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# **COLLECTION OF THESIS**

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**Game-theoretic oligopoly modelling of free  
trade agreements  
PhD dissertation**

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# 1. Motivation and previous research

Evolving of free trade agreements creates not just a free, mutually beneficial trade exchange between actors, but may result in elimination of non-tariff barriers. Since the 1950s, due to global processes, their number has increased exponentially, and this trend is likely to continue in the coming decades. At the same time, their nature has gradually changed, so that today's world trade involves a number of rapidly integrating actors who are forming ever deeper and more complex collaborations.

The examination of cooperative trade policies is made necessary by the increasing relevance of free trade agreements, which the dissertation intends to implement with game-theoretic oligopoly models. There are currently two groups of tools most commonly used to quantify trade agreements in the international literature: oligopoly models illustrate situations before and after negotiations with micro-level profit analyzes – they create the profit function with the help of income and cost functions, and then, based on the first-order condition of optimization, they show the equilibrium emission levels by using

reaction functions. (Such analyzes are dealt with, for example, by Bagwell–Staiger (1999, 2002, 2009), Zissimos (2009), or Soegaard (2013).) Gravity and Computable General Equilibrium (CGE) models based on macroeconomic elasticity are macro-level economic/commercial impact analysis is carried out. (Arkolakis et al. 2012, Felbermayr et al. 2013, Kutasi et al. 2014) With this thesis, our aim is to include a third category, the extension of the microeconomics-based game theory oligopoly toolbox to the level of countries and regions in the commercial to investigate effects.

Oligopoly models are most often given a game-theoretic approach, which is why we also apply this approach in the thesis. According to this, to set up a game, players, strategies (choices) and payoffs (consequences of choices) are needed. Basically, we use a non-cooperative game for free trade agreements: this means that during the game, if one of the parties puts the other in a worse position, they can expect a response; and the individual participants show essentially competitive behavior, – if cooperation is established, it can only be realized because it is in the interests of the parties individually. (Markusen 2002, Kreps 2005, Kapás 2017)

The basis of the concept is determined by the interactions between global economic actors. In the course of their decisions, trade partners can form agreements or maintain tariffs, which divert profits towards the internal market at the expense of foreign trade partners. Strategies can only be maintained through repeated interaction, but they can be changed at any time. The application of customs duties is unilateral or multilateral, while cooperation is the result of a multilateral decision. The main goal of economic actors is to achieve maximum prosperity, therefore during their interactions with each other – be it cooperation or conflict – they certainly make decisions that can improve their original situation; therefore, considering their own circumstances (rules, options), the actors always choose the most favorable option available to them. Economically oriented decisions are illustrated by reaction functions, which can be used to show the equilibrium situations that develop during the game, the optimal strategies of the participating parties, and determine the possible winners and losers.

Although the literature generally agrees that trade policies are aimed at maximizing economic profit, we often encounter situations where economic profit takes a backseat and is

replaced by other geopolitical or security policy interests. The actors of the agreements make their strategic decisions in the light of these. (Laidi 2008, Dieter 2014, Kutasi 2015, Eichengreen et al. 2019)

The difficulty of elections lies in determining the degree of interaction between the participants: competition results in special advocacy; collusion is a willingness to move in the other's direction; cooperation means compliance with the rules resulting from commitment; integration is an in-depth form of connection where economic policies and norms are harmonized; coordination results in the greatest dependency through joint, supranational governance. (Blahó et al. 2004)

The payouts of the actors depend on the choice of strategies, so the expected profits change. The most optimal version available to everyone is illustrated by the Nash equilibrium, its extended versions show the best strategy combinations created during oligopoly corporate competition. (Neumann–Morgenstern 1944, Axelrod–Hamilton 1981, Kreps 2005, Kóczy 2006, Colman–Gold 2017)

In our dissertation, based on what has been said so far, we are looking for answers to the two central questions: what type of interaction brings greater economic benefit, and where is the point where it is worth going to for the parties to break down customs barriers; along the lines of these two questions, we examine the impact of trade agreements on economic well-being.

## 2. Applied method

The structure of our generalized commercial model

The economies in the model are actors in a trade agreement that export products and services to each other. In the pre-cooperation period, customs duties are applied against each other, but afterwards they are abolished, but at least the existing obstacles are reduced.

Setting up the game is made possible by the combined existence of three factors:

$$\{N, (p_i), (\pi_i), i \in N\}$$



*Players: economic spots (states, regions, integrations):*  $N = 1; 2; \dots n$  úgy, hogy  $i = 1, -i = 2$  és  $i \neq -i$ . In this created environment, players interact with each other in such a way that they are strategically interdependent. This means that a player's payoff depends both on his own strategy and on the strategy of the other (others) and vice versa.

*Strategies:* maintaining the status quo or establishing a free trade agreement:  $p = pre, post$ .

*Payoffs:* players' trade profit and welfare levels for each strategy:  $\pi_i^p, \pi_{-i}^p$ , which in all cases denote a rational number ( $\pi_i^p, \pi_{-i}^p \in \mathfrak{R}$ ) for all elements of the strategy set.

The game consists of a *series of actions*, which the players perform based on their decisions, taking into account their own and others' strategies based on the existing set of information. For formulation and mathematical tractability, we write our model in normal form.

## Export revenue

The export revenue function for the players is as follows:

$$\begin{aligned}
 tr_i^p &= v_i^p q_i^p, \text{ where} \\
 v_i^p(q_i^p, q_{-i}^p) &= \alpha_i^p - (q_i^p + q_{-i}^p); \\
 tr_{-i}^p &= v_{-i}^p q_{-i}^p, \text{ where} \\
 v_{-i}^p(q_{-i}^p, q_i^p) &= \alpha_{-i}^p - (q_{-i}^p + q_i^p).
 \end{aligned} \tag{2.1}$$

In the export income function,  $\alpha^p$  the general coefficient,  $q^p$  it shows the exported quantity before and after the conclusion of the trade agreement ( $p: pre, post$ ) period, while  $v^p$  the estimated value of the export.

## Export costs

The export cost function is the general coefficient ( $\beta^p$ ), tariff ( $t^p$ ), transport ( $s^p$ ) and administrative ( $a^p$ ) cost occurs along costs depending on the exported quantity:

$$\begin{aligned}
 tc_i^p &= (\beta_i^p + c_i^p)q_i^p, \\
 tc_{-i}^p &= (\beta_{-i}^p + c_{-i}^p)q_{-i}^p, \text{ where} \\
 c_i^p(q_i^p) &= t_i^p(q_i^p) + s_i^p(q_i^p) + a_i^p(q_i^p), \\
 c_{-i}^p(q_{-i}^p) &= t_{-i}^p(q_{-i}^p) + s_{-i}^p(q_{-i}^p) + a_{-i}^p(q_{-i}^p),
 \end{aligned} \tag{2.2}$$

We note that in our theoretical model, although we show the shipping and administration costs, during the calibration we consider them as part of the total income (profit) in accordance with professional statistics.

## Trade profit

The profit from exports is determined by the difference between the total export revenue for products and services and the related costs. The markets are identified according to the two nominated groups, which simplifies but does not harm the operation of the model.

Based on this, the complete profit functions for products and services are characterized by the following equations:

$$\begin{aligned}\pi_{i,s}^p(q_{i,s}^p, q_{-i,s}^p) &= tr_{i,s}^p - tc_{i,s}^p, \\ \pi_{-i,s}^p(q_{-i,s}^p, q_{i,s}^p) &= tr_{-i,s}^p - tc_{-i,s}^p,\end{aligned}\tag{2.3}$$

where  $s = pro, ser$ .

If this breakdown is applied, the total profit of trading farms in period p is:

$$\begin{aligned}\sum \pi_{i,s}^p &= \pi_{i,pro}^p + \pi_{i,ser}^p \\ \sum \pi_{-i,s}^p &= \pi_{-i,pro}^p + \pi_{-i,ser}^p.\end{aligned}\tag{2.4}$$

## Opportunities for optimization under uncertainties

The determination of the optimum point of the commercial oligopoly model works on the same principle as the basic Cournot model. The actors recognize the conditions existing during the interaction and then maximize their objective function based on them. It is advisable for both players to follow the optimum point, as none of them can get into a better position.

The maximization is therefore realized as follows:

$$\begin{aligned}\frac{\partial \pi_{i,g}^p}{\partial q_{i,g}^p} &= 0, \\ \frac{\partial \pi_{-i,g}^p}{\partial q_{-i,g}^p} &= 0.\end{aligned}\tag{2.5}$$

The shape of the reaction functions:

$$\begin{aligned} r_{i,s}^p(q_{i,s}^p) &= \frac{(\alpha_{i,s}^p - c_{i,s}^p)}{4\beta_{i,s}^p} - q_{i,s}^p, \\ r_{-i,s}^p(q_{i,s}^p) &= \frac{(\alpha_{-i,s}^p - c_{-i,s}^p)}{2\beta_{-i,s}^p} - 0,5q_{-i,s}^p. \end{aligned} \tag{2.6}$$

Then the trade balance occurs as follows:

$$\begin{aligned} E(q_i^p) &= (\alpha_i^p + \beta_i^p - 2c_i^p) \frac{1}{8}, \\ E(q_{-i}^p) &= (\alpha_{-i}^p + \beta_{-i}^p - 2c_{-i}^p) \frac{1}{4}. \end{aligned} \tag{2.7}$$

However, the available profit of the players is affected by external uncertainties ( $U_i^p$ ); as long as the players have full information about customs and transport costs, they cannot price the bargaining position, risk behavior and geopolitical factors of the participants with complete certainty. As a result, we introduce the uncertainty variable ( $U$ ) to show the profit:

$$\begin{aligned} \pi_i^p | U_i^p, \quad q_i^p | U_i^p, \quad v_i^p | U_i^p, \quad c_i^p | U_i^p, \\ \pi_{-i}^p | U_{-i}^p, \quad q_{-i}^p | U_{-i}^p, \quad v_{-i}^p | U_{-i}^p, \quad c_{-i}^p | U_{-i}^p, \end{aligned} \quad (2.8)$$

where  $U_i^p \leq U_{-i}^p$ , vagy  $U_i^p = U_{-i}^p$ .

The expected profit then occurs as follows:

$$\begin{aligned} \pi_i^p | G_i^p &= (\alpha_i^p + \beta_i^p - c_i^p | U_i^p) q_i^p, \\ \pi_{-i}^p | G_{-i}^p &= (\alpha_{-i}^p + \beta_{-i}^p - c_{-i}^p | U_{-i}^p) q_{-i}^p. \end{aligned} \quad (2.9)$$

The reaction functions of the actors are illustrated by the following equations:

$$\begin{aligned} r_i^p(q_i^p) &= (\alpha_i^p + \beta_i^p - q_{-i}^p - c_i^p | U_i^p) \frac{1}{4}, \\ r_{-i}^p(q_{-i}^p) &= (\alpha_{-i}^p + \beta_{-i}^p - q_i^p - c_{-i}^p | U_{-i}^p) \frac{1}{2}. \end{aligned} \quad (2.10)$$

The predicted trade balance in case of uncertainties:

$$\begin{aligned} E(q_i^p) &= (\alpha_i^p + \beta_i^p - q_{-i}^p - 2c_i^p | U_i^p) \frac{1}{8}, \\ E(q_{-i}^p) &= (\alpha_{-i}^p + \beta_{-i}^p - q_i^p - 2c_{-i}^p | U_{-i}^p) \frac{1}{4}. \end{aligned} \quad (2.11)$$

In the event that the participating economies are fully informed, point E represents the equilibrium situation. If there is uncertainty, the actors step aside and optimize at another point. The greater the risk, the further they are from the original equilibrium state. With regard to commercial relations, it may also be the case that certain events do not affect the players and therefore do not pose a risk; this can also apply to 1,2,...n players, but others can strongly influence the behavior of the characters.

We add that if the players are able to price the entire set of risks surrounding them, then they are fully informed in the created situation, if they are not, then they are not fully informed. It is important to note that information is only complete in our model if we do not account for uncertainties.

### 3. Results of the thesis

- The literature carries out and describes wide-ranging impact assessments related to trade liberalization. Micro-level theories mainly examine the effects on consumer utility, product and production factor prices, as well as

corporate output, marginal cost, marginal benefit and profit depending on various variables. Approaches that examine macroeconomic factors typically explore the consequences for trade, growth, consumption, and public investment. As a complement to the previous ones, by extending oligopoly models to economies, the dissertation presents a new, novel point of view in such a way that it realizes:

- the transfer of microeconomics theory to international trade;
  - the integration of the newly created "trade model" into the theoretical models of trade.
- The so-called trade model describes precisely the decision sequences and also how two countries/groups of countries can be inserted in place of companies by making modifications to the basic settings of the original Cournot model.
  - It can also be described as a novel result that the thesis matches the concepts of the financial results of the companies with the definitions related to international trade, so it becomes possible to interpret, among other things, the customs level, or the income from exports, and the costs.



Additional results of the model:

- it is possible to examine the roles that economies play in trade interactions;
- ceteris paribus, the level of benefits at given export and customs levels can be revealed, in addition, it is also possible to show the profit of commercial actors for each level of output;
- the entire decision-making process can be modelled;
- the winners and losers of the game can be determined;
- the possibilities of the direction of displacement compared to the original state can be compared in such a way that:
  - strategies can be changed and thus the position of the actors can also change,
  - individual inputs can also be changed in order to seek greater profits, by means of which it is possible to find out what effect, for example, changes in the export volume, export price, or customs have on the players and, as a result, on the level of trade;

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- it can be seen within what framework the conclusion of a trade agreement can bring profit; since it is possible to assess what proportion of customs reduction is necessary in order for all actors to obtain mutual benefits; at the same time, it can be observed at which levels the application of restrictions becomes harmful;
- conclusions can be drawn from the observed reactions, which can be used to deal with commercial situations that arise later;
- as a result of all this, false-possible assumptions can be formulated that help in understanding commercial situations, in resolving conflict situations of this kind, and thus in selecting the strategies that are likely to generate the highest profit.
- It should be noted that in the case of free trade agreements, the size of the profit always matters, therefore the profits assigned to each output level are given special importance.
- The main benefit of the dissertation is that it wants to prove an applied economic assumption (i.e. the analysis of international trade agreements with a newly created trade

model), and thereby wants to convey a new, innovative approach to trade theory itself, based on a broad theoretical synthesis.

## 4. References

- Arkolakis, C. – Costinot, A. – Rodríguez-Clare, A. (2012). New Trade Models, Same Old Gains? *The American Economic Review*, 102(1), pp. 94–130. DOI: 10.1257/aer.102.1.94.
- Axelrod, R. – Hamilton, W. (1981). The Evolution of Cooperation. *Science*, 211(4489), pp. 1390–1396. DOI: 10.1126/science.7466396.
- Bagwell, K. – Staiger, R. (1999). An Economic Theory of GATT. *The American Economic Review*, 89(1), pp. 215–248.
- Bagwell, K. – Staiger, R. (2002). Economic Theory and the Interpretation of GATT/WTO. *The American Economist*, 46(2), pp. 3–19.
- Bagwell, K. – Staiger, R. (2009). The economics of trade agreements in the linear cournot delocation model. National Bureau of Economic Research, *Working Paper* 15492.

Blahó, A. – Palánkai, T. – Kengyel, Á. (2004). Regionális integrációk és blokkok. In: Blahó, A. (ed.), *Világgazdaságtan: Globális fejlődés, gazdaságdiplomácia*. Aula Kiadó, Budapest, pp. 353–388. ISBN: 963 947 886 5.

Colman, A. – Gold, N. (2017). Team Reasoning: Solving the Puzzle of Coordination. *Psychon Bull Review*, 25(5) pp. 1770–1783. DOI: 10.3758/s13423-017-1399-0.

Dieter, H. (2014). *The Return of Geopolitics: Trade Policy in the Era of TTIP and TPP*. Friedrich Ebert Stiftung, International Policy Analysis.

Eichengreen, B. – Mehl, A. – Chițu, L. (2019). Mars or Mercury redux: the geopolitics of bilateral trade agreements. *Working Paper Series 2246*, European Central Bank.

Felbermayr, G. – Heid, B. – Lehwald, S. (2013). *Transatlantic Trade and Investment Partnership (TTIP): Who benefits from a free trade deal? Part 1: Macroeconomic Effects*, Bertelsmann Stiftung, Global Economic Dynamics (GED) Team, Gütersloh.

Kapás, J. (2017). *Vezetői közgazdaságtan*. Debrecen: Debreceni Egyetemi Kiadó.

Kóczy, Á. (2006). A Neumann-féle játékelmélet. *Közgazdasági Szemle*, 53(1), pp. 31–45.

Kreps, D. (2005). *Játékelmélet és közgazdasági modellezés*. Budapest: Nemzeti Tankönyvkiadó.

- Kutasi, G. – Szijártó, N. – Rezessy, G. (2014). Az USA-EU kereskedelmi tárgyalások várható hatása a magyar növekedésre. *Külgazdaság*, 58(7–8), pp. 58–85. ISSN 032 442 02.
- Kutasi, G. (2015). A Transzatlanti kereskedelmi és beruházási társulás és a növekedés: Gyakorlati és módszertani kérdések. *Köz-gazdaság*, 10(3), pp. 57–71.
- Laidi, Z. (2008). How Trade Became Geopolitics. *World Policy Journal*, 25(2), pp. 55–61. DOI:10.1162/wopj.2008.25.2.55.
- Markusen, J. (2002). *Multinational Firms and the Theory of International Trade*. Cambridge: MIT Press.
- Neumann, J. – Morgenstern, O. (1944). *Theory of Games and Economic Behavior*, Princeton Univ. Press, Princeton NJ, első kiadás.
- Soegaard, C. (2013). An Oligopolistic Theory of Regional Trade Agreements. *Economic Research Papers 270542*, University of Warwick.
- Zissimos, B. (2009). Optimum Tariffs and Retaliation: How country numbers matter. *Journal of International Economics*, 78(2), pp. 276–286. DOI: 10.1016/j.jinteco.2009.04.003.

## 5. Publication in the topic of the thesis by the candidate

### **Peer reviewed journal articles in Hungarian**

Kovács, E. (2022a). Túl a vámokon: A modern szabadkereskedelmi egyezmények tartalmi elemei. *Külügyi Szemle*, 21(1), pp. 220–242. Doi: 10.47707/Kulugyi\_Szemle.2022.1.9.

### **Scientific books, book chapters in Hungarian**

Kovács, E. (2023). Újragondolt termelés: A digitalizáció, az automatizáció és a robotizáció hatásai a globális ellátási láncokra. In Kovács, Z. ed., *A mesterséges intelligencia és egyéb felforgató technológiák hatásainak átfogó vizsgálata*. Budapest, Katonai Nemzetbiztonsági Szolgálat, pp. 220–244. ISBN: 978 615 612 816 4.

### **Other in Hungarian**

Kovács, E. (2020a). A szabadkereskedelmi egyezmények dilemmái játékelméleti oligopólium megközelítésben. In *IX. Interdiszciplináris Doktorandusz Konferencia*. Pécs, Pécsi Tudományegyetem, 2020. november.

Kovács, E. (2020b). A szabadkereskedelmi egyezmények játéka. In *PEME XX. Nemzetközi Tudományos PhD-Konferencia*. Budapest, Professzorok az Európai Magyarországért Egyesület, 2020. november.

Kovács, E. (2021a). Az automatizáció hatása a jövő kereskedelmi tendenciáira. In *KNBSZ projektkonferencia*. Budapest, Katonai Nemzetbiztonsági Szolgálat, 2021. november.

Kovács, E. (2021b). Az ázsiai szabadkereskedelmi egyezmények hatásainak megközelítései. In *PEACH Junior Hallgatói Konferencia*. Budapest, Pázmány Péter Katolikus Egyetem, 2021. május.

Kovács, E. (2022b). A globális ellátási láncokat érő sokkok hatásai és a kockázatok értékelése. *Magyar Közgazdasági Társaság, Fejlődésgazdaságtani Szakosztály*. Retrieved from <https://fejlodesgazdasagtan.hu/2022/04/25/a-globalis-ellatasi-lancokat-ero-sokkok-hatasai-es-a-kockazatok-ertekelese/> (Accessed 2023.05.15.).

## **Peer reviewed journal articles in English**

Kovács, E. (2019). More cooperation, more benefit?: An analysis of modern trade agreements. *Köz-gazdaság*, 14(3), pp.271–285. Doi: 10.14267/RETP2019.03.23.

Kovács, E. (2021c). A conjectured Cournot duopoly model for the EU–US automobile trade: A game theoretic analysis of the TTIP’s most traded product. *Competitio*, 20(1-2), pp.48–70. Doi: 10.21845/comp/2021/1-2/5.

Kovács, E. (2022c). EU-US trade dilemmas in a linear Cournot model. *Köz-gazdaság*, 17(1), pp.217–233. Doi: 10.14267/RETP2022.01.13.

## **Scientific books, book chapters in English**

Kovács, E. (2020c). Companies in different states: The common logic of free trade agreements and transfer pricing. In Benczes, I., Kaponyi, E. & Szerényi, Zs. eds., *Contemporary global challenges in geopolitics, security policy and world economy*. Budapest, Corvinus University of Budapest, International Relations Multidisciplinary Doctoral School, pp. 234–251. ISBN: 978 963 503 834 3.

Kovács, E. (2020d). Transoceanic trade triangle of the US–EU–China: A game theoretical analysis on its present and future relations. In Juhász, J. ed., *Proceedings of the European Union’s contention in the reshaping global economy*. Szeged, Szegedi Tudományegyetem, Gazdaságtudományi Kar, Közgazdaságtani Doktori Iskola, pp. 68–84. ISBN: 978 963 306 852 6.



## **Other in English**

- Kovács, E. (2020e). The free trade agreements and transfer pricing. In *Second International PhD Conference of the International Relations Multidisciplinary Doctoral School*. Budapest, Budapesti Corvinus Egyetem, 2020. május.
- Kovács, E. (2021d). Climate Change and Modern Free Trade Agreements Hand in Hand? In *Environmental, social and economic sustainability in the light of the (geo)political challenges of our age: Third International PhD Conference of the International Relations Multidisciplinary Doctoral School*. Budapest, Budapesti Corvinus Egyetem, 2021. május.
- Kovács, E. (2021e). Future Trade Relations between the US-EU-China. In *Fourth Conference in cooperation with the European Association for Comparative Economic Studies*. Szeged, Szegedi Tudományegyetem, 2021. május.