


RETHINKING THE PRISONER'S DILEMMA GAME WITHIN THE FRAMEWORK OF THE PREBISCH-SINGER HYPOTHESIS¹

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ABSTRACT

In recent years, the increasing criticism of the assumptions of Orthodox economic theories has increased the interest in studies that produce heterodox economics theories. In this context, by criticizing the assumptions of orthodox economics, heterodox economics has produced new studies in areas such as international economic theories in which these assumptions are essential. These theories within heterodox economics are appropriate to be analyzed with computable methods such as network models and agent-based modeling because of their features of being adaptable to flexible assumptions and not including certainty. At this point, game theory is one of the methods that can be used alone or as an aid to the analysis methods mentioned. This study aims to contribute to the development of empirical analysis methods in a flexible structure in which the flexible assumptions of heterodox economics can be adapted. For this purpose, the game theory, which is purified from the assumptions of orthodox economics theories with the development of new Heterodox economics schools, such as the evolutionary game theory and behavioral game theory, will be used as a tool. In the context of this study, "the prisoner's dilemma game gain matrix," which is used for the expression of international trade in the practice to be performed, will be rearranged according to the claim of the Prebisch-Singer hypothesis. By this means, it will also be shown how to utilize game theory more broadly as a behavioral rule for computational methods in newly developed empirical analyses for heterodox economics theories.

Keywords: Game Theory, Prisoner's Dilemma Game, Heterodox Economics, Prebisch-Singer Hypothesis, International Trade.

Jel Codes: B59, B79, F17.

MAHKÛM İKİLEMİ OYUNUNU PREBİSCH-SİNGER HİPOTEZİ ÇERÇEVESİNDE YENİDEN DÜŞÜNMEK

ÖZET

Son yıllarda Ortodoks iktisat teorilerinin varsayımlarına ilişkin yapılan eleştirilerin artması, heterodoks iktisat teorileri üreten çalışmalara olan ilgiyi arttırmıştır. Bu bağlamda heterodoks iktisat,

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ortodoks iktisadın varsayımlarını eleştirerek, bu varsayımların önem arz ettiği uluslararası iktisat teorileri gibi alanlarda yeni çalışmalar üretmiştir. Heterodoks iktisat kapsamındaki bu teoriler, esnek varsayımlara uyarlanabilme ve kesinlik içermeme özelliklerinden dolayı ağ modelleri ve ajan-temelli modelleme gibi hesaplanabilir yöntemlerle analiz edilmeye uygun bulunmaktadır. Bu noktada oyun teorisi de tek başına veya sözü edilen analiz yöntemlerine yardımcı olarak kullanılabilir yöntemlerden birisidir. Bu çalışmanın amacı, heterodoks iktisadın esnek varsayımlarının uyarlanabileceği esnek yapıda ampirik analiz yöntemlerinin gelişmesine katkıda bulunmaktadır. Bu amaçla, evrimsel oyun teorisi ve davranışsal oyun teorisi gibi yeni heterodoks iktisat okullarının acBu çalışma kapsamında yapılacak uygulamada uluslararası ticaretin ifadesinde kullanılan mahkûm ikilemi oyunu kazanç matrisi Prebisch-Singer hipotezinin iddiasına göre yeniden düzenlenecektir. Böylece heterodoks iktisat teorileri için yeni geliştirilecek ampirik analizlerde kullanılacak hesaplanabilir yöntemler için bir davranış kuralı olarak oyun teorisinden daha geniş biçimde nasıl yararlanılabileceği de gösterilmiş olacaktır.

Anahtar Kelimeler: *Oyun Teorisi, Mahkûm İkilemi Oyunu, Heterodoks İktisat, Prebisch-Singer Hipotezi, Uluslararası Ticaret.*

Jel Kodları: B59, B79, F17.

1. INTRODUCTION

In the 60s and 70s when knowledge and rational behaviors in the world were questioned, criticisms against the rational economic man assumption increased. Classical and neoclassical economic theories have also been criticized since they conduct static analyses which results in unrealistic economic consequences, based on this assumption. These studies which criticize the classical and neoclassical theories of economics, which are now called *orthodox*, due to their assumptions, are called *heterodox economics* studies. This nomenclature was developed in the literature for the first time by Colander, Holt, and Rosser (2003) and Davis (2006). Eren (2013) underlines that Colander, Holt, and Rosser (2003) and Davis (2006) define heterodox economics as *critical studies that have become the mainstream without accepting some assumptions of orthodox economics*.

However, according to Colander, Holt, and Rosser (2003), as many neoclassical economists can be regarded as heterodox economists since they do not already accept the essential aspects of orthodox economics in their mainstream studies, additional characteristics are required to separate heterodox economists under the new school of economics. They consider this separation as heterodox economists' refusal to work with the mainstream economics framework unless due to the nature of the model used or the requirements of the emphasized assumptions (Colander, Holt, and Rosser, 2003: 5-6).

Later, Davis (2006) noted that the boundaries of research within heterodox economics had undergone significant changes for nearly three decades after the 1980s in relation to the emergence of

new research methods based on other sciences, and research which criticizes the traditional neoclassical assumptions (Davis, 2006: 2).

Eren (2013) also supports Davis (2006) by separating heterodox economics in the new economics into two as new heterodox economics and settled heterodox economics. In the distinction made in this context, mainstream studies, which criticize only the assumptions of orthodox economics, are called as *heterodox studies within the settled economics conception*. The studies based on other sciences and adapted to economic issues and producing completely innovative approaches are named as *new heterodox studies*. The common point of these two types of studies is to criticize the restrictive assumptions of orthodox economics and to provide a new perspective on economic issues by flexing these assumptions. In this respect, the Evolutionary Game theory is an example of the schools that develop within the context of new heterodox economics in areas such as Behavioral Economics, Experimental Economics, and Neuro-economics.

On the other hand, there are also studies in the literature that do not make any distinction within heterodox economics. Lawson (2006) sees heterodox economics as an "*umbrella term*" which encompasses different approaches, schools, and traditions. He separates heterodox economics from orthodox economics as a whole, with its rejections and with its dependence on ontological analyses of social realities. According to another view, in order to distinguish heterodox economics from orthodox economics, the economic theory taught in the western countries until the dissolution of the Soviet Union is called orthodox. From this aspect, it can be said that with its assumptions and economics definition, orthodox economic theory develops on the primary subjects such as production factors endowment, distribution of national income, economic stability and growth, and creates the macro and microeconomics distinction (Güngör, 2004).

The criticisms about the assumptions of the orthodox economic concept continued with the emergence of critical studies, specifically on the economic theories in which these assumptions were significant. In this process, the classical and neoclassical theories related to international trade also became the subject of critical studies, primarily due to their involving the rational individual assumption. Then, these critical studies were directed to other assumptions related to the Orthodox international trade theories, which involve the assumptions such as ignoring non-equilibrium dynamics by researching being static, being in full competition, and being in a constant state of equilibrium.

In particular, the presence of the staticity assumption seems to prevent the condition that "*living standards in the economy and development levels of countries will increase, due to the increase in income and welfare caused by international trade,*" which is included in neoclassical economics because there will not be any change in the factor endowment or technology under the assumption of being static. In this case, once the economy goes into free trade, there will be no further increase in welfare. However, when considered from a dynamic point of view, as the factor endowment and technology in the economy

increase, the welfare and therefore the level of development should continue to increase (Van Den Berg, 2015: 136).

The belief that the increase in development and improvement can be achieved through the welfare acquired as a result of the increase in international trade has caused heterodox economists working on development economics especially in the late 60s and early 70s to reconsider the subject of international trade from a dynamic point of view. As a consequence of this situation, for heterodox economists, who are dealing with developmental economics by making various developed and underdeveloped country definitions, the subject of international trade between developed and underdeveloped countries became significant. The Prebisch-Singer hypothesis that emerged within Latin American Development Theories is one of the international trade theories that addresses this subject.

In the empirical analyses related to the mentioned trade theories put forward in the context of heterodox economics, it is accepted that the computable analyses of orthodox economics are inadequate (since unlike orthodox theories, heterodox theories contain irrational individual and dynamism assumptions). Therefore, there is a need for flexible analysis methods to which the flexible assumptions of heterodox economics can be adapted.

This study aims to contribute to the development of flexible empirical analysis methods to which the flexible assumptions of heterodox economics can be adapted. For this purpose, the game theory which is purified from the assumptions of orthodox economics with the development of new Heterodox economics schools, such as the evolutionary game theory and behavioral game theory, will be used as a tool. With the practice to be performed in this context, the "prisoner's dilemma game gain matrix," which is used in the expression of international trade, will be rearranged according to the Prebisch-Singer hypothesis. In this way, it will also be shown how it will be possible to use the game theory more broadly as a behavioral rule for computational methods in newly developed empirical analyses for heterodox economics theories.

The studies carried out by Raúl Prebisch (1950) and Hans W. Singer (1949) in the 1950s were used as a means of expressing solution suggestions for the development of underdeveloped countries of the structuralist school. This school was prominent in the context of Latin American development theories and carried out heterodox studies. The structuralist school draws attention to the structural and institutional differences between underdeveloped and developed countries given below:

- Underdeveloped countries bring together foreign capital dominant modern sectors, which are shaped around the structurally and traditionally low-productivity agriculture sector and primary goods export.
- There is no domestic design or production for any product in the modern sectors, and there is also very low employment in these sectors.
- The land lease system limits the increase in agricultural output.

- There is high import growth, despite the high population growth and low export growth (Cyper and Dietz, 2009).

In international trade between underdeveloped and developed countries, these structural and institutional differences cause *a proportional reduction in export items in developing countries in which primary goods are produced, but they cause import items to remain constant or to increase*. As a consequence of this situation, the foreign trade terms, which evolve continuously against the developing countries, are expressed by Prebisch as the reason why *the developed countries gain more profit from trade in the long-term* (Kay, 2011: 34). This explained situation is now called the *Prebisch-Singer Hypothesis* and is seen as the symbol of the structuralist development understanding. It is also stated that this case caused by trade between developed and underdeveloped countries is also valid for trade between developing countries, which produce primary goods, and developed countries, which produce manufacturing industry products.

Since the emergence of the Prebisch-Singer hypothesis, it has become a subject of critical analyses with both its assertions and solution proposals. However, while some of these critical analyses have argued that the hypothesis is valid, some have found it not valid, and some others have asserted it to be unprovable. While giving information about the studies in these three groups, Aslan and Yörük (2008) argue that especially the results of postwar studies, with the effect of the Second World War, either support the hypothesis or find it to be unprovable.

In addition to this, Taşçı and Erçakar (2016) also refer to the results of studies on the Prebisch-Singer hypothesis carried out in the 2000s. Their study indicates that the studies of Bunzel and Vogelsang (2005), Kim, Pfaffenzeller, Rayner, and Newbold (2003) and Harvey, Kellard, Madsen, and Wohar (2010) reached results in support of the Prebisch-Singer hypothesis. On the other hand, the studies conducted by Ghoshray (2011) and Yamada and Yoon (2014) point out that the hypothesis is not provable. Taşçı and Erçakar identified the main reasons for these differences as the period covered in the dataset, whether structural breaks are taken into consideration or not, and the analysis techniques.

In addition to these critical studies, there have also been studies that re-examine the Prebisch-Singer hypothesis under the changing global trade conditions due to the appearance of emerging markets. Emerging markets are defined as *the economies that adopt the financial liberalization that emerged from the end of the 1980s and are turning to opening their national financial markets to the speculation of international financial capital*. These economies, which are called "developing countries" in the 60s and 70s, with their success in changing their production structures, are known today as emerging markets (Yeldan, 2005).

According to Sarkar and Singer (1991), as a factor in the emergence of the Prebisch-Singer hypothesis, the reason for the price of primary goods to be lower than manufacturing industry products is the increase in the supply of primary goods. They point out that the increase in the supply of low-

technology industrial products with the appearance of emerging market economies nowadays may lead to similar results. Similarly, Witkowska (2016) argues that in developing countries which export relatively low added-value simple industrial goods, the terms of trade will arise, similarly to those estimated by the Prebisch-Singer hypothesis in the countries, where the basic export items are primary goods. Based on this, it can be concluded that for especially current debates in the areas of development and industrialization, the concept of "terms of trade" and the Prebisch-Singer hypothesis are still meaningful. Arrighi, Silver, and Brewer (2003) indicate that the terms of international trade in developed countries decreased especially in the 1980s and 1990s, since instead of producing they preferred to import the unprofitable industrial products. On the other hand, emerging markets, which were producing goods to meet the demand of these countries, improved their terms of international trade. As a result, although the concepts of production, trade, and division of labor force, in today's global economy, are considerably different from the years when the Prebisch-Singer hypothesis emerged, it is thought that they include similar relations with changed shapes. Therefore, contemporary debates on the hypothesis continue under various schools of economic thought, focusing on the transformation of this relationship. At this point, new studies that debate the questions, whether development is being achieved in industrialized countries, whether industrialization over emerging markets is about rebuilding the world economic structure, and whether the global division of labor is similarly reconstructed are important.

2. THEORETICAL FRAME AND LITERATURE REVIEW

The theories of international trade put forward in the context of heterodox economics have flexible assumptions because of the nature of heterodox economics. Therefore, new analysis methods that can be adapted to the assumptions with the flexible structure are needed. At this point, game theory is seen as a suitable tool for developing new analysis methods due to its two fundamental characteristics.

The transformation process of the assumptions of the theory: The first version of the theory includes some assumptions that are also found in orthodox economics such as the rational individual, full knowledge and being static. However, these assumptions were flexed parallel to the transformation process of orthodox economics, and as a result, theories, which are now addressed in heterodox economics, such as evolutionary game theory and behavioral game theory, emerged.

With the emergence of fields such as evolutionary game theory and behavioral game theory after the 1980s, game theory became adaptable to the methods which take their foundations from informatics and computer science. At this point, especially with the development of computer programs and software used in parallel to the technological progress, it has become possible to solve game matrices in which flexible assumptions could be adapted. In this respect, for example, the evolutionary game theory attaches expressions reminiscent of flexible rules rather than the assumption, similarly to studies that criticize the assumptions of the classical game theory, to the games. In a sense, it aims to make the analyses closer to the real world, through software that provides these expressions.

After this change, game theory, either alone or with some analysis methods, became usable in investigating economic subjects. These analysis methods are the methods which produce empirical analysis methods adjunct to heterodox economics, take their origins from the computational methods of new heterodox economics based on informatics and computer science, and involve learning within the scope of agent-based computational economics, like geographic information systems (GIS), network models, or cellular automation systems.

Nowak and Sigmund (2000) argue that, although at first glance they seem to be different areas, the use of game theory and cellular automation together is increasing with each passing day. They emphasize in their study, in which they addressed the subject from a game theoretical point of view, that cell automation could be used to enlighten the emergence of cooperation. Alexander (2007) shows how game samples with various numbers of players can be used together with network models. Ganjali and Güney (2017) include an application in which they combine geographic information systems (GIS) and game theory, for the management of water resources, in their study. At the same time, they point out that the combination of these two methods will be a profitable platform also for future studies on the management of water resources. Similarly, Moradi, Delavar, and Moshiri (2017) in the study in which they combined Geographic Information Systems and game theory to study earthquake susceptibility emphasized that to determine the role played by each criterion, and inter-criteria interactions, the game theory could be used in the decision-making process.

When international trade is the subject of the mentioned analysis, these computable methods enable the analyses to reflect real-world conditions since they offer some features such as defining the individual characteristics for the countries involved in the trade, locating these countries and expressing trade networks between these countries. Due to these features they offer, Lee, Park, and Cho (2010) created an artificial grid model including countries and regulatory bodies for the international trade market and used specific genotypes based on the evolutionary game theory as a strategy. By using the advantage of the analysis method of offering the opportunity to identify country characteristics, they defined developed and developing features to the countries, so that they pointed out that it would be possible to reach the closest model to the real world international trade market.

Becoming of the prisoner's dilemma game a classicized example of international trade: Since its inception, the Prisoner's Dilemma game is being used to explain international trade because it includes both conflict and cooperation at the same time (Conybeare, 1984; Conybeare, 1987; Krugman, 1987; Krugman, 1991).

The use of the Prisoner's Dilemma game in the expression of international trade is encountered for the first time in Conybeare's (1984) study. In this study, Conybeare reveals that free trade can be expressed by the Prisoner's Dilemma game. Then, in the book *Trade Wars* he wrote in 1987, he discussed in detail the cases of "big countries against big countries," "big countries against small countries," and

"small countries against small countries." In the asymmetric relationship in the trade war between the big country and the small country, he indicated that the big country adopts withdrawing as the dominant strategy and the small country adopts cooperating as the dominant strategy. As a result, this relationship reveals the Prisoner's Dilemma game.

In the same year, the study carried out by Krugman (1987) addressed the new trade policies developed against the idea of the free trade that is valid up to that date. In this study, it is stated that free trade cannot be regarded as outdated despite these policies. In this study, Krugman examined the effects of subsidies with the prisoner's dilemma game on a sample in which he dealt the Boeing and Airbus aircraft companies. Krugman's study carried out in 1991 examined free trade agreements and trade blocs and pointed out that international trade performed by trade blocks under different circumstances can be expressed by the Prisoner's Dilemma game. It can also be used after being adapted nowadays in the expression of many economic events that involve conflict and cooperation.

3. METHODOLOGY

In the experiments reported by Flood (1952), a general statement of the nonzero-sum prisoner's dilemma game was established, keeping the basic fiction used for the prisoner's dilemma game the same.

$$T > V > Y > Z \quad (1.1)$$

$$V > (T+Z)/2 \quad (1.2)$$

In this general expression, to provide the inequalities given in 1.1 and 1.2, T, V, Y, Z are presented with the gain matrix given in Table 1 and when each of the prisoner's dilemma game players has the information given below.

Actors A and B have committed a common crime and have been arrested;

- If one confesses the crime and the other does not, the one who has confessed will be punished with Z unit and the other one with T unit.
- If they both confess the crime, they will be punished with V unit each.
- If the two do not confess the crime, they will both be punished with Y unit.

Table 1. Gain Matrix Display of the Prisoner's Dilemma Game

A	B	
	Strategies	Confess
Confess	V, V	Z, T
Do not confess	T, Z	Y, Y

When the gain matrix given in Table 1 is examined, it is observed that the game is primarily a two-actor game with no zero total. From the values in the matrix, the first notation shows the gain of actor A, and the second notation shows the gain of actor B. From the point of view of actor A, if he thinks that actor B will confess, his best strategy will be to confess, because he will prefer to be punished with V unit instead of being punished with T unit penalty ($T > V$). If he thinks that actor B will prefer not to confess, his best strategy will be again to confess, because he will prefer to be punished with Z unit, instead of being punished with Y unit ($Y > Z$). Actor B will also assume that confessing strategy is the best strategy for himself if he takes into consideration that the preferences of both himself and actor A will be done under the assumption of rationality. This is because the actors are in the same position relative to each other, and they think in the same way as the opposite one, in other words, the game is symmetrical. In this case, the Nash equilibrium of the game will occur in the "confession-confession" strategy pair, and the actors will be punished with V unit although $V > Y$.

It appears that the punishment the actors will receive in the case of the Nash equilibrium, which is the result of reaching the "confess-confess" pair by acting rationally, seems to be not always better than the punishment they will receive in other non-rational situations. In other words, if the actors had the opportunity to communicate, they would be punished less by agreeing about choosing "not to confess-not to confess" strategy. The differences that may arise in terms of the formation and solution of the game (such as the possibility of communication of prisoners at the stage of formation, and the preference of equilibrium which results in less punishment due to this communication at the stage of solution) mean that there is cooperation in this situation. If the actors can communicate during the game, it is highly probable that they act collaboratively in the interests of both. However, if there is no possibility for communication between the actors, the "confess-confess" strategy dominates the strategy of "not to confess-not to confess." Therefore, prisoners' using the "confess-confess" strategy is called as not Pareto²-efficient equilibrium since there is a strategy to be punished less.

If all the explanations given above are considered, it can be concluded that the prisoner's dilemma game is an example of the game which is symmetrical, non-zero-sum and not Pareto efficient, and which contains conflict and cooperation and multiple Nash equilibrium. In that sense, the prisoner's dilemma game was deemed appropriate to be used for the expression of free trade in international trade.

3.1. Expression of International Trade with the Prisoner's Dilemma Game

² Pareto efficient equilibrium: Pareto means improvement as a word. It is an economic term that indicates that the actor cannot increase his gain without reducing the gain of other actors by changing his strategy while Pareto is at the active equilibrium point. The fact that in the equilibrium point Pareto is not efficient shows that at this point one of the actors can increase his/her gain without reducing the gain of the other actors, by changing the strategy.

In this part, the prisoner's dilemma game, of which gain matrix is shown in Table 1, will be rearranged to indicate that the classical trade view, in which countries provide equal gains using bilateral trade advantages, is valid.

There are two original strategies for the prisoner's dilemma game that will be created for international trade: "to confess" and "not to confess." Among them, "to confess" means to be noncooperative, that is, not agreeing to make free trade agreements, and "not to confess" means cooperating, that is, negotiating free trade agreements. The gain matrix in the latter case, since its values differ from the initial situation because of the gain instead of punishment, will be as shown in Table 2 on the assumption that the cooperative situation provides more gains.

Table 2. Prisoner's Dilemma Game for International Trade

Country A	Country B	
	Strategies	
Non-cooperative	Non-cooperative	Y, Y
Cooperative	Non-cooperative	T, Z
	Cooperative	Z, T
	Cooperative	V, V

The issue that should be considered in Table 2 is that, although the gain matrix values are the same with Table 1, the gain obtained from the game is stated as punishment in Table 1 and as gain in Table 2, thus, they must have been relocated among themselves. In this way, the gain provided by the non-cooperative - non-cooperative strategy pair for a new situation is not always better than the gain provided in other non-rational cases, because the cooperative - cooperative strategy pair ensures that they gain more from international trade. When it is known that actor B is in a non-cooperative strategy, the best option is to be non-cooperative for rational actor A ($Y < Z$). If actor A believes that actor B will be in a cooperative strategy, he/she will choose to be non-cooperative, provided that he/she takes a rational decision ($T > V$) again. Thus, in the case of players who do not have the possibility of communication, it is observed that the game will result in a non-cooperative - non-cooperative strategy, which is one of the Nash equilibrium.

4. APPLICATION

In the application part of the study, "the prisoner's dilemma game gain matrix," which is rearranged for international trade in Table 2, will first be expressed by adhering to the classical game theory. While doing it, the restrictive assumptions for the theory of comparative advantages, which reflects the view of orthodox economics on international trade, will be considered. Then, according to the claim of the Prebisch-Singer hypothesis which is one of the international trade theories of heterodox economics, by flexing the assumptions of the game theory, it will be explained how the "prisoner's dilemma game gain matrix" can be expressed.

Since the prisoner's dilemma game has already emerged as an expression of the classical trade perspective which argues that countries provide equal gains from international trade by using their comparative advantages, in the first step, only the gain matrix values indicated previously by notations in Table 2 will be formed by the author with the smallest possible values by adhering to the inequalities of $T > V > Y > Z$ and $V > (T + Z)/2$. The values were selected as small, in order to prevent the cooperative actor from working to optimize his/her gain by changing his/her strategy from non-cooperative to cooperative, respectively, in iterative games. The relevant gain matrix is presented in Table 3.

Table 3. Comparative Advantages Theory Prisoner's Dilemma Game Gain Matrix

Country A	Country B		
	Strategies	Cooperative	Non-Cooperative
Cooperative		0,6 ; 0,6	0 ; 1,1
Non-Cooperative		1,1 ; 0	0,3 ; 0,3

In the gain matrix given in Table 3, there is no information about which types of goods have a comparative advantage concerning country A and country B. Therefore, it is not known whether the countries are primary good producers or producers of manufacturing industry products. The only assumption is that it is possible to provide equal gains from international trade, provided that countries produce goods in which they have comparative superiority, specialize in these goods and export these goods. By selecting the values as $T = 1.1$; $V = 0.6$; $Y = 0.3$; $Z = 0$, the inequalities;

$$T = 1.1 > V = 0.6 > Y = 0.3 > Z = 0$$

$$0.6 > (1.1 + 0) / 2$$

are met. Thus, since international trade is not a case which occurs once and never occurs again, with the values given, it prevents the actors from optimizing their gains by changing their strategies consequently from "cooperative" to "non-cooperative," respectively. In this way, the gain matrix is suitable to the empirical analysis of orthodox economics.

4.1. Construction of the Prisoner's Dilemma Game According to the Prebisch-Singer

Hypothesis

In this part of the application, in accordance with the purpose of the study, the "prisoner's dilemma game's gain matrix" will be rearranged according to the claim of the Prebisch-Singer hypothesis that addresses trade between developed and developing countries. For this, the original assumptions of the trade theory that were mentioned earlier will be considered.

To this end, the assumption of the Prebisch-Singer hypothesis, which argues that in the trade between a developing and a developed country, the developing country profits less, will be made suitable

to being analyzed by the computational methods of the new heterodox economics, by adhering to the inequalities of the Prisoner's Dilemma Game Gain Matrix given in 1.1 and 1.2.

Table 4. Prebisch-Singer Hypothesis Prisoner's Dilemma Game Gain Matrix

Country A	Country B	
	Strategies	
	Cooperative	Non-Cooperative
Cooperative	0,6 ; 1	0 ; 1,1
Non-Cooperative	1,1 ; 0	0,3 ; 0,3

To rearrange the gain matrix given in Table 4 according to the claim of the Prebisch-Singer hypothesis, firstly, the actors were made heterogeneous, by making definitions of developed and developing countries. Then, T, V, Y, Z values from Table 3 to be used for providing the inequalities given in Equation 1.1 and Equation 1.2 were rearranged in order to perform a consistent analysis. According to this, the rearranged gain matrix values provide the inequalities given in 1.1 and 1.2, provided that country A is a developing country and country B is a developed country.

$$T=1.1 > V_1=1 > V_2=0.6 > Y=0.3 > Z=0$$

$$1 > (1.1+0)/2$$

$$0.6 > (1.1+0)/2$$

When determining the gain matrix values, care was taken to fulfill especially the $T > V$ and $V > (T+Z)/2$ conditions at the same time (for the values $T=1.1$ in Table 3 $V >= 0.6$ and in Table 4 $V_1=0.6$ and $V_2=1$). Again by giving these values, the case, which is the maximizing the gain of actors by changing their strategy continuously using the repeatability of the prisoner's dilemma game as in international trade, will be avoided.

After considering the specific assumptions of the discussed trade theory, the assumptions of the classical game theory will be flexed within the framework of the general assumptions of heterodox economics.

As mentioned earlier, international trade is considered to be an *iterative* game. This situation results in the use of *iterative games* which emerges with the deviations from the assumptions of classical game theory, in the analyses that will be done for comparative advantages theory prisoner's dilemma game given in Table 3. However, since heterodox theories do not have restrictive assumptions such as *rational players* inherent in the nature of iterative games, they are generally considered to be more appropriate for evolutionary game theory, which allows for flexible assumptions. Therefore, in the analysis of heterodox theories such as the Prebisch-Singer hypothesis given in Table 4, using behavioral rules displaying evolutionary features such as retaliatory behavior gives better results. In this way, actors

do not make their strategy choices according to rational individual behaviors, but according to the evolutionary behavioral rules that have been determined beforehand. Therefore, the case of failure to reach equilibrium because of the strategy changes that will occur due to playing the game iteratively can be overcome by evolutionary decisive strategies that are expected to be achieved through the behavioral rules exhibiting an evolutionary feature. Thus, the analysis of heterodox theories by game theory becomes possible with the adaptation of these theories to the tools of evolutionary game theory.

The Prisoner's Dilemma game's gain matrix given in Table 4 was rearranged to express the claim of the Prebisch-Singer hypothesis, which is a theory emerging within the context of heterodox economics, about international trade. With this study, it is shown how this matrix can be made suitable for the analysis with the computational methods of new heterodox economics by defining behavioral rules that exhibit evolutionary features.

5. CONCLUSION

The heterodox economics studies, which have emerged in recent years with the criticisms of orthodox economics and its restrictive assumptions, also re-examine the international trade theories like the other economic theories. The Prebisch-Singer hypothesis, which is the symbol of the foreign trade concept of the structuralist school, which came to the forefront in the Latin American Development Theories, is one of the heterodox theories that emerged in this way. However, such theories can be partially analyzed or not analyzed at all by empirical methods, which are used by orthodox economists in examining international trade because of the restrictive assumptions. This situation causes the inability of the analysis results to reflect the real world all the time. The need for new analysis methods caused the computational methods of new heterodox economics to emerge with the progress in informatics and computer sciences. By using the heterodox fields such as the evolutionary game theory and behavioral game theory, which have emerged as a result of criticisms on the assumptions of the game theory, it has become possible to integrate game theory with these computational methods. However for this, firstly, flexible assumptions of the economic subject to be addressed with the game theory need to be reflected in the gain matrix.

The Prebisch-Singer hypothesis emerged primarily to explain the trade between developed and developing countries and claimed that *in the long-term, developed countries will turn out to be more profitable from the trade between developed and developing countries*. The study is rephrasing this claim of the Prebisch-Singer hypothesis with the Prisoner's Dilemma game gain matrix. Thus, the created gain matrix is adapted to be used as a behavioral rule for geographical information systems (GIS), network models, cellular automation systems, simulation, or artificial intelligence algorithms, within the context of agent-based computational economics, which is one of the computational methods of new heterodox economics.

These analyses will guide contemporary discussions which are based on the assumption that the Prebisch-Singer hypothesis is still valid for international trade, which occurs between emerging market economies and developing countries that export simple industrial products with a relatively low percentage added value. Besides, for different heterodox trade theories, the prisoner's dilemma game gain matrix can be reconstructed on the basis of the comparative advantages theory prisoner's dilemma game gain matrix, as it was done in this study. By this means, newly created gain matrices will also become suitable for analyzing by the computational methods of the heterodox economics mentioned.

The application performed in the study can also be expressed as a multi-actor prisoner's dilemma game since it is about an economic issue that is suitable to be transformed into a multi-country analysis from a two-country analysis. Since multi-country models are more likely to reflect the real world when examining the international trade, their use, especially in combination with methods that use geographic information systems, is expected to contribute to the emergence of more realistic analyses.

Except for the prisoner's dilemma game used in the expression of international trade, which is the economic subject addressed in this study, with the game theory, new gain matrices can be created for all economic issues that can be expressed as a game theory in future studies. In this respect, it is thought that it can be the subjects of all analyses, which primarily support the idea that economic phenomena emerging in recent years should not contain strict rules and restrictive assumptions.

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