Studia Sieci Uniwersytetów Pogranicza | 2023 | 7
DOI: 10.15290/sup.2023.07.07

Adrian Korkus

- University of Lodz
- e-mail: UL0245817@edu.uni.lodz.pl
- ORCID: 0009-0008-0249-8793

RATIONAL AND COOPERATIVE STRATEGIES IN AN ARMS RACE. CONCLUSIONS FROM EMPIRICAL RESEARCH

Abstract

- *Goal* – this article describes a proposed model of arms race game and the results of its application in an experiment measuring the inclination of human players to participate in a non-productive competition such as an arms race.
- *Research methodology* – methods in this research include: designing a game of an arms race based on a prisoner's dilemma and one dollar auction, theoretical analysis of strategies to determine the best rational strategy for the player, conducting the experiment in various conditions and comparison between theoretical and empirical results.
- *Score/results* – the analysis of various strategies showed that the most rational strategy is the minimum expenditure on armaments to allow effective defense against an adversary. The empirical results showed that players spent significantly higher amounts on armaments than theoretical predictions would have assumed, and 15 out of 26 games did not end close to Nash Equilibrum, which showed that the participants did not play according to rational calculation. The ability to communicate effectively resulted in players being more cooperative. In addition, those who said they played computer games performed better than the others, and finance and accounting students were more likely to choose strategies based on competition. The research supports the thesis that people are inclined to compete even when the competition brings them losses.
- *Originality/value* – the proposed game of an arms race is a new model, that can be used to simulate an arms race and to measure rationality of human players. The conducted experiments also provide evidence about human behavior regarding choosing cooperation or competition.

Keywords: game theory, competition, experimental economics, arms race.

1. Introduction

The arms race is a competition between two or more contenders spending large amounts of resources to achieve military superiority, deter other rivals and exert political pressure. That phenomenon clearly demonstrates how competition can lead to waste when efforts are not aimed at improving the overall welfare, but at gaining an advantage over the rival. The research hypotheses that are to be tested in this article regard the following: human players are more willing to play cooperatively than the rational player would; certain game conditions such as increased profitability of cooperation or communication between players can result in the more cooperative play, and finally, that certain personal features, such as playing strategy or multiplayer games, field of study, political views, gender, and personality traits can influence the way the players behave. The methods used to examine these hypotheses involve: formulating a game model based on the previously proposed arms race models in which players would make decisions about allocating resources to peaceful development or arms building; conducting the experiment in which students of the Faculty of Economics and Sociology at the University of Lodz played the game of An Arms Race; performing statistical tests to measure the results of the research. As it will be shown, human players tend to play more aggressively than predicted and some of the mentioned game conditions and personal features influence the game.

2. Historical examples and modelling of an arms race

Before the atomic age, one of the examples of an arms race was the construction of a fleet of battleships in the early 20th century. According to the Fleet in Being doctrine, their very existence was intended to put pressure on the enemy. The main rival to Britain before WWI was Germany (Germany's GDP in 1914 was $244 billion and Britain's was $226 billion [Broadberry & Harrison, 2005: 7, 10]), and after WWI – Japan and the US. In January 1919, these countries had battleships and battlecruisers in numbers: Britain – 52, the US – 39, Japan – 17. The arms race was a heavy burden on the economies (HMS Dreadnought in 1906 the cost the British economy was about £1.7 billion [Ross, 2010]), so in 1921 the Washington Conference was convened, stipulating a halt in battleship construction for 10 years and a reduction in the number of battleships (Britain and the US to 18, Japan to 6) and limits on the tonnage of line ships in the fleets of these countries [Dyskant, 1983: 119]. A second example is the atomic arms race that began in 1949, when the Soviet Union developed its own atomic bomb. Further advances in technology led to the invention of intercontinental ballistic missiles (ICBMs) and nuclear submarines, which gave rise to the Deterrence Doctrine, which relies on the ability to inflict losses on the attacker and outweigh the benefits of victory and the enemy's awareness of that ability. However, it required large expenditures, the USSR's spending on armaments in 1950–1970 was 20% of the national income, while the US was 10% [Ricón, 2016]. To reduce the scale of armaments, negotiations and agreements were initiated, such as the Nuclear Test Ban Treaty of 1963 [Schwelb, 1964], the Nuclear Non-Proliferation Treaty of 1968 [United Nations Office for Disarmament Affairs, 2021], the ABM Treaty [Sofaer, 1986], SALT1 in 1969–1972 [Holzer, 2012: 557]. This period of agreements called Détente lasted until the late 1970s. In the 1980s, President Ronald Reagan significantly increased arms spending and pursued a confrontational policy toward the USSR, announcing work on the Strategic Defense Initiative project [Atomic Heritage Foundation, 2018; Nuti, 2009: 99]. This was a defense system against Soviet missiles using orbital weapons, capable of challenging the existing Deterrence Doctrine. Combined with the increased spending on arms, it put pressure on the Soviet Union in its final years.

Game theory scientists have noted parallels between the arms race Auction for a Dollar [Costanza, 1984], in which the sunk costs incurred to win the top prize drove players to persist in this costly competition. As in the Auction for a Dollar, the powers incur expenditures on armaments to gain an advantage, offset by the analogous actions of the opponent.

Ploeg and Zeeuw [1987], on the other hand, compared the arms race to the Prisoner's Dilemma, according to which players can choose cooperation or a selfish strategy that gives a player a better outcome, regardless of the other player's choice, but the choice of this strategy by both players results in worse outcomes for them than cooperation. The matrix of such a two-player game is as follows (the number of pluses and minuses at the payoffs represents the scale of benefits):

Table 1. Arms race as the Prisoners' Dilemma

US / USSR	Armament	Disarmament
Armament	Costly Safety (-/-)	US Advantage (++/--)
Disarmament	USSR advantage (--/++)	Safety and prosperity (+/+)

Source: the author's own work.

They formulate the gun vs butter dilemma [Ploeg & Zeeuw, 1987], in which two states choose between raising the welfare of their populations through an increase in leisure time and in the production of consumer goods and producing weapons to ensure security. In this model, security is an increasing function of one's own weapons stockpile and a decreasing function of an enemy power's weapons stockpile. The cooperative solution in such a scenario would be to refrain from expanding military capabilities.

Another model is presented by Michael Intriligator and Dagobert Brito [2018], according to which powers with similar high nuclear capabilities are in an "equilibrium of fear" situation, in which peace is guaranteed by the specter of unacceptable and unavoidable damage [Wolfson, 1987]. Simply put, the model is based on the variables specific to each of the powers, which are the number of ballistic missiles (*M*), the ability of one's own missiles to destroy opponent's missiles (*f*) and the level of acceptable losses (*K*). Atomic peace takes place if the following inequalities are satisfied:

$$\begin{cases} M_a \geq f_b M_b + K_b \\ M_b \geq f_a M_a + K_a \end{cases}$$

If the difference in the arsenal of the powers is large enough, one of them will be ready to attack the other, according to the following transformation:

$$M_a > \frac{M_b - K_a}{f_a}$$

Lewis Richardson proposed a model in which military spending is a function of an adversary's military strength (positively), the level of one's own military potential (negatively), and some fixed level of resentment toward the other country (positively). This model is expressed by a system of equations:

$$\begin{cases} \dot{x}_1 = \alpha_1 x_2 - \beta_1 x_1 + \gamma_1 \\ \dot{x}_2 = \alpha_2 x_1 - \beta_2 x_2 + \gamma_2 \end{cases}$$

where the values of parameters α, β, γ (responsiveness, resistance, hostility) for each player are positive, $\dot{x}$ indicates the desired level of military strength and x indicates the actual level of combat potential [Richardson, 1960; Simaan, Cruz, 1975].

3. Research design

To formulate an Arms Race model, I will use game theory concepts according to definitions from Philip Straffin Game Theory, with the concept of game itself: “A game is a model in which at least two players participate (…), each player has a variety of possible strategies to choose from (…), the result of the game is determined by the combination of strategies chosen by individual players, each game result corresponds to a set of payoffs to individual players, the amount of which can be expressed numerically” [Straffin, 1993: 1].

The game of Arms Race involves two players being the leaders of two contending nuclear superpowers. The game can be described by the following rules:

1. the players have a certain initial pool of resources (resources, income, etc.).
2. the players play a certain unknown number of turns, during which they simultaneously decide how much of their resources they spend on investing in development and how much on armaments.
3. resources spent on investments increase the income in the next turn according to the return rate. Funds spent on armaments increase (in a 1 : 1 ratio) the player’s arms level.
4. At the beginning of the turn, players receive information about both players about the current arms level and income, and about the expenditures on armaments and investments from the previous turn.
5. If the difference between arms levels exceeds a given critical advantage threshold, the player with the higher arms level achieves critical advantage and wins, the game ends. The winner gets a high (highest possible) payoff, and the defeated player’s payoff is 0. If the game is not resolved after the last turn, the players’ payoffs are equal to the income they would have earned in the next turn.
6. The critical advantage threshold is not less than the difference between the players’ initial resources.

In this game, the players’ strategies in each turn will be the ratio of their arms and investments spending. The game is based on a gun and butter dilemma, but for simplicity I have assumed two variables. What is more, funds spent in the civilian sector are not spent on consumption, but invested, which puts the player in a better position in future turns. Instead of the security function as a component, the crossing of a critical threshold by one player creates the threat of losing everything for the opponent. The payoff for gaining a critical advantage is the equivalent of a bidding dollar in an auction, while both players are motivated and able to pay the cost to keep their foe from winning. Any outcome that does not end in one player being defeated is Pareto suboptimal against total disarmament (which means that at least one player would get higher payoff without loss of any other player), which is the equivalent of cooperation in the prisoner's dilemma and, due to the uncertainty of the opponent's actual decision, involves the risk of losing. The higher the critical advantage threshold, the lower the cost needed to prevent the opponent from winning. For example, if players start with equal income and the advantage threshold is 0, the dominant strategy would be spending all resources on arms (it would give victory if the opponent spent less, and protection from defeat if he spent the same amount on arms, any other strategy would lead to a worse result in every case).

In each turn, players have a certain resource d, arms levels Z, and their choice of pure strategies depends on a single variable $z \in [0, d]$ corresponding to the amount of resource allocated to armaments. I will use the labels Player A, Player B and denote their respective variables as d_a, d_b, z_a, z_b, Z_a, Z_b from now on. According to these variables and the critical advantage threshold k, we can indicate the following groups of strategies:

1. *Aggressive strategies* – are the ones that offer a chance for a "military" victory and force the rival to spend resources on arms. In the case of player A, this means that $z_a > k - Z_a + Z_b$.
2. *Defensive strategies* – ensure that in the current turn the opponent will not reach a critical advantage. For player A, this means that $z_a \geq d_b - k - Z_a + Z_b$, because even if player B spends everything on armaments, the difference of arms levels will be $(Z_b + d_b) - (Z_a + z_a) \leq k$.
3. *Peaceful strategies* – are the ones of arms spending lower than aggressive and defensive strategies.

The lower the arms spending, the higher the income in the future, which can be used for further investment or to replenish the arms level, so if no player wins in a given turn, lower arms spending is more beneficial. Since defense strategies are not aimed at gaining an advantage, but at security, the strategy where $z_a = d_b - k - Z_a + Z_b$ will be the best among them. From now on I will refer to it as the *minimal defense strategy*. If a player has decided to play aggressively, he should maximize the chance of winning by spending all resources on arms. Peaceful strategies should not assume a level of arms spending lower than that which gives protection against the minimum defense strategy, which is $z_a \geq d_a - 2k$.

The game has no saddle point (situation in which the change of strategy by any player would not increase his payoff). The best response to an aggressive strategy is a defensive one, to a defensive one a peaceful one, and to a peaceful one an aggressive one. A rational player would assume that the opponent will play smart and if he can protect himself from losing, he will do so. Peaceful strategies, on the other hand, may induce the opponent to arm aggressively. Because of this, the minimal defense strategy seems to be the most sensible choice. It is also a maximin strategy (one that returns the highest payout assuming the worst-case scenario). The Nash equilibrium of mixed strategies (probability distributions according to which a particular strategy is chosen) would return the same expected value as the minimal defense strategy, but the minimal defense strategy produces a predictable outcome, which means lower risk. The constant choice of a minimal defense strategy can prompt the opponent to play a peaceful strategy and discourages the choice of an aggressive strategy, which is beneficial. On the one hand, it reduces the pressure on the player's armaments, and, on the other hand, it increases chances for a surprise attack. The above reasoning shows that the minimal defense strategy is the best strategy for a rational player. If both players choose the minimum defense strategy, their expenditures are as follows:

$$ArmsA = IncomeB - Treshold - Advantage$$
$$ArmsB = IncomeA - Treshold + Advantage$$

where *Advantage* is the arms level of player A minus arms level of player B. Investments can be described as the following:

$$InvestmentsA = Treshold - IncomeB + IncomeA + Advantage$$
$$InvestmentsB = Treshold - IncomeA + IncomeB - Advantage$$

We can see that the sum of both player's investments equals *2 * Treshold*. In the next turn, their income will be:

$$NewIncomeA = IncomeA + (Treshold - IncomeB + IncomeA + Advantage) * ReturnRateA$$
$$ewIncomeB = IncomeB + (Treshold - IncomeA + IncomeB - Advantage) * ReturnRateB$$

It means that their new minimal defense strategies will be:

$$ArmsA = IncomeB + (Treshold - IncomeA + IncomeB) * ReturnRateB - Treshold - Advantage$$
$$ArmsB = IncomeA + (Treshold - IncomeB + IncomeA) * ReturnRateA - Treshold + Advantage$$

Amounts of investment in the new turn would be:

$$InvestmentsA = IncomeA + (Treshold - IncomeB + IncomeA) * ReturnRateA - IncomeB - \\ -(Treshold - IncomeA + IncomeB) * ReturnRateB + Treshold + Advantage$$

$$InvestmentsB = IncomeB + (Treshold - IncomeA + IncomeB) * ReturnRateB - IncomeA - \\ -(Treshold - IncomeB + IncomeA) * ReturnRateA + Treshold - Advantage$$

The sum of their investments will still equal:

$$InvestmentsA + InvestmentsB = 2 * Treshold$$

In some cases, minimal defense strategy is not preferable. For instance, if one of the players has a lower initial income but a much higher return rate, his rival would like to engage him in an arms race to hamper his investment and development.

Cooperative solution would be a total resignation of both players from arming themselves and investing all resources for a peaceful development. Such a scenario would give the best overall results.

4. Research results

For the sake of the experiment, I created a scenario in which both players have an initial resource of 20 and a return rate of 15%, the critical advantage threshold equals 12, the payout to the winner is 70, and the game lasts 8 turns. If both players had opted for full cooperation, their payoffs would have been 61.18. The predicted course of the experiments, assuming a minimal defense strategy chosen by both players, would have result in payoffs equal to 34.40, as shown in the Table 2:

Table 2. Minimal Defense Strategy

Turn	Income A	IncomeB	Arms A	ArmsB	InvestA	InvestB	ReturnA	ReturnB	ArmsLevelA	ArmslevelB	Advantage	Aggr.A	Aggr.B
1	20.00	20.00	8.00	8.00	12.00	12.00	1.80	1.80	8.00	8.00	0.00	0.00	0.00
2	21.80	21.80	9.80	9.80	12.00	12.00	1.80	1.80	17.80	17.80	0.00	0.00	0.00
3	23.60	23.60	11.60	11.60	12.00	12.00	1.80	1.80	29.40	29.40	0.00	0.00	0.00

Turn	Income A	IncomeB	Arms A	ArmsB	InvestA	InvestB	RetumA	ReturnB	ArmsLevelA	ArmslevelB	Advantage	Aggr.A	Aggr.B
4	25.40	25.40	13.40	13.40	12.00	12.00	1.80	1.80	42.80	42.80	0.00	0.00	0.00
5	27.20	27.20	15.20	15.20	12.00	12.00	1.80	1.80	58.00	58.00	0.00	0.00	0.00
6	29.00	29.00	17.00	17.00	12.00	12.00	1.80	1.80	75.00	75.00	0.00	0.00	0.00
7	30.80	30.80	18.80	18.80	12.00	12.00	1.80	1.80	93.80	93.80	0.00	0.00	0.00
8	32.60	32.60	20.60	20.60	12.00	12.00	1.80	1.80	114.40	114.40	0.00	0.00	0.00
9	34.40	34.40	–	–	–	–	–	–	–	–	–	–	–

Source: the author’s own work.

The empirical study was conducted using files made in Excel and placed on a network drive. Each player had his own interface file, which allowed him to decide on the distribution of resources and to transfer decisions to a record file, from where data could be downloaded for the next turn. The experiment was run at the Faculty of Economics and Sociology at the University of Lodz. 52 people participated, mainly students of *Economics* and *Finance and Accounting*. Participants could win money equal to the payoffs received in the game (from 0 to 70 PLN). The players were split into three groups according to the following scenarios (a lower return rate in group 1 was balanced by a higher number of turns to make the expected payoff similar, a lower return rate is supposed to make players willing to spend less on investments and more on armaments):

Table 3. Groups of players

Group	Initial income	Critical advantage treshold	Return rate	Communication between players	Number of turns (secret)	Number of players
1	20	12	10%	Not allowed	11	26
2	20	12	15%	Not allowed	8	14
3	20	12	15%	Allowed	8	12

Source: the author’s own work.

Each group participated in the experiment in separate rooms (2 and 3) or on different days (1), so they had no contact with each other, and no participant took part in the game more than once. Groups 1 and 2 were arranged so that players in the same pair sat on the opposite sides of the studio and could not communicate or see each other's interfaces. In group 3, players sat facing each other so that they could not see each other's interfaces but were able to communicate and were given paper and pens. The research examined whether the following variables influenced the way the game was played:

- Return rate 15% vs 10%;
- Possibility of communication;
- Gender;
- Field of study;
- Gaming (especially strategy and MMO games);
- Economical views (left vs right) and social views (liberal vs conservative);
- Personality traits – declaration of being guided by feelings or rational calculation, sociability, trust in other people.

The way the players played was evaluated in two dimensions:

- *Payoff:* which players received.
- *Aggresiveness:* The average (of all turns) of the difference between a player's actual arms spending and that of the minimal defense strategy. Positive values indicate higher arms spending, negative values indicate lower spending.

For all tests, I assumed a significance level of 0.05. The distribution of players' scores is not close to a normal distribution due to the extreme values (0 and 70), but the scores of the games that not ended in victory of one player are close to a normal distribution, as are the levels of aggression. There were Kolmogorov-Smirnov (D) and then t-student (t) tests for distributions close to normal and Mann-Whitney (z) for the rest. On average, players spent 5.25 more on arms than indicated by the minimum defense strategy. The payoffs were similar to those predicted (32.28 vs. 34.40), but 15 of 26 games ended up exceeding the critical advantage threshold. This means that the players are not playing rationally. The test results are shown in the Tables 4 and 5:

Table 4. Overall test

Attribute	N	Kolmogorov-Smirnov Test Results	Observed value	Theoretical value	Significance (t-student test results)
Payoff	52	D(52) = 0,21, p = 0,021	32.28	34.40	No
Payoff (stalemate)	22	D(22) = 0,24, p = 0,126	28.58	34.40	Yes t(22) = -197.8, p < 0.001
Aggresiveness	52	D(52) = 0,085, p = 0,817	5.25	0.00	Yes t(52) = 5.02, p < 0.001

Source: the author's own work.

Table 5. Group comparison

Return Rate					
Attribute	Group 1 (10%) N = 26	Group 2 (15%) N = 14	Test value	p-value	Significance
Payoff	30.35	32.31	z(40) = -0.52	0.3	No
Aggresiveness	5.83	5.29	t(40) = 0.28	0.39	No
Communication Possibility					
Attribute	Group 2 No N = 14	Group 3 Yes N = 12	Test value	p-value	Significance
Payoff	32.31	36.43	z(26) = -0.18	0.43	No
Aggresiveness	5.29	0.63	t(26) = l.8	0.04	Yes

Source: the author's own work.

The example of two Economics students who coordinated their arms expenditures to be equal and then gradually reduced them to 0 is particularly noteworthy. In this way they both obtained a payoff of 49.43, a result closest to 61.18, which could be obtained by full cooperation and far higher than minimal defense strategy scenario. This is unfortunately an exception among the players, but it shows that peaceful cooperation is possible in such a game. The course of their game is shown in the table below:

Table 6. Pair of players cooperating

Turn	Income A	IncomeB	Arms A	ArmsB	InvestA	InvestB	ReturnA	ReturnB	ArmsLevelA	ArmslevelB	Advantage	Aggr.A	Aggr.B
1	20.00	20.00	9.00	9.00	11.00	11.00	1.65	1.65	9.00	9.00	0.00	1.00	1.00
2	21.65	21.65	10.61	10.61	11.04	11.04	1.66	1.66	19.61	19.61	0.00	0.96	0.96
3	23.31	23.31	9.09	9.09	14.22	14.22	2.13	2.13	28.70	28.70	0.00	-2.22	-2.22
4	25.44	25.44	6.61	6.61	18.82	18.82	2.82	2.82	35.31	35.31	0.00	-6.82	-6.82
5	28.26	28.26	0.00	0.00	28.26	28.26	4.24	4.24	35.31	35.31	0.00	-16.26	-16.26
6	32.50	32.50	0.00	0.00	32.50	32.50	4.88	4.88	35.31	35.31	0.00	-20.50	-20.50
7	37.38	37.38	0.00	0.00	37.38	37.38	5.61	5.61	35.31	35.31	0.00	-25.38	-25.38
8	42.98	42.98	0.00	0.00	42.98	42.98	6.45	6.45	35.31	35.31	0.00	-30.98	-30.98
9	49.43	49.43	–	–	–	–	–	–	–	–	–	–	–

Source: the author’s own work.

Gender

No significant impact was proven:

Table 7. Gender comparison

Gender					
Attribute	Female (N=24)	Male (N=28)	Test value	p-value	Significance
Payoff	34.8	30.1	z(52) = -0.31	0.38	No
Aggresiveness	5.93	3.33	t(52) = l.46	0.076	No

Source: the author’s own work.

Field of study

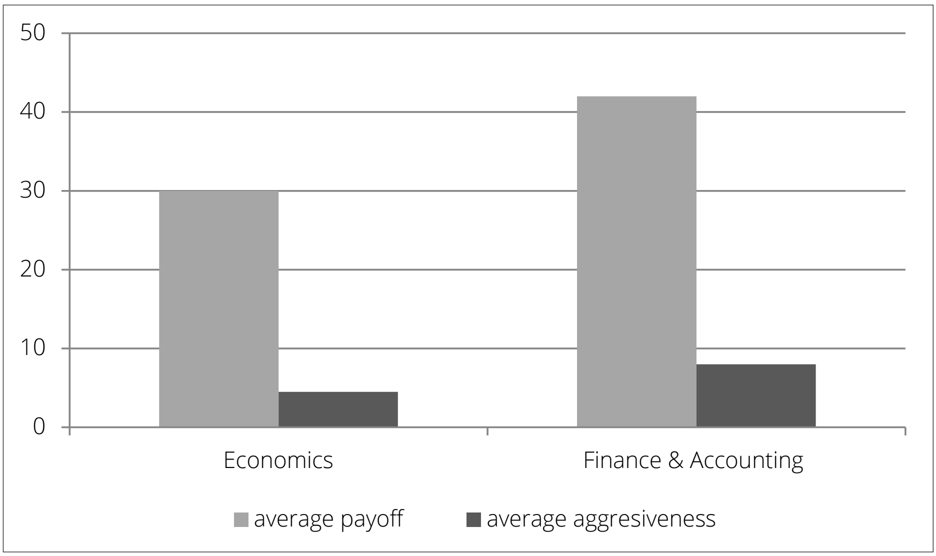
Finance and accounting students are more inclined to arms spending than Economics students:

Table 8. Field of studies comparison

Field of studies					
Attribute	Economics N=39	Finance & Acc. N=12	Test value	p-value	Significance
Aggresiveness	3.73	7.83	t(51) = -l.98	0.027	No

Source: the author's own work.

Plot 9. Field of study and playstyle



Source: the author's own work.

Gaming

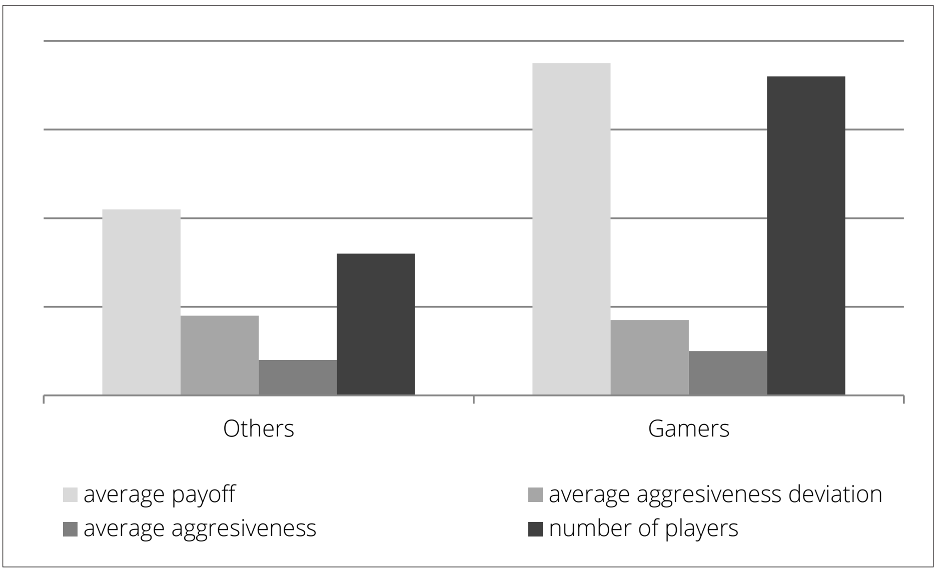
Those who play computer games (especially MMO games) gained higher payoffs than others:

Table 10. Gamers vs others

Field of studies				
Attribute	Yes N = 36	No N = 16	Test value	p-value
Payoff	37.22	21.19	z(52) = 2.14	0.016
MMO Games				
Attribute	Yes N = 21	No N = 31	Test value	p-value
Payoff	40.60	26.65	z(52) = -l.98	0.024

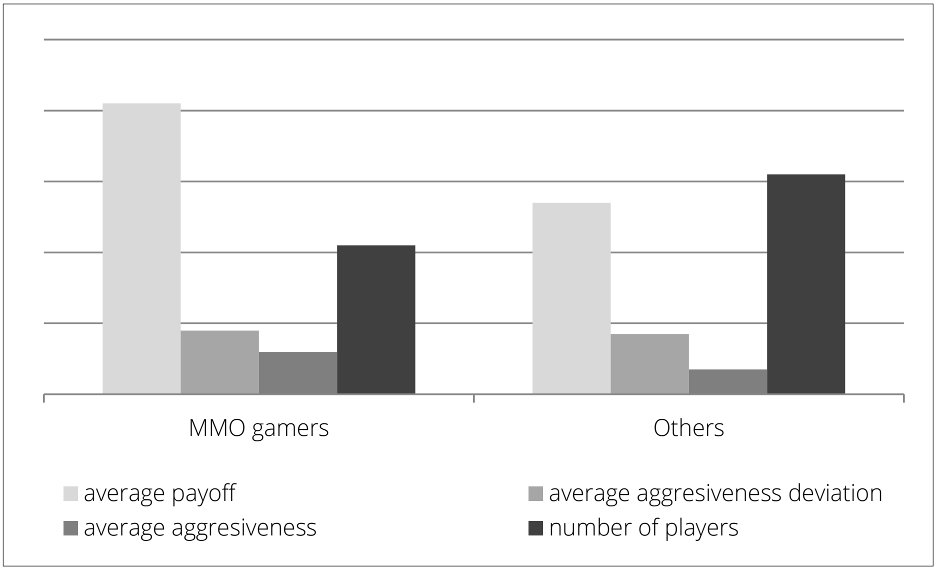
Source: the author's own work.

Plot 11. Gamers vs others



Source: the author's own work.

Plot 12. MMO gamers vs others



Source: the author's own work.

Political views

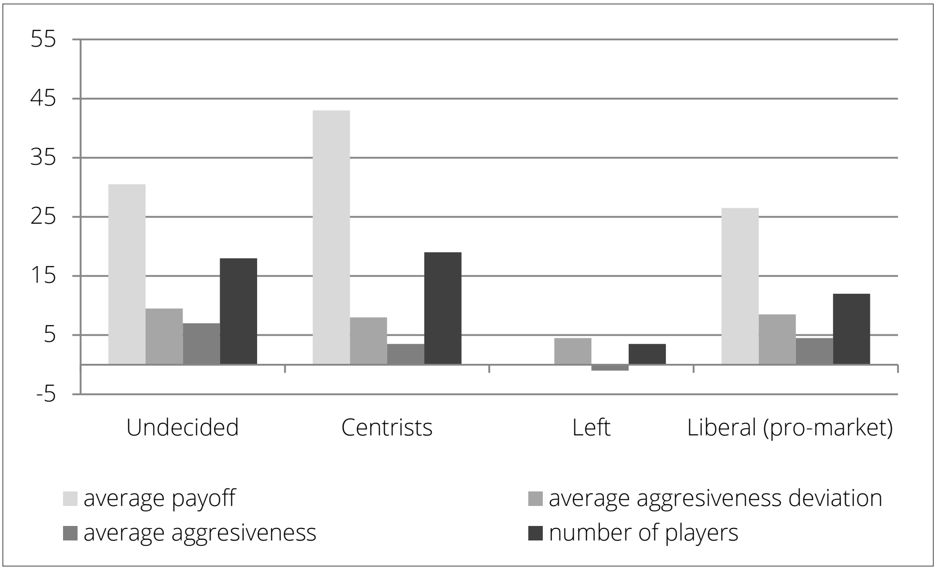
All players declaring left-wing economic views earned a payoff of 0. This was the only group in which the average arms spending was lower than the minimal defense strategy. All respondents declaring conservative views achieved a payoff of 70. Sadly, due to the small size of these groups (3 people each), we cannot make any conclusions about the general population. Players who declared centrist views on the economic field received higher payoffs than the rest of the respondents:

Table 13. Economical centrists vs others

Economical views				
Attribute	Centrists N = 19	Others N = 33	Test value	p-value
Payoff	42.86	26.19	z(52) = -2.41	0.008

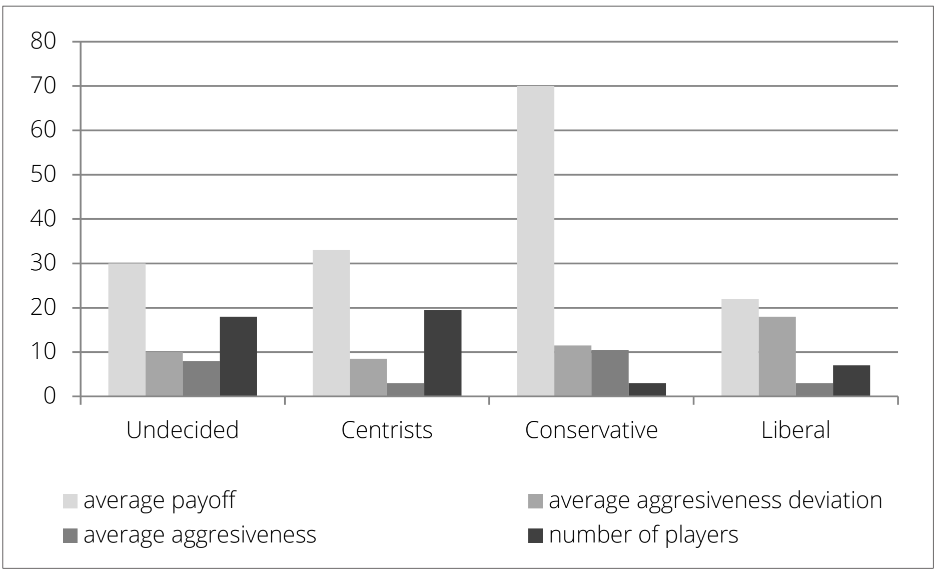
Source: the author's own work.

Plot 14. Economical axis views



Source: the author's own work.

Plot 15. Social axis views



Source: the author's own work.

Personality traits

No significant differences were found:

Table 16. Personality traits

Guided by feelings or rational calculation				
t(52) = -0.03	0.49	Feelings N = 23	Test value	p-value
Payoff	29.9	35.3	z(52) = -0.89	0.187
Aggresiveness	3.72	5.55	t(52) = -l.01	0.159
Sociability				
Attribute	Yes N = 27	No N = 25	Test value	p-value
Payoff	26.3	38.7	z(52) = -l.63	0.052
Aggresiveness	5.38	3.6	t(52) = 0.98	0.166
Trusting other people				
Attribute	Yes N = 30	No N = 22	Test value	p-value
Payoff	31.5	33.3	z(52) = -0.33	0.37
Aggresiveness	4.55	4.5	t(52) = -0.03	0.49

Source: the author's own work.

5. Discussion

A similar experiment examining the propensity to engage in harmful competition, namely a €1 auction, was conducted by Morone, Nuzzo and Caferra [2019]. Players, playing in pairs (or, in another variant, in two teams), were allowed to declare sums the nearest to 0.01 euro, and the declared amounts were paid by all players. The opponents were not allowed to communicate with each other (intra-team communication was allowed in group games). Although in theory Nash's equilibrium consisted of the declaration of a minimum bid by the first player and the second player giving up, the results of the experiment showed that both individual players and teams were engaged in bidding. For individual players, the average bid price of €1 was €0.77, while the cost to losers was

€0.68. For groups, these results were lower, at 0.51 and 0.43 euros, respectively, leading to similar conclusions.

We can also relate the conflict between cooperative and competitive action to the iterated prisoner's dilemma, where the most successful strategies in the computer simulations were variants of the tit-for-tat strategy with permissible forgiveness of the opponent one or two turns in which he played aggressively [Dawkins, 1996]. The success of this strategy was the ability to defend against aggressive players without sacrificing the potential gains of cooperating with peaceful players [Axelrod, 1981]. In my experiment, the player who chose the peaceful strategy could not make a rematch against the player who chose the aggressive strategy. Strategies that gave this advantage were defensive strategies, but these proved to be less frequently chosen than the aggressive strategies.

6. Conclusions

The model I proposed explains the tendency to incur expenses to expand the arsenal and the associated losses, as in the other arms race models I cited in my paper. As in the Prisoner's Dilemma or the Gun vs Butter Dilemma, rational action does not lead to Pareto optimal outcomes, because the players' efforts are counterproductive. Although the mutual disarmaments by players would lead to the best results for the group as a whole, the non-participation in the arms race poses serious dangers for a player, which would be exploited by opponents, as confirmed by the results of the experiment.

The research I conducted shows that the participants were willing to compete counter-productively to a greater extent than the desire for security would indicate. Players were willing to incur high expenses on armaments to increase their advantage over their opponents, thus accepting the excess costs even if the benefit of military advantage was uncertain and easily preventable. As expected, the ability of the players to communicate was a key factor that could induce them to reduce arms spending in favor of cooperation, however, cooperation under conditions of communication was not the norm, but the exception, indicating that this factor is not sufficient to solve the issue of futile competition.

Another finding of the study is the impact of computer games on people's strategic thinking. Strategy games require calculation and decision-making, and thus may develop players' intellectual abilities toward solving economic problems and enhance rationality in dilemmas like the one they faced in this experiment.

The higher tendency to arms spending among finance and accounting students compared to economics students may be explained by the general-academic nature of the economics of study and by the practical nature of finance and accounting. Additionally, students enrolled in the Finance & Accounting had higher high school diploma scores, which means that their tendency to compete may be higher.

Political views seem to have a role in the way the game is played, as those with centrist economic views scored higher than other players. Players with conservative views played aggressively and achieved victory, while those with economically leftist views played peacefully, which resulted in their loss. Unfortunately, the above-mentioned views occurred too rarely for us to try to find any correlation on this basis.

The study found no significant differences in the way the game was played or in its results depending on gender, sociability, trust in other people, or even the claimed guidance of reason or feelings.

The model I have formulated is a simplified description of the arms race and could be extended in several ways: critical advantage threshold would be replaced by continuous small benefits from higher arms level (such as the ability to export weapons to allied governments) or the possibility to monitor opponents' arms spending. Although the model describes a competitive situation within the military competition in the production of weapons of mass destruction, we can relate the studied phenomenon to social problems. These could be the funds that corporations spend on advertising their products to take away customers from competitors, which could be spent on research and development. Another example is voting systems in contests, where audiences send their votes via paid text messages. Simulating the competition of companies operating in the market requires other rules, such as rewards in the form of direct, albeit smaller, benefits from investing in advertising, instead of a large, but requiring a certain threshold, reward, or scenarios with more than two players. The Arms Race game, however, can serve as a basis for further games of this type allowing a better approximation of the institutional framework in which the indicated processes take place.

References

Atomic Heritage Foundation, 2018, *Strategic Defense Initiative (SDI)*, https://ahf.nuclearmuseum.org/ahf/history/strategic-defense-initiative-sdi [date of access: 25.11.2023].

Axelrod R., Hamilton W.D., 1981, *The Evolution of Cooperation*, "Science", No. 211(4489), pp. 1390–1396.

Brito D.L., Intriligator M.D., 2018, *Arms Races*, [in:] *The New Palgrave Dictionary of Economics*, London, DOI: 10.1057/978-1-349-95189-5_396.

Broadberry S., Harrison M., 2005, *The Economics of World War I*, Cambridge.

Costanza R., 1984, *Review Essay: The Nuclear Arms Race and the Theory of Social Traps*, "Journal of Peace Research", Vol. 21(1).

Dawkins R., 1996, *Samolubny gen*, M. Skoneczny (transl.), Warszawa.

Dyskant J.W., 1983, *Konflikty i zbrojenia morskie 1918–1939*, Gdańsk.

Holzer J., 2012, Europa zimnej wojny, Kraków.

Morone A., Nuzzo S., Caferra R., 2019, *The Dollar Auction Game: A Laboratory Comparison Between Individuals and Groups*, "Group Decis Negot", No. 28, pp.79–98, DOI: 10.1007/s10726-018-9595-5.

Nuti L. (ed.), 2009, *The Crisis of Détente in Europe: From Helsinki to Gorbachev. 1975–1985*, London.

Pedersen G., 2005, *Stanislav Petrov World Hero*, "Fellowship", Vol. 71(7–8), pp. 9–10, https://www.proquest.com/openview/99d8a34911f1c57fa5ebc13ff5286c88/1?pq-origsite=gscholar&cbl=2041863 [date of access: 25.11.2023].

Ploeg F. van der, Zeeuw A.J. de, 1987, *Conflict over Arms Accumulation in Market and Command Economies*, Research memorandum, Tilburg University, , Vol. FEW 265.

Richardson L.F., 1881–1953, 1960, *Arms and Insecurity: A Mathematical Study of the Causes and Origins of War*, L. Richardson, N. Rashevsky, E. Trucco (eds.), Kennebunk (ME, USA).

Ricón J.L., 2016, *The Soviet Union: Military Spending,* Nintil, https://nintil.com/the-soviet-union-military-spending [date of access: 31.05.2016].

Ross A., 2010 (HMS Dreadnought, 1906), *A Naval Revolution Misinterpreted or Mishandled?*, "The Northern Mariner", No. 20(2), pp. 175–198.

Schwelb E., 1964, *The Nuclear Test Ban Treaty and International Law*, "American Journal of International Law", No. 58(3), pp. 642–670, DOI: 10.2307/2196663.

Simaan M., Cruz J.B., 1975, *Formulation of Richardson's Model of Arms Race from a Differential Game Viewpoint*, "The Review of Economic Studies", No. 42(1), pp. 67–77, DOI: 10.2307/2296820.

Straffin P.D., 1993, *Teoria gier*, Warszawa.

Sofaer A.D., 1986, *The abm Treaty and the Strategic Defense Initiative*, "Harvard Law Review", No. 99(8), pp. 1972–1985, DOI: 10.2307/1341216.

Sun Tzu, Sun Pin, 2008, *Sztuka wojny*, Gliwice.

Thompson N., 2009, *Inside the Apocalyptic Soviet Doomsday Machine*, "Wired News", No. 17.

United Nations Office for Disarmament Affairs, 2021, *Treaty on the Non-Proliferation of Nuclear Weapons*, https://treaties.unoda.org/t/npt [date of access: 25.11.2023].

Wolfson M., 1987, *A Theorem on the Existence of Zones of Initiation and Deterrence in Intriligator-Brito Arms Race Models*, "Public Choice", No. 54(3), pp. 291–297, http://www.jstor.org/stable/30025129 [date of access: 25.11.2023].