Article

Adapting to Multipolarity: Insights from Iterated Game Theory Simulations—A Preliminary Study on Hypothetical Optimal Global Cooperation

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Abstract: The global geopolitical landscape is characterized by the rise of new powers and a shift toward multipolarity. This study examines the impact of multipolarity on international cooperation using an iterated game theory approach, particularly the classic prisoner's dilemma, extended to a multiplayer setting. This effort can be regarded as a preliminary study of hypothetical optimal global cooperation. The main hypothesis is that an increase in the number of large countries in the international system will lead to higher levels of cooperation. Our simulation approach confirmed this. Our findings extend to the conclusion that multipolarity, under appropriate cultural and value systems, can foster new economic development and fair competition. Furthermore, we emphasize the importance of evolving strategies and cooperative dynamics in a multipolar world, contributing to discussions on foreign economic policy integration, sustainability, and managing vulnerabilities among great powers. The study underscores the necessity of strategic frameworks and international institutions in promoting global stability and cooperation amidst the complexities of multipolarity.

1. Introduction

One of the main characteristics of the current global geopolitical landscape is the emergence and rise of new powers and deglobalization tendencies. Currently, the global geopolitical scene is characterized by (i) a pervasive climate of cooperation deficiency among major countries, (ii) increased prospects for major power wars in Europe and the Indo-Pacific, and (iii) increasing instability in the Middle East (Haas 2022). These conditions could create one of the most dangerous junctures since World War II (Haas 2022).

The world order built mainly by the United States after the end of the Second World War is experiencing extremely strong fluctuations in the dynamics between the West and East. This is largely due to the rise of other powerful actors in the international geopolitical scene (Zakaria 2008), such as China, which possesses an economic and political value portfolio that diverges significantly from that of the United States. Such a portfolio could change the economic and political constants of the world, as we know today.

There is, therefore, a crisis between the West and the East (United States and China) that can escalate and even take the form of armed conflict, as evidenced by events in Taiwan that lie at the heart of American–Chinese tensions.

In general, the financial crisis of 2008, the COVID-19 pandemic, and the energy crisis of 2022 collectively led to a broader shift towards protectionism and self-sufficiency, which reduced the degree of dependencies and interconnections, thus affecting delicate trade balances. The Ukrainian war deepened the tensions between Russia, the United States, and Europe, generating migrant flows and rising inflation (Kimmage and Notte 2023). Among other things, Russia's invasion of Ukraine strikes a blow against the concept of liberal

democracy, and thus, even though the United States is geographically "far away" from Ukraine, they are ideologically involved in defending liberal democracy.

Furthermore, in the Middle East, power and ideological multipolarity have been transposed onto a highly volatile landscape resulting from an unprecedented proliferation of weak or collapsing states (Kamrava 2018). According to Carlstrom (2024), the ongoing war between Israel and Palestine could be a turning point in the world order, revealing that the Middle East is neither unipolar nor multipolar, but nonpolar.

As a result, geopolitical settings are vulnerable to conflicts between states over the control of supply chains (AFOF Geopolitical 2020). Under these conditions, geopolitical risk is increased, as well as existential uncertainty and multipolarity (Gomart 2016).

The transition of the international system into multipolarity is a complex process, given the co-existence of regional identities, diverse interests, and cultures, as well as geopolitical morphology and historic ties. At the same time, our economies and societies are experiencing great connectivity due to technological advancements, cost reductions, and cultural globalization (Watson 2010). Such characteristics increase systematic complexity, leading to "new globalization", which is characterized by multipolarity in international relationships and an accelerated reproduction of structural crises and development prospects (Vlados et al. 2022). In other words, in a highly interconnected and multipolar world, a large-scale shock can spread rapidly, generating the snowball effect (Hulsman et al. 2010) and profoundly impacting the future.

These conditions require preparedness for the future (Hulsman et al. 2010). Adaptation to multipolarity is an effort to maintain economic security, but it does not necessarily fall into the domains of either traditional national security or free-market economics (Farrell and Newman 2023). Thus, it is of significant interest to consider the possible behaviors and sets of actions of states in a proper analytical framework. States, like individual players, have interests derived from their geographical positions, claims, and cultures. Over time, changes may occur in the borders of states as well as in their cultural identities. Such changes and rearrangements create winners, losers, stable equilibria, unstable equilibria, and equilibria of terror.

From an economic perspective, these relationships are akin to game theory exercises. According to Snidal (1985), the strategic analysis of international political relations through game theory raises important questions about the interdependence and relations of player states. However, this requires the use of complementary auxiliary hypotheses and a substantial study of the evolution of cooperation under certain circumstances. Hence, the game theory approach is not an explanatory solution but a strategic exercise to assess various adverse outcomes. The study of international relationships through game theory allows individuals to understand and analyze the outcomes of multipolarity and formulate new policies to ensure long-term stability and sustainability. Therefore, a game theory approach is in a position to generate informed decision making (Farson 2023).

Having said that, the present study employs iterated game theory simulations to model the interactions between countries of varying sizes and attributes. This analysis is based on a purely theoretical hypothesis regarding the competition and cooperation of a large number of de facto entities/countries participating in the evolution of the global economy. More specifically, we extend the classic prisoner's dilemma to an iterated multiplayer setting, in which countries repeatedly interact with one another over multiple rounds. For the simulations and computational analysis, we utilized the Wolfram Mathematica computational environment. The departure point of the analysis is the general idea that power distribution affects international relationships. This study is based on the hypothesis that a higher number of large countries in the international system will lead to increased levels of cooperation. That is, multipolarity itself does not rule out cooperation (Perskaya 2017). Our findings confirm this assumption.

The insights provided by the study suggest that large countries, with their significant economic and military capabilities, can play a stabilizing role in the international system by promoting cooperative behavior among states. Multipolarity can be viewed as a set of

economic and political conditions that can act as tools for forming new poles of economic development and fair competition under proper cultural and value systems (Perskaya 2017). These insights further contribute to the promotion of sustainability and de-risking of the process of managing vulnerabilities between great powers (Farrell and Newman 2023), specifically in the regional architecture of world politics (Garzón 2016). By the latter, it is understood that multipolarity does not rule out regionalization and the emergence of strategic interests (Perskaya 2017). Therefore, the present study contributes to the discussion on the beneficial integration of different parties in foreign economic policy as a strategic guideline for a favorable global economic future.

2. Theoretical Background: On the Evolution of Cooperation and Its Structural Features in International Relationships

A common question in both biology and social sciences concerns the foundations and emergence of cooperative behavior (Zhang and Pei 2022). Cooperation is common between members of the same species and even between members of different species (Axelrod 1984). In the biological sciences, the most important forms of cooperation are not based on kinship but on indirect reciprocity and spatial selection (Kornilakis 2023). For Dugatkin (1997), there are four paths for cooperation: (i) reciprocity, (ii) byproduct mutualism, (iii) kinship, and (iv) group selection.

Anthropologically, societies balance competitiveness, cooperativeness, and individualism, depending on their living circumstances (Mead 1937). The notions of culture and personality are the bridge between biological and social sciences, such as economics, because they depict different aspects of socialized human beings (Mead 1937). In economics, cooperative dynamics are complex because of the main and contradictory assumption that individuals are selfish (Axelrod 1984). However, cooperation is possible but requires social structure (Axelrod 1984). For example, in a society in which everyone acts selfishly, there is no ground for a tit-for-tat strategy. Selfishness is an interpretation of behavior obtained either through direct knowledge (perfect information) or secondhand experience. Labels in terms of behavior are observable, fixed characteristics of the players or the overall cultural structure that can influence behavior and lead to stereotypes (Axelrod 1984).

In addition to behavioral qualities and attributes, the time factor is also important in determining whether cooperation will take place. In a prisoner's dilemma game with predetermined turns, two rational individuals will never cooperate. On the other hand, in the iterated version of the game, cooperation, trust, strategic decision making, and adaptability could arise (Axelrod 1984). Successful social decision making depends on the ability to identify trustworthy interaction partners and evaluate time variables correctly (Evans and van de Calseyde 2017). For example, when one player makes quick decisions, the other player tends to make extreme decisions because fast decision makers are perceived as less moral, less conflicted, and extremely selfish (Evans and van de Calseyde 2017).

Applications of game theory, which address social phenomena and power dynamics, can depict the relationships between countries (Chiesi 2015). International relationships in a game theory framework concern the interplay between specific actors, including nation-states (Correa 2001). Game theory can assist the analysis of international relationships to acquire a comprehensive understanding of the evaluation and significance of complex cooperative dynamics in social and economic systems (Correa 2001; Kanzola 2023). In the case of nation-states as actors, the main assumption is that they are motivated by their own interests (Correa 2001). This is generally accurate, as national interests drive global alliances.

For instance, the liberalization of international trade can be modeled as a prisoner's dilemma, where all countries have a mutual economic interest in the advantages of free trade but also have motivations to safeguard their sensitive domestic industries (Krugman 1992). Trade liberalization is an iterative game that allows countries to respond to each other's past moves. According to Axelrod (1984), iterations of the prisoner's dilemma allow countries to adopt cooperation strategies, gradually and mutually opening their

markets and choosing to cooperate. Evolutionary approaches to game theory suggest that cooperation and defection follow each other in successive waves (Nowak and Sigmund 2004; Nowak 2006).

Subsequently, within the framework of evolutionary game theory, small groups employing cooperative tactics such as tit-for-tat can establish alliances within a population dominated by defectors. Once cooperation becomes prevalent in the population, a transition toward unconditional cooperation may occur, as tit-for-tat strategies do not penalize unconditional cooperation. However, when the entire population collaborates, unconditional defection becomes a favorable strategy, as it exploits the cooperative behavior of others. Consequently, this leads to an ongoing cycle in which the level of cooperation in a given population initially increases and then declines. Such an evolutionary model allows for a dynamic approach to international cooperation (Krapohl et al. 2021).

In the study of foreign affairs using game theory approaches, it is important to consider the presence of several powerful nation-states as well as the existence of powerful megatrends (Naisbitt 1988), which might encourage or discourage cooperation. For example, globalization defined economies during the Great Moderation (1980–2007) at the economic, political, and social levels and promoted world cooperation. It involved an international shift towards a global economic system not based on autonomous economies (Holm and Sorensen 1995; Godet et al. 1994).

Currently, we are gradually witnessing a de-globalization phenomenon that involves the weakening of international economic relations, economic protectionism, cultural backlash, and the rise of populism (Garg and Sushil 2021). According to Bello (2004), de-globalization is not about withdrawing from the international economy, but rather an emphasis on economies channeling their own exported products into the international market. The emergence of de-globalization requires an alternative system of international institutions and governance (Bello 2004). Such a shift in international economics creates significant uncertainty and affects international stability (Aftab and Phylaktis 2022). One of the greatest problems facing the current economic organization is the fact that neoliberalism has reached its limits (Peters 2022). Nevertheless, the future of capitalism, as we experience today, will be shaped by the influence of swinging factors of a social, political, and economic nature (Petrakis 2022). These forces will affect the future of capitalism through either unsustainable or transformed paths (Petrakis 2022).

Another important phenomenon is multipolarity, which refers to the balance and distribution of global power between more than two state powers. The concept essentially indicates that no global power has a direct and clear influence over other world powers (de Aguiar Patriota 2017), and theoretically, it partially aligns with the balance of power theory (Waltz 1979).

In a multipolar world with constant power shifts, there are competitive dynamics that can lead to armed conflict and instability (Allison 2017)[1]. According to the power transition theory, wars emerge as a result of a rising power surpassing the most powerful state at the moment (Goldstein and Pevehouse 2014). During these times, power distribution is relatively equal and the proximity to war is high (Goldstein and Pevehouse 2014). The emergence of multiple powers and player nation-states translates into multiple political agendas that may converge or diverge. When forces and agendas diverge, the phenomenon of geopolitical revisionism may arise whereby different powers seek to revise the existing status quo (Mead 2014).

The distribution of power among states has long influenced international relations. Theories such as realism and liberalism offer differing perspectives on whether a unipolar, bipolar, or multipolar world is conducive to peace and cooperation (Waltz 1979). For instance, realism posits that the international system is anarchic and that states must rely on self-help to ensure their survival (Morgenthau 1948). In contrast, liberalism emphasizes the role of international institutions and economic interdependence in promoting cooperation (Keohane 1984).

Power is always realized with the use of resources (Vuving 2009). The exercise of power can occur either through cultural and economic appeal (soft power) or in the form of forced actions such as military interventions (hard power) (Nye 2004). Soft power is the ability to affect the behavior of others by influencing their preferences (Vuving 2009). It can be a critical tool to navigate through complexity because it reduces the possibility of armed conflicts. Soft power concerns attracting someone to desire certain things or circumstances (Nye 2008). This definition in the context of the network economy signifies the possible emergence of strong networking relationships to achieve common agendas (Nye 2008). At the social level, networks satisfy the need for belonging (Moser and Ashforth 2022). At the economic level, networks are generated from hierarchies and refer to a concentration of interactive behaviors (Economides 1996). Even though networks do not emerge randomly, because they are founded under mutual interests, network operators (exercising hard or soft power) can opt for lock-in conditions to ensure stability (Kanzola 2023).

The importance of multipolarity in modern interconnected international relationships concerns its impact on the overall stability of the global system (Posen 2009). In addition to power distribution, the emerging multipolarity concerns the reconfiguration of a more diversified world in terms of social values and perceptions, which do not necessarily include the cultural values or practices of the West (Wang and Miao 2022). In multipolarity, the relations of the states are more complex and less predictable than when bipolarity prevails (Waltz 2000). Thus, a methodological framework such as game theory can offer interesting insights. Game theory for international relations analysis expands the rational actor model beyond the restrictive confines of the traditional realist perspective to a more complex world (Snidal 1985).

3. Methodology

In this study, we built on the foundations of evolutionary game theory, which has been extensively used in biology to study the emergence and stability of cooperative behavior among organisms (Nowak 2006).[2] The study of evolutionary games allows us to understand the emergence of cooperation in different contexts (Scatà et al. 2016). Specifically, inspired by Krapohl et al. (2021), we apply an evolutionary game theory approach for international trade in order to evaluate the impact of multipolarity on international cooperation. In general, evolutionary game theory models consist of two main components: (i) a game that is continuously played among all possible pairs of players, and (ii) a model of the evolutionary process where successful strategies are favored over unsuccessful ones. Owing to the large number of players and repeated interactions, it is impossible to predict the behavior of such models in advance. Consequently, computer simulations are necessary for their analysis.

This study focuses on two key hypotheses that explore the dynamics of international cooperation in a multipolar world.

H1. *The presence of multiple large powers (multipolarity) leads to higher levels of cooperation among states.*

H2. *The emergence of cycles of cooperation and competition reflects long-term cyclical patterns influenced by shifts in power, strategy evolution, and external conditions.*

It should be noted that our study models international relations under idealized conditions emphasizing the potential benefits of cooperation. However, the current global landscape often deviates from these theoretical scenarios. Major powers frequently engage in trade disputes, political tensions, and other confrontations, illustrating the complexity of international relations where strategic, economic, and security concerns lead to adversarial behavior instead of cooperation. Trade wars between the United States and China, geopolitical maneuvers by Russia, and regional conflicts involving Israel and India exemplify how real-world interactions diverge from the cooperative frameworks our model explores.

These deviations underscore the challenges of applying theoretical models to practical situations where competing national interests and power dynamics often supersede co-operation. Nevertheless, our model aims to explore scenarios where cooperation could be beneficial despite adversity. By highlighting the potential for cooperative strategies to yield mutual benefits, our study provides insights that could inform efforts to reduce conflict and foster negotiation, offering a theoretical basis for more stable and constructive international relations.

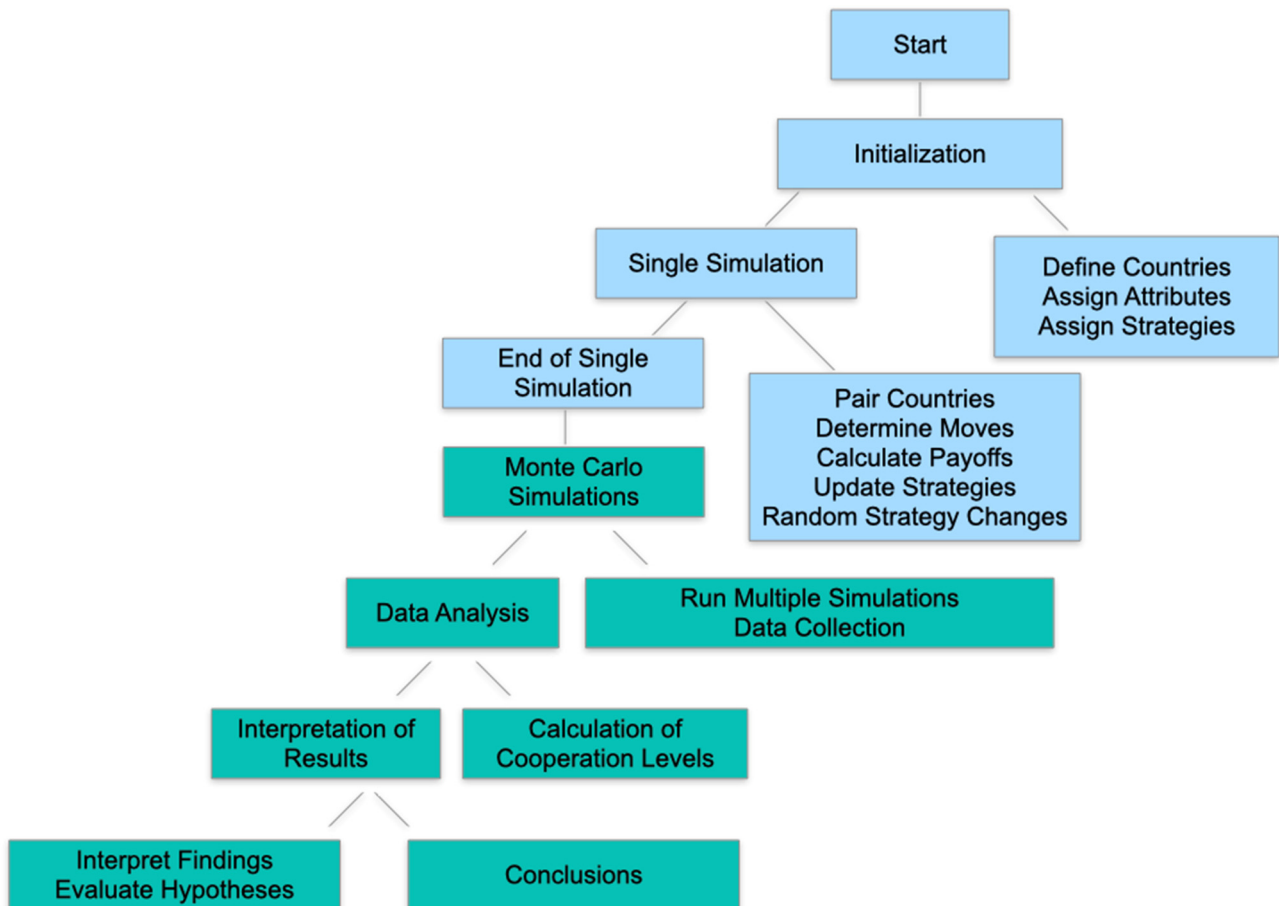The following Figure 1 displays the conceptual map of the simulation.

Figure 1. Flow chart of the simulation.

We extend the classic prisoner's dilemma to an iterated multiplayer setting. The simulation involves a total of 15 countries divided into three categories: large, medium, and small. The initial number of countries in each category can be adjusted, but it was chosen to reduce the complexity associated with scenario generation.

Real-world countries were categorized into the three aforementioned groups based on their gross domestic product (GDP). This categorization involved ranking countries by GDP and subsequently dividing them into these groups to reflect their relative economic size. This approach allows for the inclusion of a wide spectrum of countries within each group, facilitating a comprehensive analysis of diverse economic contexts.

- Large Countries: This group comprises the highest-ranking countries by GDP, such as the United States and China. These nations typically exert significant global influence and possess substantial economic power.
- Medium Countries: Countries in this category, such as Japan and Germany, have mid-range GDPs, indicating moderate economic power. These countries play crucial

roles in regional markets and often maintain substantial trade relationships with both larger and smaller economies.

- Small Countries: The small-country group includes nations with the lowest GDPs in the study, such as Norway and Argentina. These countries have smaller economies and may be more susceptible to external economic pressures, yet they often exhibit high levels of export dependency.

Random values within the range of three key indicators for each real-world country group were used as attributes for the countries in the simulation. The attributes were chosen following Krapohl et al. (2021). These attributes influence payoffs in the game, with specific benefits and costs associated with cooperation and defection. The attributes in question are as follows:

- The size (M) represents the economic power of a country. It reflects a country's GDP or economic output. Larger economies may have more resources to invest in cooperation and can derive greater benefits from stable international relations (Keohane 1984).
- The Export orientation (e) is calculated as the ratio of a country's exports to its GDP, representing the share of the export industry.
- The Barriers (i) refer to protectionist policies. They are measured by the weighted average tariff rates on imports, indicating the level of protection against foreign imports.

The specific value ranges for these indicators were derived from World Bank data (see Appendix A Table A1). The interactions between countries were modeled over 100 iterations, allowing us to observe the evolution of strategies and cooperation levels over time.

Table 1 depicts the country attributes and the range of values they take based on their size (small, medium, and large).

Table 1. Country attributes and range of values according to each of the three categories.

Size (M) (Current USD bn.)			Export Orientation (e) (% of GDP)			Barriers (i) (%)		
Small	**Medium**	**Large**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
From 14 to 503	From 1650 to 5035	From 17,820 to 23,315	From 2.2 to 99.3	From 18.1 to 47.3	From 10.9 to 19.9	From 0 to 12.7	From 7 to 7.8	From 1.5 to 2.3

Each country adopts one of several strategies. The outcomes of these interactions are influenced by each country's attributes, which affect the payoffs received from cooperation or defection. The strategies used in our simulation are defined as follows:

- Always Defect: This strategy always chooses to defect regardless of the opponent's previous actions.
- Always Cooperate: This strategy always chooses to cooperate regardless of the opponent's previous actions.
- Tit-for-Tat: This strategy cooperates on the first move and then mimics the opponent's last move in subsequent rounds (Axelrod 1984). This has been shown to be effective in promoting cooperation during repeated interactions.
- Generous Tit-for-Tat: This strategy is similar to Tit-for-Tat, but includes a 25% chance of forgiving a defection by cooperating (Nowak and Sigmund 1993). This allows for the possibility of repairing damaged relationships and avoids retaliation cycles.

In the first round of the simulation, an initial strategy is randomly assigned to each country, with large countries being more likely to receive cooperative strategies. Table 2 presents the strategies alongside the randomly assigned attributes for the 15 countries included in the simulation. The values of these attributes are selected from within the ranges specified the Appendix A Table A1.

Table 2. Random assignment of initial country attributes.

Country	Category	Strategy	Size (M)	Export Orientation (e)	Barriers (i)
1	Small	Generous Tit-for-Tat	91.574	0.675	0.037
2	Large	Tit-for-Tat	18,394.005	0.112	0.025
3	Medium	Always Defect	2,562.558	0.413	0.052
4	Medium	Always Defect	3,438.514	0.331	0.024
5	Small	Always Cooperate	357.210	0.987	0.036
6	Small	Tit-for-Tat	34.012	0.771	0.007
7	Small	Tit-for-Tat	86.936	0.724	0.018
8	Medium	Always Cooperate	3,734.833	0.408	0.050
9	Small	Always Cooperate	92.504	0.743	0.049
10	Small	Tit-for-Tat	77.867	0.601	0.049
11	Small	Tit-for-Tat	347.261	0.980	0.049
12	Small	Tit-for-Tat	448.817	0.500	0.025
13	Medium	Always Defect	4,391.060	0.435	0.026
14	Small	Always Defect	457.881	0.499	0.027
15	Small	Always Cooperate	129.965	0.442	0.028

As mentioned, the countries repeatedly interacted with one another in pairs, all against all, over 100 rounds. Table 3 presents the payoff matrix between two potential Countries A and B.

Table 3. Payoff matrix.

			Country B	
			Cooperate	Defect
Country A	Cooperate		$e_a M_b - i_a e_b M_b$	$-i_a e_b M_b$
			$e_b M_a - i_b e_a M_a$	$e_b M_a$
	Defect		$e_a M_b$	0
			$-i_b e_a M_a$	0

The benefits and costs associated with cooperation and defection and the payoffs for each interaction were calculated based on the moves of the two countries. The cumulative gains of each country were used as a measure of the success of each strategy. Thus, the most successful countries are more likely to find imitators in their strategies. As a measure of success, we consider the gains or losses from interacting with other countries. The gains are not constant for all players, as in simpler models, but depend on the characteristics of each pair of countries.

Essentially, the potential benefits that Country A may gain from establishing a mutual cooperative relationship with Country B are defined as follows:

$$e_a M_b - i_a e_b M_b$$

If Country A cooperates while Country B defects, Country A incurs a cost equal to $(-i_a e_b M_b)$ and Country B gains benefits equal to $(e_a M_b)$ from the interaction. In this game, after each round, a country is selected to reproduce its strategy with the probability of selection corresponding to its relative success. This is achieved using the current cumulative gains as weights. Subsequently, another country is randomly chosen to adopt the strategy of

the successful country. A country's success is determined by the total returns it accumulates through interactions with every other country during each game round.

Success is defined as the advantage a country gains from access to international markets minus the costs associated with opening its domestic market. In the prisoner's dilemma of trade liberalization, a country's export industry benefits from increased profits due to comparative cost advantages and economies of scale as it gains greater market access. Conversely, as a country opens its domestic market for imports, its protected industries face negative impacts from heightened competition. To achieve a successful strategy, a country must maximize its market access in each round of the repeated prisoner's dilemma game while simultaneously minimizing the costs associated with trade liberalization.

For the analysis, we developed a single simulation methodology and then included it in a Monte Carlo simulation. For the simulations and computational analysis, we utilized the Wolfram Mathematica computational environment.

3.1. Single Simulation

In a single simulation, each country interacts with every other country in each round. The decisions to cooperate or defect are determined by the countries' strategies, which can be influenced by past interactions. The payoffs for each interaction are calculated based on the countries' attributes and the outcomes of the interactions. The results of each round were recorded, and the cooperation levels were tracked throughout the iterations. The simulation flow is as follows.

1. Initialization: Random strategies and attributes are assigned to each country based on their size categories (see Appendix A). The initial allocation of strategies and attributes among countries in the model reflects the diverse and unpredictable nature of international relations. By starting with random strategies and economic attributes, we avoid introducing any bias and allow the model to explore how different approaches evolve naturally over time. Importantly, the randomness was balanced through 100 iterations within each simulation and 100 single simulations. This extensive repetition ensures that the outcomes reflect underlying patterns and trends rather than just the initial randomness, providing robust insights into the dynamics of international cooperation.

2. Iterations: Each country pairs with every other country, resulting in 105 interactions per round. In each interaction, countries choose their moves based on their strategies and the history of previous interactions. The payoffs are calculated by taking into account each country's size, export gains, and barrier costs.

3. Adjustment of strategies: A country is selected based on cumulative gains to potentially influence the strategy of another country. This captures the diffusion of information and the ability of countries to monitor what is happening in the international economic and political scene and adjust their policies accordingly. Note that an additional random strategy change occurs with a 10% probability. This represents random events and/or non-rational behaviors that may influence policy decisions in an unexpected way.

4. Measurements: The measurements were performed as follows:

    - Level of cooperation: Percentage of cooperative moves in each round.
    - Distribution of strategies: Frequency of each strategy across iterations.
    - Cumulative gains: Recorded for each country.

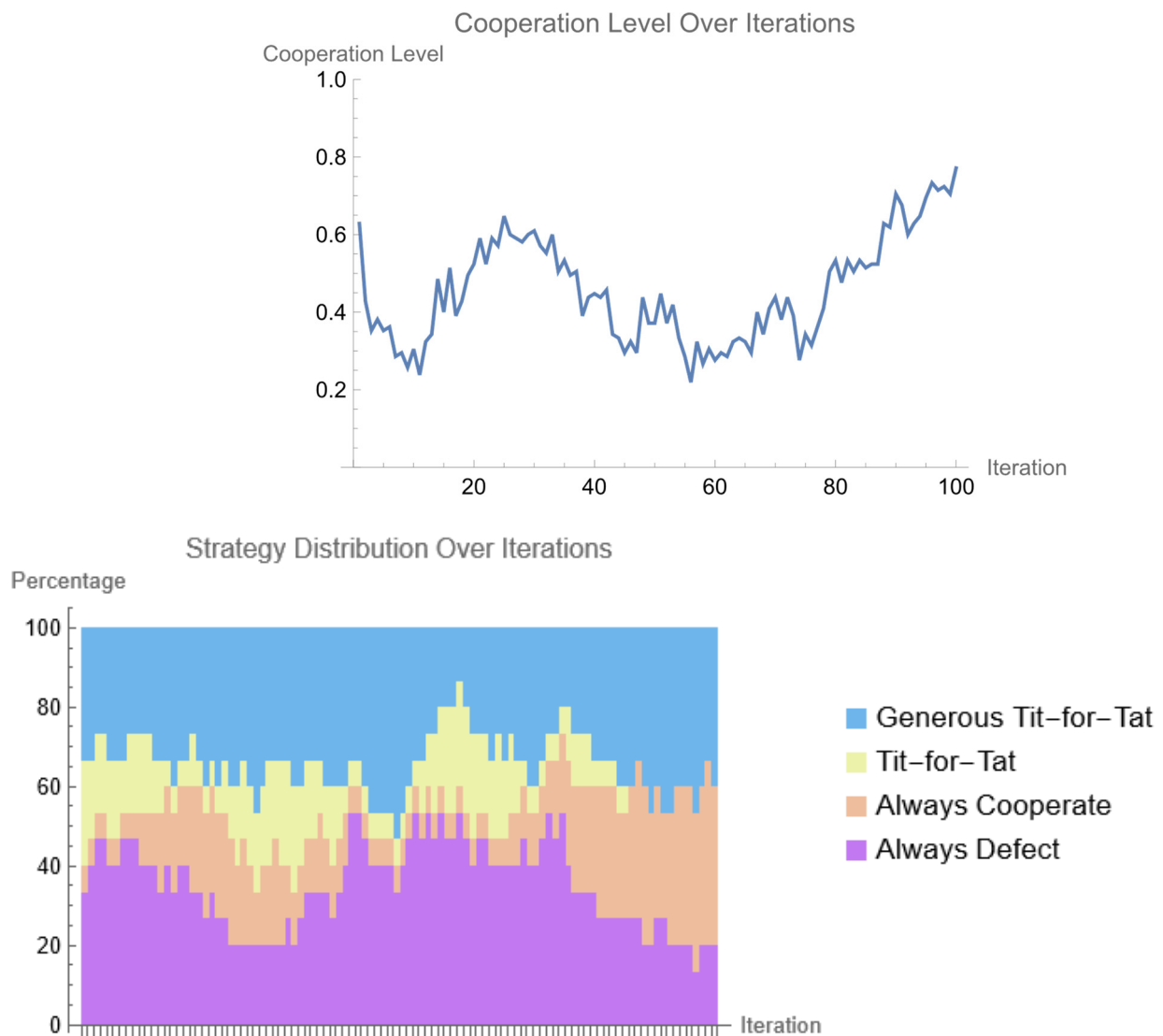Figure 2 depicts the cooperation level and strategy distribution over 100 iterations.

Figure 2. Cooperation level and strategy distribution over 100 iterations.

Cooperation levels are dynamic in nature and vary significantly over time. This is attributed to the fact that the players' strategies are adapting in response to the actions of other players. In the last round, we observed a slight increase in cooperation, suggesting a possible stabilization or adaptation towards more cooperative strategies. We notice that the Always Defect strategy is dominant at the beginning of the game, while the Generous Tit-for-Tat and Tit-for-Tat strategies increase towards the end, indicating that they are more successful in the long run. The Always Cooperate strategy shows an intermittent presence, implying that while cooperation can be beneficial, it may not always be the dominant strategy, probably because cooperation requires trust (Kuipers 2022).

In Table 4, the cumulative payoffs for each country after 100 iterations are presented in relative units. These units represent the aggregated value of the payoffs a country receives throughout the simulation process. These relative units are dimensionless and are used to compare the performance of different countries within the simulation, reflecting the cumulative success of their chosen strategies.

Table 4. Cumulative payoffs for each country after 100 iterations.

Country	Category	Final Strategy	Cumulative Payoffs
1	Small	Generous Tit-for-Tat	3,287,319
2	Large	Tit-for-Tat	27,818,081
3	Medium	Always Cooperate	5,314,262
4	Medium	Tit-for-Tat	36,690,050
5	Small	Always Cooperate	5,133,721
6	Small	Always Defect	3,765,800
7	Small	Tit-for-Tat	3,782,402
8	Medium	Always Cooperate	7,461,958
9	Small	Always Cooperate	3,950,124
10	Small	Always Cooperate	4,483,764
11	Small	Always Cooperate	5,500,975
12	Small	Always Cooperate	3,223,603
13	Medium	Tit-for-Tat	8,087,985
14	Small	Always Defect	2,903,647
15	Small	Always Cooperate	4,524,781

3.2. Monte Carlo Simulation

To ensure robustness and account for variability in the results, we employed a Monte Carlo approach, running the simulation 100 times with different random seeds. This allows us to generate a distribution of outcomes from which we can calculate the mean and standard error of the cooperation levels. By analyzing these results, we can draw more reliable conclusions about the relationship between multipolarity and cooperation.

4. Results and Discussion

4.1. Single Simulation Results

After applying the single run simulation and accounting for a world with one large country, four medium-sized countries, and ten small countries, Figure 3 emerges after 100 iterations.
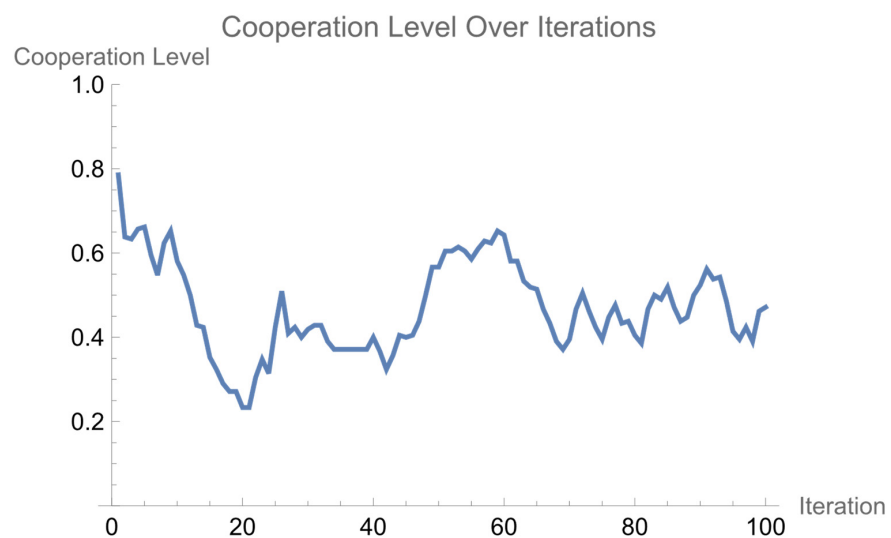

Figure 3. Cooperation levels in a world with one large, four medium- and ten small-sized countries.

The mean cooperation level was 0.468476, and the standard error was 0.0108516. Initially, we observe a drop in the levels of cooperation, followed by a volatility period and several stable fluctuations. After 100 iterations, the cooperation level followed an upward

slope. Thus, the overall level of cooperation is moderate for a scenario characterized by unipolarity.

In general, a unipolar distribution raises issues regarding the exercise of power and control over other countries (Ikenberry et al. 2009). In this setting, cooperation levels are low due to increased conflict likelihood and reliance on ad hoc coalitions (Monteiro 2012) because establishing cooperation does not necessarily moderate existing asymmetries of power (Faul 2016). This might also indicate lower percentages of risk sharing and make us rethink the operation of the balance of power, the meaning of cooperation, and the behavior of certain countries (Ikenberry et al. 2009). For example, small- and medium-sized countries adapt to a unipolar framework by maintaining autonomy (defect posture) or using cooperative schemes to bandwagon with the greatest power, form alliances, or seek shelter and hedging strategies (Tit-for-Tat or Generous Tit-for-Tat) (Schweller 1994; Vaicekauskaitė 2017).

Pure unipolarity is relatively uncommon (Kreps 2011) because it eventually gives rise to other types of distributions (Ikenberry et al. 2009). For this reason, it is essential to consider how different states of foreign affairs influence cooperation levels.

Figure 4 illustrates cooperation levels in a world with two large countries, five medium-sized countries, and eight small ones.
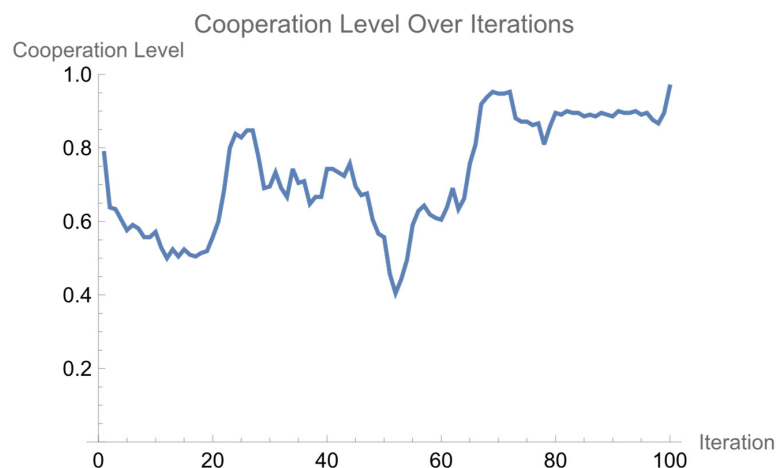

Figure 4. Cooperation levels in a world with two large countries, five medium- and eight small-sized countries.

The mean cooperation level is 0.727429 and the standard error is 0.0149597. Again, in the initial rounds, we observe a declining level of cooperation following a volatility period and a sharp decline around the middle of the game. Afterwards, cooperation levels increase and display the biggest value thus far. In this scenario, which is characterized by a bipolar setting and an increase in medium-sized countries, we observe that overall cooperation increases. This finding might be explained by the hypothesis that under bipolarity, cooperation converges towards the models provided by the leading powers (Väyrynen 1995). In this scenario, it is possible that the bipolar competition forces the two superpowers to form bounded regional orders of allies and client states (Bertelsen 2022).

The main question that arises is the following:

What happens in a multipolar setting in terms of cooperation levels?

In a multipolar system, the impact of systemic political and military factors is more complex. Such complexity affects the evolution of the international economy (Väyrynen 1995). In a scenario characterized by multipolarity, no country has a commanding international position (Väyrynen 1995). Changes in the distribution of powers can cause tipping points and determine the structure, welfare, and sustainability dynamics of the international system (Stein 2015).

Thus, multipolarity is considered a potential destabilizing factor for foreign affairs (Thompson 1986).

In our Monte Carlo simulation, we gradually increased the multipolarity levels to gain insights into the evolution of the mean cooperation levels, as presented below.

4.2. Monte Carlo Simulation Results

The results of the Monte Carlo simulations provided an indication of a positive correlation between the number of large countries and the mean cooperation level in every scenario. Specifically, with five medium countries and increasing the number of large countries from one to eight, Table 5 emerged.

Table 5. Monte Carlo simulation results for gradually increasing multipolarity.

Number of Large Countries	Mean Cooperation Level	Standard Error
1	0.6191	0.0189
2	0.6657	0.0171
3	0.6392	0.0198
4	0.6584	0.0179
5	0.7116	0.0159
6	0.6950	0.0171
7	0.7470	0.148
8	0.7582	0.0152

Contrary to the argument that multipolarity is more dangerous for global cooperation than unipolarity and bipolarity (Laïdi 2014), our simulations reveal that increasing the number of large countries is associated with higher levels of overall cooperation. Our findings align with the predictions of liberal international relations theory, which emphasizes the role of economic interdependence and international institutions in promoting cooperation (Doyle 1986). The presence of multiple large countries can enhance the stability of international institutions and create a predictable environment for cooperation (Keohane 1984).

4.3. Statistical Validation

The Pearson correlation coefficient between the number of large countries and the mean cooperation level (Figure 5) is 0.9335, indicating a very strong positive correlation. The *p*-value of 0.0007 confirms that this correlation is statistically significant.
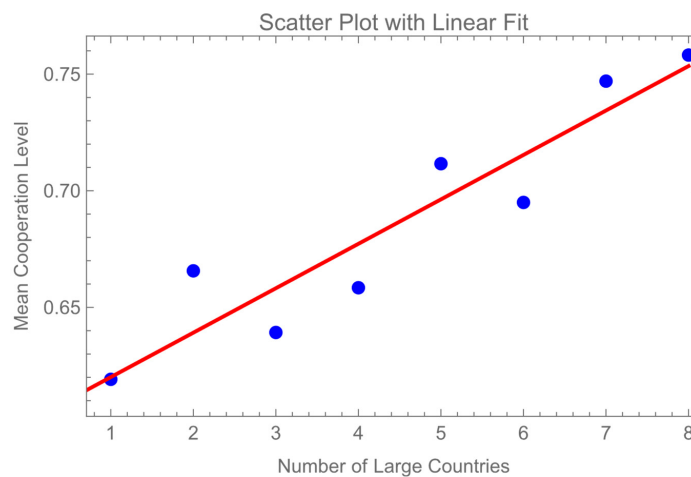

Figure 5. Scatter plot of the mean cooperation levels by the number of large countries. The fit line shows a clear positive correlation.

Furthermore, the *t*-test between the mean cooperation levels of the extreme cases—one large country and eight large countries (Figure 6)—indicated a significant difference, with a *p*-value of 0.032.
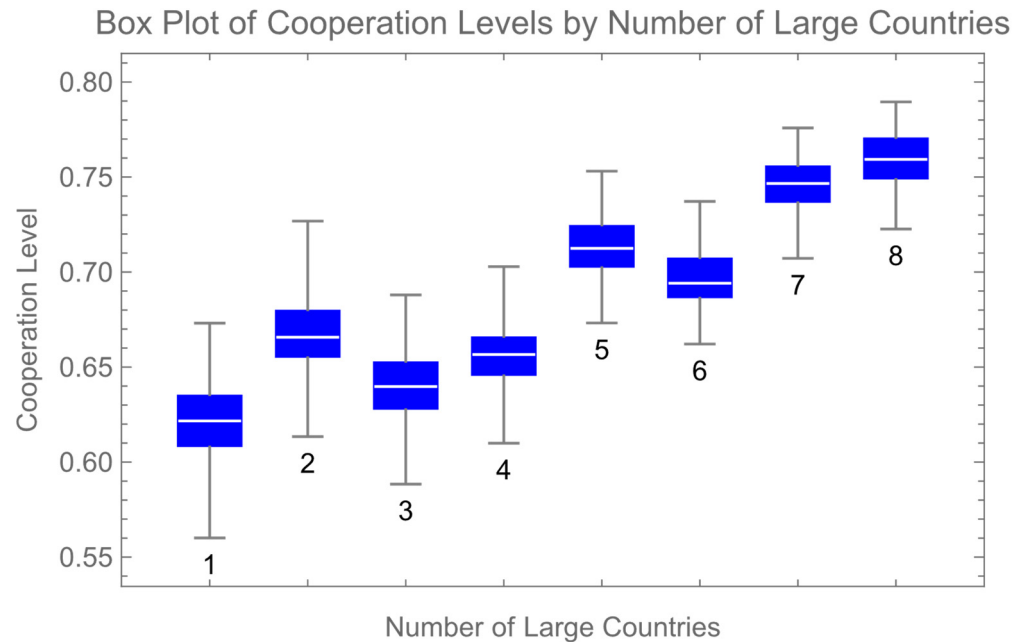

Figure 6. Box plot of cooperation levels for five medium and an increasing number of large countries.

Similar results were obtained when examining four and three medium countries while increasing the number of large countries from one to eight. The respective Pearson correlation coefficients were 0.8657 and 0.8650, both with *p*-values around 0.05, indicating statistically significant strong positive correlations.

4.4. Specific Insights from Our Findings

We found that multipolarity, characterized by the presence of several powerful states, could enhance the likelihood of international cooperation. Thus, H1 is confirmed. In essence, large, powerful countries can play a stabilizing role in the international system by promoting cooperative behavior among states. Large countries have more resources to invest in cooperative ventures, which can serve as anchors for stability and predictability (Waltz 1979). Additionally, their greater technological and economic capabilities may lead to higher gains from cooperation, incentivizing them to pursue collaborative strategies (Keohane 1984).

These findings support the idea that multipolar systems are more flexible and contain more interaction opportunities (Väyrynen 1995). Under multipolarity, countries could exhibit greater risk aversion, leading to a more pluralistic and balanced state–society relationship due to greater variations in beliefs and institutions (Väyrynen 1995). This could decrease the global risks associated with the economy, society, and geopolitical domains (Acharya et al. 2023).

On the other hand, the main concern associated with multipolarity is the isolation of states that are capable of building advanced weapons, posing a significant threat to global welfare (Posen 2009). Negative risk perceptions could also trigger a feeling of insecurity, followed by an organized shift towards self-sufficiency and autarky (Malcomson 2021). Major-power autarky is defensive, and it is not necessarily associated with a more dangerous world scenario (Malcomson 2021); however, because of the inevitable locked-in situations in the global system, this is a very concerning situation to address. An unagonized return to protectionism and autarky could lead to a situation known as a

"security dilemma" (Axelrod 1984), in which agents prioritize their own security over the security and welfare of others.

In the context of our analysis, global cooperation can falter for several reasons. One significant factor is when cooperation reaches a low point, creating a fertile ground for generalized disruption. Our simulations consistently exhibit a pattern of alternating cycles between increasing cooperation and increasing competition, akin to Kondratieff cycles observed in economic theories, regardless of the chosen parameters or number of large countries involved. Therefore, H2 is confirmed. In such scenarios, minor disagreements or conflicts can escalate rapidly, undermining trust and collaboration among nations, leading to armed conflicts and destabilization (Keohane 1984).

Additionally, the introduction of new, aggressive strategies by influential countries aiming to alter the status quo can destabilize the existing balance of power (Jervis 1978). This shift can lead to an environment in which competitive rather than cooperative behaviors dominate, increasing the likelihood of widespread international crises (Mearsheimer 2001).

Multipolarity could take two possible directions: (i) multi-growth and cooperation with sustainability, or (ii) multi-threat of the world as we know it today (Perskaya 2017). In an international geopolitical setting, multipolarity supported by conflicting agendas is the most serious source of uncertainty concerning global governance. On the other hand, a more optimistic development for international cooperation in a multipolar framework is cooperative multipolarity (de Aguiar Patriota 2017).

To achieve sustainability and welfare at a global level, institutions and legislative frameworks operating at a global level are in a position to define, apply, monitor, and enforce technical and economic conditions and rules for a set of operators (Agrell 2015). Consequently, if societies and countries aim to promote social welfare, the role of institutions and specific economic structures in fostering sufficient, sustainable, and inclusive growth through the interconnection effect is crucial (Kanzola 2023).

This discussion is already prominent because promoting stability under multipolarity is critical (Roberts 2023). In this direction, there is an emerging need for the configuration of conditions that favor cooperation. Multilateral organizations such as the International Monetary Fund (IMF), World Bank, and the North Atlantic Treaty Organization (NATO) will play a pivotal role (Tago 2017). Nonetheless, the aforementioned international cooperation platforms as well as the overall global governance architecture need reform (Sithole et al. 2024). This argument is supported by the historical evolution of these mechanisms. They were established after World War II, when the dynamics of world powers differed significantly from those today. It is questionable whether the current institutional framework can adequately respond to the challenges posed by the diverse influences on universal balance.

The international system of intervention and supervision of the global cooperation agenda, such as the IMF, World Bank, and World Trade Organization (WTO), should adapt to the new conditions. In this direction, it is important to redefine the meaning of development, economic growth, global threats, and sustainability in order to align with life values and, therefore, be acceptable to all players (Orliange 2021). In economics, there is also the rising question of whether the dollar, as a reserve currency, is slowly but steadily losing its influence. This is a double-edged sword because it raises issues regarding the global lender of the last resort and questions global stability. For the time being, the USA remains at the top of the global power hierarchy (Ryan 2023).

Another example of the destabilization of the world order is the possibility of a food crisis. During the 2008 food crisis (De Schutter 2009), it was required to use new "unconventional" policy measures, highlighting the need for the establishment of new cooperation tools capable to prevent universal hunger (Peres and De Souza Daibert 2017). Hence, the absence of effective world back-stop mechanisms (in economic and security relations) increases the difficulty of keeping the ball from leaving the field—by increasing the risk and the possibility of systematic world welfare leakages.

A factor that potentially promotes cooperation is global trade, but this does not include the globalization of production (Brooks 2024). Furthermore, enhancing trust, transparency,

and respect for cultural and national values as well as establishing an accepted agenda for common global action are indispensable for effective cooperation and conflict resolution in our increasingly interconnected world.

In the history of human cooperation, forces and changes have bound us together, while others have driven us apart. As a principle, the future is simultaneously unknown and known because it is generated in the present (Kanzola 2023). Taking action in the present will favor a desirable future in terms of global developments, provided that individuals, institutions, and governments are forward looking. Nevertheless, it is important to remember that the future also depends on elements of order and randomness (McKinsey Global Institute 2023; Watts 2003). In other words, it is impossible to predict negative or positive serendipity; we can only prepare for what we know. Therefore, efficient cooperation is possible and promotes stability but is not inherently guaranteed; it requires time, trust, effort, and proper dynamics. In return, it offers stability, risk mitigation, and security.

4.5. Limitations, Contribution, and Future Research Guidelines

Despite its insights, the present study has certain limitations. One noteworthy constraint is the simplified set of strategies, which includes only the Always Defect, Always Cooperate, Tit-for-Tat, and Generous Tit-for-Tat strategies. Although these strategies provide a foundational understanding of cooperation dynamics, they do not encompass the full spectrum of real-world behavior. More advanced strategies, such as the Pavlovian and probabilistic approaches, can yield richer insights into strategic interactions (Pereira and Martinez 2010). Additionally, the fixed strategy assignment in any given round does not allow for the evolution of different strategies against each player. This feature is crucial for capturing the realistic evolutionary dynamics of players' competitive coalitions (Płatkowski 2016). A relatively small number of countries may also be insufficient to observe long-term evolutionary trends in a more realistic setting. Some strategies may only show true efficacy or failure in an environment of strategic alliances and rivalries between shifting coalitions.

Future research should incorporate more diverse and sophisticated strategies to expand the scope of simulations. Including strategies that adapt based on historical interactions or environmental cues would provide deeper insights into the mechanisms driving cooperation and defection (Smith 1982). Furthermore, a larger number of countries in the model allows for a more realistic simulation of global interactions, thereby capturing the complexity and diversity of international relations. This expansion will enable the model to include a wider variety of strategies and behaviors, reflecting the heterogeneity of real-world geopolitical dynamics.

Finally, the model can be improved with a network-based approach in which players depict nations in alliances or competitive relationships with other countries. Each player's strategy can then be influenced not only by individual interactions but also by the behavior of their allies and adversaries. Alliances could encourage coordinated strategies and promote mutual cooperation within the coalition, whereas rivalries could lead to more aggressive competitive strategies between opposing groups. This networked structure allows us to simulate how geopolitical dynamics, such as the formation and dissolution of alliances and the impact of rivalries, affect overall cooperation and defection patterns (Jackson and Wolinsky 1996).

In terms of contributions, this paper contributes to the field by expanding an evolutionary iterated game to explore future scenarios and provide insights into long-term dynamics. Utilizing a Monte Carlo framework enhances the robustness of the simulation, allowing a more comprehensive analysis of strategic interactions under varying conditions. This approach helps to understand how different strategies perform over time and under different scenarios, thus offering a valuable tool for predicting and studying the evolution of cooperation and defection in complex systems.

Consequently, the present study generated a framework for developing strategic insight into complex, multi-actor situations that is well suited for addressing real-world problems (Bekius and Gomes 2023). This framework is also useful for strengthening the

various roles of foresight, understanding the relationship dynamics in the real economy, and speculating about a desirable future (van der Duin et al. 2014). Thus, the present approach allows for the use of models to understand the different aspects of international relationships in terms of a unified theory (Snidal 1985). This approach has both empirical and theoretical significance because it generates insights and understandings beyond the perceived relationships. These expansions also stimulate the integration of game theory simulations in political economies, international politics, and scenario design. Consequently, the analysis emphasizes the necessity of an interdisciplinary supportive social structure for cooperation under multipolarity, considering the impact of global sociopolitical and economic trends.

5. Concluding Remarks

In this study, we explored whether multipolarity contributes to cooperation using an iterated game theory approach. Our findings suggest that the presence of multipolarity tends to increase the likelihood of cooperation, at least from a theoretical perspective. This finding is important given the current discussion that the new multipolar order of the world economy could undermine global stability. Nevertheless, in order to ward off this dangerous possibility, proper institutional structures and the alignment of social goal setting are required (Waltz 2000). Under these conditions, a multipolar system could lead to the development of the global economy by avoiding the use of military conflicts. In any case, it should be mentioned that the promotion of cooperation is a difficult attempt given that policymakers and governments often discard theoretical models and insights for reasons related to the importance of historical path dependence, national interests, and tradition.

To ensure global sustainability, it is important to introduce a consistent framework for the market economy that balances risks and rewards and promotes systematic resilience (Roberts 2023). Otherwise, trying to minimize risks reduces rewards and creates vulnerabilities (Roberts 2023). At the same time, trying to always maximize rewards could lead to overlooking potential threats and risks (Roberts 2023). Therefore, the future of global cooperation and welfare in a multipolar setting depends on finding mutually beneficial activities and a strict legislative framework that prohibits one party from overruling the other and mitigates several conflicts of interest (Axelrod 1984).

Therefore, one pivotal contribution of the present study is to describe the conditions under which global cooperation can break down. Understanding these conditions is crucial, as it facilitates the identification of tipping points capable of generating disruption in international relationships and potentially triggering a global crisis. Cultivating this ability to foresee the dangers and opportunities of a changing order of things before their actualization (Machiavelli [1566] 2008)[3] is vital for maintaining international stability and peace (Oye 1986).

Author Contributions: Conceptualization, P.E.P. and A.-M.K.; methodology, I.L.; software, I.L.; formal analysis, I.L.; investigation, A.-M.K. and P.E.P.; resources, P.E.P.; data curation, I.L.; writing—original draft preparation, A.-M.K. and I.L.; writing—review and editing, I.L. and A.-M.K.; supervision, P.E.P.; project administration, P.E.P. and A.-M.K. All authors have read and agreed to the published version of the manuscript.

Appendix A

The following Table A1 of Appendix A consists of the real economies used in order to assign attributes to the countries in our model.

Table A1. The real economies used in order to assign attributes to the countries in our model.

Category	Countries	GDP (Current USD bn.)	Exports of Goods and Services (% of GDP)	Tariff Rate, Applied, Weighted Mean, All Products (%)
Large	China, USA,	17,820–23,315	10.9–19.9	1.5–2.3
Medium	Brazil, Canada, France, Germany, India, Italy, Japan, Korean Rep., Russian Federation, United Kingdom	1650–5035	18.1–47.3	0.7–7.8
Small	Albania, Algeria, Angola, Argentina, Armenia, Austria, Azerbaijan, Bahrain, Bangladesh, Belarus, Benin, Bolivia, Bosnia and Herzegovina, Botswana, Brunei Darussalam, Bulgaria, Burkina Faso, Cambodia, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czechia, Denmark, Dominican Republic, Ecuador, El Salvador, Estonia, Ethiopia, Finland, Georgia, Ghana, Greece, Guatemala, Guinea, Honduras, Hungary, Iceland, Israel, Kazakhstan, Kenya, Latvia, Lithuania, Macao SAR, Madagascar, Malaysia, Mali, Moldova, Mongolia, Morocco, Nepal, New Zealand, Nicaragua, Niger, North Macedonia, Norway, Oman, Pakistan, Paraguay, Peru, Philippines, Portugal, Qatar, Romania, Senegal, Serbia, Slovak Republic, Slovenia, South Africa, Sri Lanka, Sudan, Tanzania, Uganda, Ukraine, Uruguay, Uzbekistan, Viet Nam, Zambia, Zimbabwe	14–503	2.2–99.3	0.00–12.7

Source: World Bank Open Data for the year 2021.

Notes

1.   For example, the "Thucydides Trap" refers to the conflicts that can arise when a rising power (China) threatens to surpass a ruling power (the United States of America—USA).

2.   Traditional game theory focuses on interactions between perfectly rational individuals. Conversely, evolutionary game theory concentrates on (i) large populations that interact randomly, and (ii) the assumption that players employ adaptive rules instead of engaging in perfectly rational behavior (Wallace and Young 2015). It is concerned with finding the dominant strategy as well as with the fact that frequency-dependent fitness introduces a strategic aspect to evolution.

3.   Niccolo Machiavelli in *The Prince* (Machiavelli [1566] 2008, pp. 43–44) not only states this, but also explains the reason behind the significance of being able to foresee future troubles: Leaders should *"[...] regard not only present troubles but also future ones, for which they must prepare with every energy, because, when foreseen, it is easy to remedy them; but if you wait until they approach, the medicine is no longer in time because the malady has become incurable; for it happens in this, as the physicians say it happens in hectic fever, that in the beginning of the malady it is easy to cure but difficult to detect, but in the course of time, not having been either detected or treated in the beginning, it becomes easy to detect but difficult to cure. This happens in affairs of state, for when the evils that arise have been foreseen (which it is only given to a wise man to see), they can be quickly redressed, but when, through not having been foreseen, they have been permitted to grow in a way that every one can see them, there is no longer a remedy".*

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