarized the result of the last day exam.

If we change variable 'expectation points' for 'collusion possibility', the following outcomes are observed (Table 11).

Table 11. Nash equilibrium in case of prevailed mathematical reasoning

		Subgroup 1	
		Participate	*Don't participate*
Subgroup 2	*Participate*	2,3*; 2,3	2,3; 1,34
	Don't participate	1,34**; 2,3	-2,2***; -2,2 OR -0,216; -0,216

Notes: we use in this case *b*-coefficients of *Logit* – matrix for the * - col_p, ** - math, *** - intuit OR graph.
Source: own research

In this case, we obtain a proper Nash equilibrium for our exam task. We had three days and three attempts for every exam, which were followed by discussion of the capability of employing the folk theorem. Nevertheless, this outcome is not rational. Examining politics yields similar results, often without a logical explanation. We are unable to quantify the exact profits and losses.

Let's consider in this case the 'Nash disequilibrium,' as opposite to the previous table (Table 12).

Table 12. Nash disequilibrium in the case of prevailed mathematical reasoning

		Subgroup 1	
		Participate	*Don't participate*
Subgroup 2	*Participate*	2,3*; 2,3	2,3; 1,34
	Don't participate	1,34**; 2,3	-2,2***; -2,2 OR -0,216; -0,216

Source: own elaboration

We choose the less desirable option to create disturbance on the market according to Schumpeter's[1] approach. It's the best result in the case of not rational choice. The system will then attempt to operate in spite of the actions of those who seek to disrupt it. The cooperation will be advanced through the mobilization of all system resources. Much like in case of Defector

[1] *Creative destruction* – a term coined by Joseph Schumpeter in "Capitalism, Socialism and Democracy" in 1942, describes the "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one". This occurs when innovation deconstructs long-standing arrangements and frees resources to be deployed elsewhere. Since Schumpeter, the term has been adopted into many other contexts outside of economic theory. See: *Creative Destruction*, https://goo.gl/aaVnJ2, [online: 20.08.2017].

activity (one of the strategies in Axelrod tournament) the society requires a Defector Hunter who, upon overcoming destructive forces will act mainly as a Cooperator.

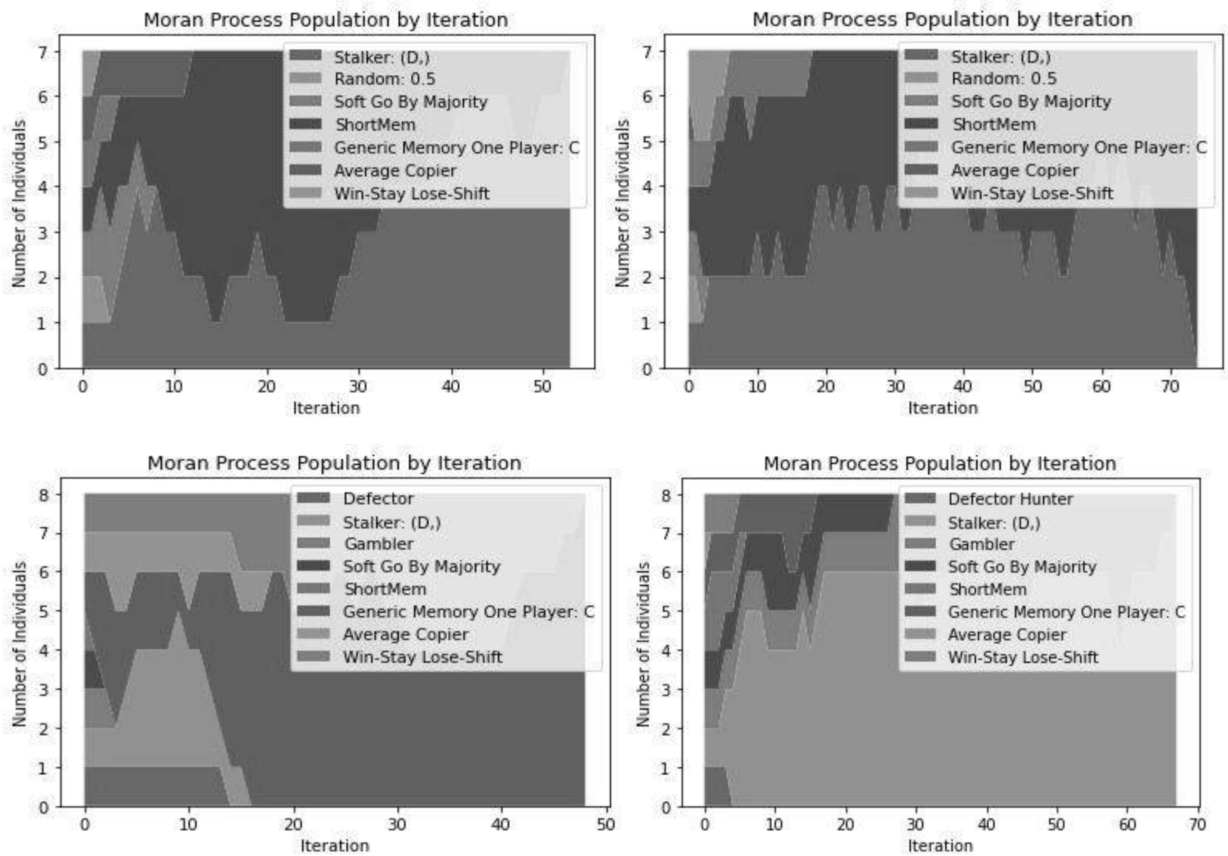
3.3 Modeling of the current state of society (the case of Ukraine)

According to our research, it would be feasible to develop a basic game for the various stages of Ukrainian timeline – pre-war, war-time and post-war. The above analysis allows us to propose the main behavioural strategies. Obviously, their list is not exclusive (Fig. 3), but at the same time it sufficiently identifies the majority of the players. The chosen strategies for pre-war period are Stalker, Random, GoByMajority, ShortMem, MemoryOnePlayer, AverageCopier, and WinStayLoseShift. This list will experience considerable modifications in the forthcoming stages. A Moran process was selected for the initial analysis. It is a commonly accepted practice in biology to describe finite populations and can be used as a way to simulate natural selection. In each time step a random individual is chosen for reproduction and for death; thus ensuring that the population size remains constant. It is obvious that such a simplified and unacceptable mechanism for society cannot be sufficient for our analysis. Code examples have been situated in Addition 2.

The model's factor 'noise' has been recognized mainly as a form of random errors. However, the more chaotic or ungoverned an atmosphere is, the more profound the level of randomness in the act of decision-making. It can be identified in terms of level of shadow economy. The player in such system has no intention for generosity or contrition. Simultaneously, effecting a prompt adjustment of strategy in the face of frustration of one's role appears to be a challenging accomplishment. Despite the parameters stated in the initial part of our article, the "Cooperation Strategy" in the context of repeated games proved successful, attaining the 50% level of the shadow sector, which is why it was included in the list of strategies: Average Copier and Go By Majority.

In time of Russian aggression, the system is replenished with a significant number of destroyers, which makes the strategy 'Defector' relevant (See also: Murthy & Lakshminarayana, 2006; Osiichuk & Shepotylo, 2020; Semigina, 2019; Shevlin, Hyland & Karatzias, 2022; Stadnik, Melnyk, Babak, Vashchenko, Krut, 2022). At the same time, this system is characterized by a minimum noise level due to significant trust in the authorities.

Figure 3. Modeling the interaction of the main strategies in Ukrainian society based on the Axelrod tournament



Notes: Moran Process. Game Upper Left (before the war): players = [Stalker, Random, GoByMajority, ShortMem, MemoryOnePlayer, AverageCopier, WinStayLoseShift]. Winning strategy is **Stalker.** Turns = 100 (long term). Game Upper Right (before the war): Turns = 25 (short term). Noise = 50%. Winning strategy is **GoByMajority**. Game Lower Left (war): Defector as additional player. Noise = 5%. Turns = 100. Winning Strategy is **MemoryOnePlayer**. Game Lower Right (after the war): DefectorHunter as additional player. Players = [DefectorHunter, Stalker, Gambler, GoByMajority, ShortMem, MemoryOnePlayer, AverageCopier, WinStayLoseShift]. Noise = 20%. Turns = 100 (the same result for Turns = 25). Winning Strategy is **Stalker**.
Source: own elaboration

Table 13. Winning strategies in conditions of different games

Game. Period.	*Conditions*	*Resulting ranking of strategies*
Chicken Game. War	turns = 100, noise = 0.05	Stalker, Generic Memory One Player, ShortMem …
Prisoner Dilemma. War	turns = 100, noise = 0.05	Defector, Generic Memory One Player, Stalker, …
Hunt Game. After war	turns = 100, noise = 0.2	Defector Hunter, Soft Go By Majority, ShortMem, Average Copier, …
Deadlock Game. After war	turns = 100, noise = 0.2	Stalker, Gambler, Average Copier, Soft Go By Majority, …
Investment Game. After war	turns = 100, noise = 0.2	Defector Hunter, Stalker, Soft Go By Majority, ShortMem, …

Notes: the differentiation in the noise level is explained by a significantly greater determination of goals during wartime. Additionally, the origination of the Defector Hunter technique is explicable by the obligation to oppose the Defector tactic implemented from external sources during the war.
Source: own research

What happens to such a system after the war? The noise level has restored to the pre-war level, however Stalker will only prevail in the instance of Deadlock game (Table 13). In this game, there is no conflict between self-interest and mutual usefulness. Here, we need to identify the characteristics of the 'Stalker' strategy. This is a strategy which is only influenced by the score. If *current_average_score* > *very good score*, it defects. It makes this player close to the innovator. In other cases a new player, i.e. Defector Hunter, enters the scene. This was crafted through intensive clashes with the Defector in a wartime environment. This player is unable to defeat the offender alone, yet with a customary combination of strategies, it emerges victorious.

Other model enables us to identify an additional significant player – BackStabber (Table 14). It could be determined as "Even my patience has its bounds." The impetus for this strategy arose from the financial turmoil and other predicaments in Ukraine, as well as the futile revolutions to oust the oligarchs. Concurrently, this gave Ukrainians the facility to oppose armed attack from a geographically proximate adversary who was militaristically more potent, but less tactical in approach. To avert the repercussions of this war-influenced policy, it is essential to create a state of affairs in which there is no discord between personal gain and collective advantage. Other words it means to go to Deadlock Game avoiding Prisoners Dilemma (*hypothesis 4*).

Table 14. More realistic approach for the strategy's identification

Original name of subgroup	*Proposed close substitute*	*Original name of subgroup*	*Proposed close substitute*
Conscious Galician	BackStabber	Thrifty individualist	Memory One Player
Philistine	Average Copier	Enterprising	Stalker
Postmodern	Alternator		

Data source: https://kpl.org.ua/news/2007/10/08/447. Some used strategies: AverageCopier: will cooperate with probability *p* if the opponent's cooperation ratio is *p*, Stalker: if current averages score > very good score, it defects. Strategies source: https://axelrod.readthedocs.io/en/stable/_modules/index.html

Table 15. Differentiation of games to determine the winning strategy

Game type	*Additional conditions*	*Winning strategy*
Hunt Game	Before the war, turns = 100, noise = 0.2	BackStabber
Deadlock Game	Before the war, turns = 100, noise = 0.2	Stalker
Chicken Game	In wartime, additional player – Defector, turns = 100, noise = 0.05	Stalker
Hunt Game	After the war, additional player – DefectorHunter*, turns = 100, noise = 0.2	BackStabber

Notes: * Defector Hunter – a player who hunts for defectors. This player will stay in game environment even after war that created this strategy. Strategies are borrowed from Table 14.

In line with the survey, GfK Ukraine divided Lviv residents (strongly pro-Western component of society) into five main categories in terms of value preferences. The identified number of 'Conscious Galicians' in Lviv was 26%. 22% were 'Philistine,' 20% – 'Thrifty individualists,' 19% – 'Enterprising' and 13% – 'Postmodernists.' If we adopt the same Axelrod's Tournament with 'Defector' in wartime and 'DefectorHunter' in postwar period, thus the optimal strategy will be 'BackStabber' or 'Stalker' (Table 15). It is evident that the Ukrainian society in its western region, as a result of the conflict, will be the predominant force, and is thus equipped to confront arduous trials, while also embracing the opportunity for entrepreneurial ventures and overcoming substantial impediments. This is a clear confirmation of hypothesis 3.

4. *Final remarks*

Most of the hypotheses presented by us have been confirmed by the present research (hypothesis 2 is only partially confirmed). The analyzed student audience has demonstrated three types of thinking. In short-term – intuitively and graphically thinking; while in long-term – mathematically one. In the context of the whole society, this is an excellent explanation for the fact that the language on the screen, the success of the costume of a candidate, or the appearance of actors in the list, suddenly makes a political party a winner of the elections. At the same time, troublesome grassroots work requires calculations, predictions, analysis, and can also be a winning strategy but on the basis of long-term work. The level of collusion in such an audience is very high. The individual behavior is rather the exception to the rules. The distorted ability to form a common position on the basis of an irrational decision is an obvious problem for social dynamics and development.

The ability to collude is correlated in the long-term with all three types positively, while in the short-term: mathematically – negatively, graphically and intuitively – positively. Mathematical reasoning is a way to diminish irrational cooperation and thus, for example, corruption, but only in the short-term. It can be suggested that a strong mathematical background is an essential component for a thriving and assured future of the state. If necessary, separate groups can cooperate, yet the aim of such cooperation and type of cooperation is illogical. Students analyze the current task (using 'mathematical reasoning' as an instrument) based on past experience, despite the new problem with changed conditions. Interacting collaboratively in this way does not render the most conducive outcome, since the decision has not been made on the basis of accurate data. Thus, the sense is of collusion against such cooperative behavior. Such collusion is possible in the long-term only if the mathematical reasoning is based on the correct statistical data. In the short-term, mathematical reasoning impedes irrational behavior.

In the case of Ukrainian society, the best choice in pre-war time was any of the options of 'Nash – disequilibrium' by making the disturbance on the market according to Schumpeter's approach of real entrepreneurial choice. In our opinion, this kind of conditional game took place in Ukraine, which created such a player as Backstabber in society. This strategy involves resilience, purposefulness, and the ability to sacrifice. The presence or even dominance of this strategy in the Ukrainian society became one of the reasons for the failure of the Russian aggression.

Another aspect of the Ukrainian victory can be considered the unacceptability of Prisoner's Dilemma-based interactions for Ukrainian society. It turned out that the Ukrainian society is capable of cooperation based on the Hunt game or Investment game. The best confirmation of this fact is pervasive volunteer activity. This outcome follows the same pattern as the research mentioned previously by Karhina, Ghazinour, Ng, & Eriksson (2017).

Thus, we believe that the war significantly changed the prevailing strategies of the Ukrainian citizens. Axelrod's tournament can serve as a simple and effective analysis of such changes. If in pre-war time the noise level (random decisions due to the imbalance of society and economy) was approximately at 50% (which is confirmed by repeated erroneous elections and the resulting Maidan), then in post-war it will be significantly lower. We can predict that Ukraine will move from a society of cooperation between ineffective players like in our intuitive previous game (Table 13) to the prevailing strategy 'Stalker'. This will mean the formation of a demanding society that is always ready for protests and innovative approaches.

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Appendix 1. Students' abilities

	Student 1 …	**Student K …**	**… Student N (≈20)**
Graphically thinking ability	From 0,1 to 0,9	From 0,1 to 0,9	From 0,1 to 0,9
Mathematically thinking ability	From 0,1 to 0,9	From 0,1 to 0,9	From 0,1 to 0,9
Intuitively thinking ability	From 0,1 to 0,9	From 0,1 to 0,9	From 0,1 to 0,9
Level of collusion possibility	0 (K=0)	*K+1/≈20 (Group)	1
The way of thinking (slow, middle or fast)	0; 0,5; 1	0; 0,5; 1	0; 0,5; 1
Participation in the game	0 OR 1	0 OR 1	0 OR 1
Expectation points	From 51 to 100	From 51 to 100	From 51 to 100
Price of my choice*	From 1 to 100	From 1 to 100	From 1 to 100
Passed/not passed exam	1 OR 0	1 OR 0	1 OR 0

Notes: *How much I am ready to lose by taking into account my colleagues' wrong choice or weak preparation? Each group takes an exam in 3 stages, except for students who demonstrate ideal knowledge from the beginning.
Source: own research

Appendix 2. Code examples

Moran process

```
import random
import matplotlib.pyplot as plt
import axelrod as axl
players = [axl.OriginalGradual(), axl.AverageCopier(), axl.HardProber(),
        axl.Stalker(), axl.Cooperator()]
mp = axl.MoranProcess(players=players, turns=1825, seed=2)
populations = mp.play()
mp.winning_strategy_name
ax = mp.populations_plot()
plt.show()
```

………………….

Hunt game

```
import axelrod as axl
hg = axl.game.Game(r=3, s=0, t=2, p=1)
players = [axl.OriginalGradual(), axl.AverageCopier(), axl.HardProber(),
        axl.Stalker(), axl.Cooperator()]
tournament = axl.Tournament(players, game=hg)
results = tournament.play()
results.ranked_names
```

………………….

Deadlock game

```
import axelrod as axl
dg = axl.game.Game(r=1, s=0, t=3, p=2)
players = [axl.OriginalGradual(), axl.AverageCopier(), axl.HardProber(),
        axl.Stalker(), axl.Cooperator()]
tournament = axl.Tournament(players, game=dg)
results = tournament.play()
results.ranked_names
```

....

Investment game

```
import axelrod as axl
ig = axl.game.Game(r=30, s=-15, t=0, p=0)
players = [axl.OriginalGradual(), axl.AverageCopier(), axl.HardProber(),
    axl.Stalker(), axl.Cooperator()]
tournament = axl.Tournament(players, game=ig, turns = 1825, noise = 0.1)
results = tournament.play()
results.ranked_names
```

....

Chicken game

```
import axelrod as axl
chg = axl.game.Game(r=0, s=-1, t=1, p=-10)
players = [axl.OriginalGradual(), axl.AverageCopier(), axl.HardProber(),
    axl.Stalker(), axl.Cooperator()]
tournament = axl.Tournament(players, game=chg, turns = 1825, noise = 0.1)
results = tournament.play()
results.ranked_names
```