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EU-US TRADE DILEMMAS IN A LINEAR COURNOT MODEL

The most commonly used models for quantifying trade agreements in the international literature can be divided into two groups. Microeconomic models illustrate pre- and post-negotiation situations with micro-level profit analyses. Macroeconomic models deal with the study of macro-level economic effects. Our aim, using the Cournot model, is to add another category, namely the extension of the microeconomics-based game theory oligopoly tool to the level of countries and regions, to examine the impact of trade agreements. In this article we present the economic dilemmas surrounding the Transatlantic Trade and Investment Partnership (TTIP) between the European Union and the United States. If the two actors choose an export output level at the same time, a linear Cournot model can be set up. The version of this extended to trade relations identifies the market equilibrium that emerges in a duopoly situation. On the other hand, it establishes the point at which it is worthwhile for the parties to remove tariff barriers.

Egyelőre a nemzetközi szakirodalomban a kereskedelmi egyezmények számszerűsítésre leginkább alkalmazott modellek két csoportba sorolhatók. A mikroökonómiai modellek tárgyalások előtti és utáni helyzeteket illusztrálnak mikroszintű profitelemzésekkel. A makrogazdasági modellek makroszintű gazdasági hatások vizsgálatával foglalkoznak. Célunk a Cournot modell alkalmazásával, hogy felvessünk egy újabb kategóriát, azaz a mikroökonómia alapú játékelméleti oligopólium eszköztár országok, régiók szintjére való kiterjesztését a kereskedelmi egyezmények hatásának vizsgálatához. Ebben a cikkben bemutatjuk az Európai Unió és az Egyesült Államok közötti Transzatlanti Kereskedelmi és Beruházási Partnerséggel (TTIP) kapcsolatos gazdasági dilemmákat. Ha a két szereplő egyszerre választ exportkibocsátási szintet, akkor felállítható egy lineáris Cournot modell. Ennek kereskedelmi kapcsolatokra kiterjesztett változata azonosítja a duopólium helyzetben létrejövő piaci egyensúlyt. Másrészt bemutatja azt a pontot, ameddig megéri a feleknek elmenni a vámjellegű akadályok lebontása tekintetében.

I. INTRODUCTION

In this paper, we present a possible method for calibrating the Cournot model. This method helps in testing, and at the same time quantifies the effects of TTIP. The economies in the agreement are considered to be profit-oriented individuals. We put the data into the oligopolistic competition model in the observed period (2017-2019) and analyse which strategy is more profitable for the parties (a tariff increase or a tariff reduction). In our study, on the one hand, we illustrate the game-theoretic behaviour and decision-making possibilities of the players, and on the other, we also set up an interval in which the players can move. The latter is specifically an option offered by oligopolies as opposed to simple game theory models.

In our calculations, we apply the general economic approach of markets. Within the framework of the analysis, we use factual data. The values are only used in an aggregate and rounded form, so they may show minor differences compared to those reported in databases. The effect of each input variable is presented from a comparative static point of view.

For the examined period, we only collected data on export activity, as in addition to individual benefits, we were also interested in the benefits that the parties could collectively obtain. If import trade is also taken into account, due to the sum of the relevant foreign trade surplus and the deficit, the gross profit is zero; therefore imports were excluded from the analyses.

The strategies illustrate two situations: before and after the conclusion of the agreement. In these situations we observed what happens when we change the parameters of the players. In our extended Cournot model, the amount of profit that can be maximized by competition is the function of total export revenue and total export cost. This means that profit can be increased by reducing tariffs.

The optimal balance used to assess the gaming situations was established on the basis of the relationship between relevant tariff levels and total export revenues. At this point, both parties make a maximum profit depending on the decision of the other player. With another strategy, it is possible to move from the optimum situation, but then one party gains greater benefits to the detriment of the other. Otherwise, the game does not rule out the possibility of a different

equilibrium situation with a change of strategy². In the case in which more than one equilibrium is created during the game, the Nash trade equilibrium will show the closest equilibrium based on the parameters set.

In evaluating results, we take into account not only the economic processes but also the geopolitical orientation of the parties involved, which can sometimes be explanatory factors as to why the agreement was not implemented by the examined time period.

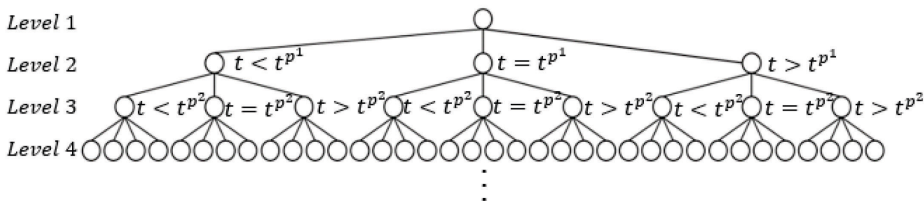
The structure of the article, based on the above, is organized as follows. After the introduction, we briefly describe the trading conditions between the players for the period under review. Next, we present the parameters of the model and create the profit function followed by the equilibrium situation, which illustrates the optimal amount of profit with the corresponding tariff level. Finally, we conclude and formulate our position.

2. CALIBRATION FOR TTIP

The United States and the European Union are the two participants of our model, negotiating a possible free trade agreement. The elimination of tariff and non-tariff barriers and investment concessions to each other already exist, but this raises questions about what further steps the current Biden government is taking to ensure that an agreement can actually be reached between the parties.

Calibration was performed for the three-year period 2017–2019 for both countries, where the parameters were estimated based on weighted averages. We had the opportunity to do so because, on the basis of the data, there were no major changes in volume and price overall during that period. Changes in tariffs during the year were not taken into account either, as they did not cause a significant difference in aggregate demand. We stipulate that this distorts the results

² In the examined interval (t, t^{p^1}, t^{p^2}) the following decision tree illustrates the outputs related to each strategy. (Semantic form)



- Level 1: First period decision of one player
- Level 2: First period decision of another player
- Level 3: Second period decision of one player
- Level 4: Second period decision of another player

somewhat but should not show values that deviate excessively from reality due to quantification.

The two parties waged a tariff war during the period under review. Under the Trump administration, in 2017 the US initiated the introduction of protective tariffs on steel and aluminium products toward the EU. As a result, the EU applied countervailing duties to the full list of US products submitted to the WTO to reimburse that amount. From 2019, the US (due to prohibited subsidies³) imposed additional duties on, among other things, aircraft parts and automotive products, which it has amended several times since then. Then, in 2020, the EU imposed digital taxes on a number of large US technology companies. In response, the US envisaged raising car import duties. The principle of most favoured nation (MFN) already applies to several product groups, but the parties still apply duties to each other in the product groups with the highest turnover. (CRS 2019, CRS 2020, CRS 2021)

Responses and counter-responses between the EU and the US will be seen as bargaining chips with alternating offers⁴. The game is written based on the temporal reactions of the two participants to predict and evaluate the possible outcome of the negotiation series. In making the forecast, we use the methodology laid down by Selten (1975) to examine the credibility of threats and promises. Although retaliation is clear in the game, we do not expect any striking results in the future.

2.1. Estimation of pre-agreement export profit

The shape of the inverse export revenue function in our trade model is:

$$t_{EU}^{pre} = a - b(tr_{EU}^{pre})$$

$$t_{US}^{pre} = a - b(tr_{US}^{pre})$$

where tr_{US}^{pre} illustrates US export earnings, tr_{EU}^{pre} illustrates European Union export earnings in the pre-trade period, and t^{PRE} is the estimated export duty.

³ Subsidies between Boeing and Airbus have been under discussion between the EU and the US since 2004. The WTO Dispute Settlement Body condemned the European Union in 2018, and the United States in 2019.

⁴ In this case, the offer will be the sanction. In the game, players take turns making an offer, so an offer is followed by a counter-offer. The point of the game is that as time goes by, the characters get worse and worse, so it is worth making a deal at the very beginning of the game. Osborne–Rubinstein (1990), Kreps (2005) among others, have dealt with these types of games.

Given that the parties have not yet signed the agreement, we can carry out the study by limiting the period before (*pre*) the conclusion of the agreement to three years. In this way, we are counting on the latest data currently available.

The parameters of each sector are estimated for the two countries as follows: the level of the import tariff imposed on the sub-sectors is weighted on the basis of the tariff revenues associated with them, and then a sector average is formed from their sum. In 2017, the United States and the European Union applied an average of 5 percent to imports from each other. In 2018, the European Union made significant increases in the level of tariffs on certain products. As a result, the duty level increased to an average of 10 percent. A year later, the US initiated the imposition of almost the same level of tariffs, resulting in an increase in average tariffs to 15 percent (Table 1).

Table 1. Average import tariff imposed by actors per sector during the examined period (Percent)

	<i>2017</i>			<i>2018</i>			<i>2019</i>		
	<i>agr</i>	<i>ind</i>	<i>ser</i>	<i>agr</i>	<i>ind</i>	<i>ser</i>	<i>agr</i>	<i>ind</i>	<i>ser</i>
<i>EU⁵</i>	3	6	5	15	20	10	15	15	10
<i>US</i>	2	4	6	10	10	5	12	20	15

Note: The value of the sectors is derived from the average tariff rates of the subsectors.

Source: GTA (2020), USTR (2020)

The data show that the actors respond to each other's increases in the level of tariffs with retaliation (carousel retaliation), so the tariff burden is constantly increasing (Kutasi 2020). In the trade war between economic centres, it is not only competition between the various sectors which emerges, the parties also try to cause harm to each other in the most sensitive areas (Stoll et al. 2020). The European Union is otherwise ready to suspend tariffs if the United States takes the same step.

In a game theory approach, these types of reactions can also be illustrated with another game, the penalty game, in which the optimal strategy depends not on the payoff (profit) of the other party, but rather its own payoff. In the game, the Nash equilibrium situation arises from mixed strategies, so neither side has a strategy

⁵ It covers 28 Member States during the period under review.

with a probability of occurrence of one (Tsebelis 1990). The promise of the EU proves to be credible, so the strategy in question here strikes a sub-game-perfect balance. This means that we rule out the possibility that this solution is not based on credible promises. We will continue this line of reasoning later in this section.

The aggregate export revenues of the actors continue to increase in the period under review (Table 2). However, broken down by sub-sector, where tariff levels suddenly rise, export earnings also fall steadily. Such was the case with the US tariff on steel (25 per cent) and aluminium products (10 per cent) under the Trump government in March 2018, which boosted EU export revenues by \$ 6.4 billion. Retaliatory tariffs applied by the EU since June 2018 (10 and 25 percent import tariffs on many products) have generated \$ 2.8 billion in revenue losses for the US. Due to the additional ad valorem duties, exports of agricultural products on the EU market fell by 33 percent between 2018 and 2019 (Grant et al. 2019). In October 2019, the United States initiated additional tariffs on European products worth \$ 7.5 billion, representing 1.5 percent of total EU exports (Johnson et al. 2020).

Of the export-generating groups, the contribution of the machinery and automotive industries was the highest (accounting for about 40 percent of total export earnings), followed by the chemical industry (approximately 25 percent) and the 'other' category (an average of 18 percent) for both economies during the period under review (Eurostat 2020a⁶).

Table 2. Actors' export revenue by sector during the examined period (Billion USD)

	2017			2018			2019		
	<i>agr</i>	<i>god</i>	<i>ser</i>	<i>agr</i>	<i>god</i>	<i>ser</i>	<i>agr</i>	<i>god</i>	<i>ser</i>
<i>tr</i>^{PRE}_{EU}	29.2	437.3	193.0	31.9	489.9	196.0	33.0	517.8	208.3
<i>tr</i>^{PRE}_{US}	14.8	284.9	259.9	17.1	320.4	271.5	15.2	338.4	279.0

Note: unadjusted data.

Source: GTA (2020), USTR (2020)

The EU also exports almost 50 percent more in agriculture and industrial products, while the United States accounts for a larger share in services. The

⁶ Eurostat (2021) carries out the classification of products as defined in the SITC (Standard International Trade Classification). It uses a FOB clause for exports and a CIF clause for imports to determine trade values.

largest group of exports is represented by industrial goods in both economies. In terms of goods, the European Union's trade balance is in surplus, even when services, investment and capital flows are taken into account, while the export-import ratio shows a slight deficit in favour of the United States (EC 2020, Eurostat 2020b).

Although the level of duties increased in a number of product groups, the overall increase in profits was due to the loss of product groups affected by the extra duties being offset by the increase in exports in the other categories.

Based on the data, it can be seen that demand is relatively flexible, so higher tariffs reduce demand, thereby reducing the export revenues of the sub-sectors. However, the degree of flexibility varies greatly from one product group to another. Since these products account for only 0.5 percent of total demand, the model simulation assumes that player demand is essentially flexible.⁷

Regarding $t_i^p = a - b(tr_i^p)$, and $t_{-i}^p = a - b(tr_{-i}^p)$, the estimation of the parameters a and b is obtained as follows:

In the years under review, the values show that in those product categories where tariffs increase by 10 to 20 percent, export revenues decrease by an average of USD 2 billion in both regions; therefore:

$$b = \frac{0.01}{2} = 0.005$$

During this period, the average annual export revenue was 1312, but the duty rates differ significantly. In this case, it is true that the a parameter is:

$$a_{2017} = 0.05 + 1219.1b = 6.146$$

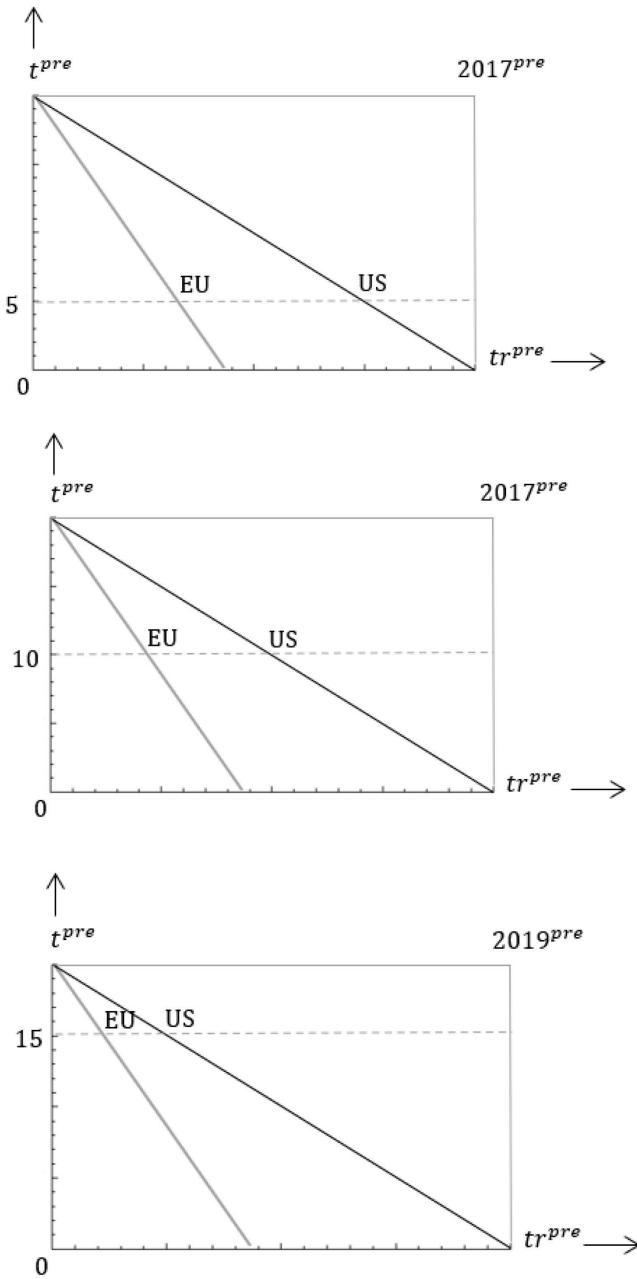
$$a_{2018} = 0.10 + 1326.8b = 6.196$$

$$a_{2019} = 0.15 + 1391.7b = 6.246$$

The equations (3) indicate the value of the a parameter in our simulation model when the annual export gains are given for each group. Based on the above, the export earnings function is as follows (Figure 1).

⁷ In the hyperbolic case, the duty function can be written in the form $t_i^{pre} = b(tr_i^{pre})^{-\epsilon}$ and since $|\epsilon| > 1$, the increase in duty for a given product group reduces the export income related to it, and on the other side, the demand. Even for special product groups (products that can only be accessed in each other's markets), a change in tariffs changes consumption only slightly.

Figure 1. EU–US linear export revenue function in the examined period



In the simulation, costs take a linear form (Figure 2), as the increase in tariffs exactly follows the decrease in export earnings.⁸ The equation describing the cost assumes, according to the assumptions of the Cournot oligopoly model, that the expenditure is determined exclusively by the tariffs⁹, i.e.

$$tc_{EU}^{pre} = t^{pre} tr_{EU}^{pre}$$

$$tc_{US}^{pre} = t^{pre} tr_{US}^{pre}$$

Equation (4) shows that export duties increase the cost of exports if $t > 0$. Since both actors are engaged in export activities in all three groups, $tc^{PRE} > 0$.

Table 3. Actors' export tariff costs by sector in the examined period (Billion USD)

	2017			2018			2019		
	<i>agr</i>	<i>ind</i>	<i>ser</i>	<i>agr</i>	<i>ind</i>	<i>ser</i>	<i>agr</i>	<i>ind</i>	<i>ser</i>
tc_{EU}^{PRE}	1.5	21.9	9.7	3.2	49.0	19.6	5.0	77.7	31.2
tc_{USA}^{PRE}	0.7	14.2	13.0	1.7	32.0	27.2	2.3	50.8	41.9

Note: nominal data

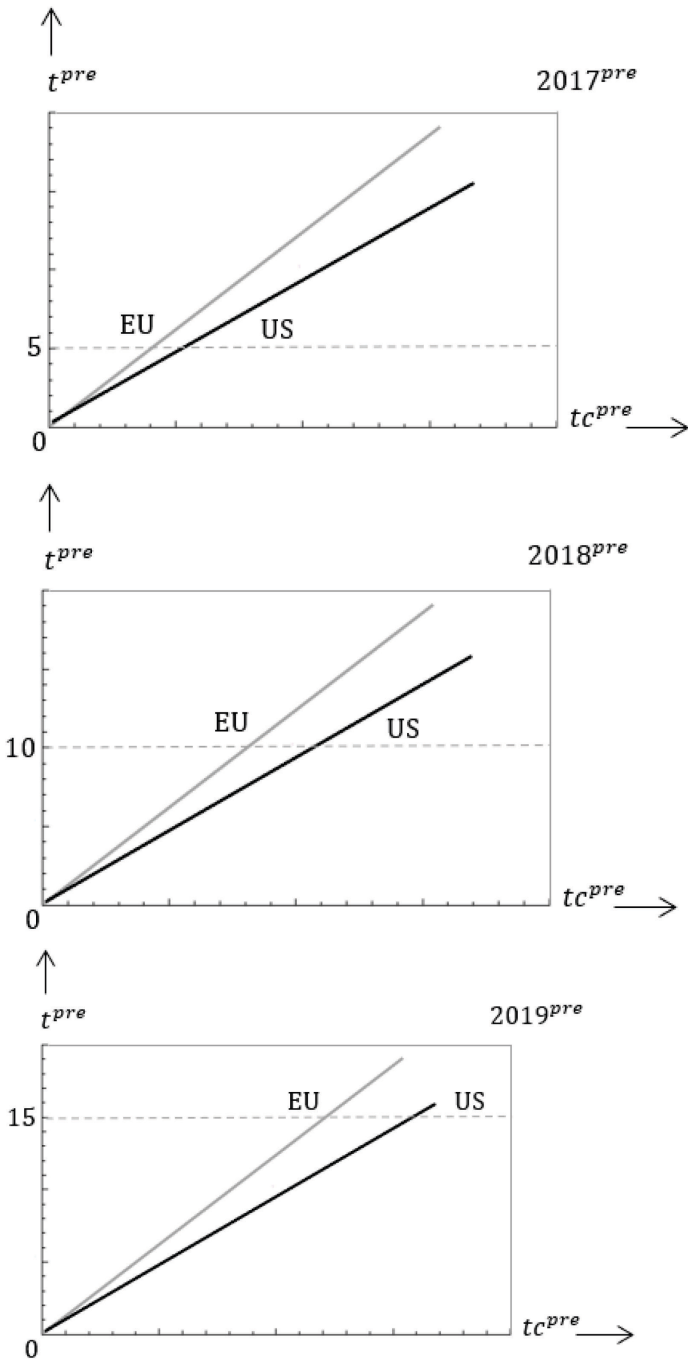
Source: Author's calculation based on GTA (2020)

Special attention is drawn to the fact that in addition to the increase in tariffs, higher aggregate revenues also contribute to the increase in costs in Table 3.

⁸ In the case where the change in export costs is faster than the increase in tariffs, the relationship between the two variables is progressive; if it is slower, it is degressive.

⁹ Thus, in the present case, we disregard the administrative licensing and transportation costs incurred in connection with the export.

Figure 2. EU–US linear export cost function in the examined period



The profit function is then:

$$\pi_{EU}^{pre} = tr_{EU}^{pre} - tc_{EU}^{pre}$$

$$\pi_{US}^{pre} = tr_{US}^{pre} - tc_{US}^{pre}$$

The space charts illustrate the magnitude of the demonstrable profit. The one on the left, starting from zero, moving towards tr_{EU}^{pre} represents the profit on specific export earnings of the European Union, and the one on the right, moving from zero to tr_{US}^{pre} , the profit of the United States.

2.2. Estimation of post-agreement export growth

In this section, we present the possible (post) changes after the conclusion of the convention and the dilemmas related to them. In our estimate, we define the parameters of duty-free trade in a 10-year perspective. We do not change the rules of the game when making a prediction, either.

According to the draft agreement, 99 per cent of the tariff levels will be abolished between the two parties, so we set the parameter t^{post} to 0.01:

$$t^{post} = a - b(tr_{US}^{post} + tr_{EU}^{post}) = 0.01.$$

Annual profit dynamics are observed to increase by about 1.7 percent. This increases the value of the expected profit, i.e.:

$$\pi_{EU}^{post} = (tr_{EU}^{pre} - tc_{EU}^{pre})1.017$$

$$\pi_{USA}^{POST} = (tr_{US}^{pre} - tc_{US}^{pre})1.017$$

In this case, the profit levels in each sector show an increase in the abolition of duties in each case (Table 4):

Table 4. Potential export profits of actors by sector after the conclusion of the agreement (Billion USD)

	<i>Initial values</i>			<i>Simulation values</i>			<i>Change</i>		
	<i>agr</i>	<i>god</i>	<i>ser</i>	<i>agr</i>	<i>god</i>	<i>ser</i>	<i>agr</i>	<i>god</i>	<i>ser</i>
π_{EU}^{PRE}	28.1	440.1	177.1	33.2	521.3	209.7	5.2	81.2	32.7
π_{USA}^{PRE}	12.9	287.6	237.2	15.3	340.7	280.9	2.4	53.1	43.8

Note: unadjusted data

Source: GTA (2020), USCB (2020)

This means that the parties will be able to achieve the greatest improvement in goods and services in the year following the agreement, according to the Nash trade balance.

2.3. Possible outcomes

With our trading oligopoly model, we determined the profit space where players can move. This means options between 0 and 764.3 for π_{EU}^{post} , and options between 0 and 636.9 for π_{US}^{post} , given that we assumed that profit cannot take on a negative value.

At this point, we continue our line of thinking that the European Union has made a credible promise to abolish extra tariffs if its competitor takes the same step. Then, ceteris paribus, the EU at $\pi_{EU}^{pre} = 683.2$, and the US at $\pi_{US}^{pre} = 569.3$, can make a maximum profit¹⁰. However, after the conclusion of the agreement, the potential profit levels will be as follows, at which point the EU benefits with EU $\pi_{EU}^{post} = 764.3$, while the US has $\pi_{US}^{post} = 636.9$.

We undertook to predict the possible outcome of the game. To do this, it is worth first examining the promises of the parties. Based on Selten (1975), we are of the opinion that the actors, by keeping the promise (to reduce and abolish tariffs), take steps that make the game optimal compared to the circumstances. Therefore, in the present case, we consider the promises of the parties to be credible.

We consider the TTIP trading game to be perfect information, as each set of information has only one decision point, so both the United States and the

¹⁰ In this step, we reduced the tariff level by 5 percent.

European Union knew in each examined year what had happened before. On the other hand, the threats were credible, so they could also expect what the other would do. (This is why a pure strategy with Nash-trade equilibrium can emerge.¹¹) By having complete information about the previous outputs, our foresight also brings us closer to exploring reality. The reason for this is simply that we are able to solve the game with a reverse induction procedure¹², i.e. to predict the probable outcome.

Given that neither player has the same benefit in the examined period, nor in the predictive model, there is only one equilibrium at the end of the game that can be produced by removing trade barriers. For this reason, it can be considered the winning strategy. However, we would like to point out that during the game several subgame perfect equilibria were noticed. At these π_{EU}^{post} , π_{US}^{post} points, both players' strategy is optimal, i.e. the principle of sequential rationality is fulfilled (Selten 1975).

All things considered, we believe that the conclusion of the agreement is economically justified, therefore we expect that in the future we will see a shift from the parties towards each other.

3. EVALUATION

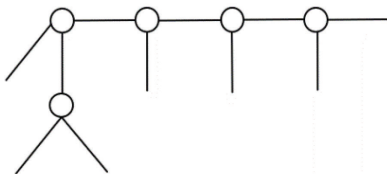
The analysis in this study can be used to assess the advantages and disadvantages of the economies included with the established parameters, and then to indicate the degree of displacement experienced in the equilibrium.

In addition, it has been examined whether it was worthwhile for the parties to embark on a path of mutually beneficial transatlantic free trade.

¹¹ In his essential writing, Kuhn (1953) formulated his theorem on the pure Nash equilibrium point of perfect-information finite games. For a more modern processing of the solution to the game, see Mas-Colell et al. (1995).

¹² The method goes from the last step from branch to branch to the beginning of the game, while creating the optimal strategy for both players (Figure 3). Its substantiation with theoretical arguments can be found in most books on game theory.

Figure 3. A complete and perfect information game



Note: semantic shape

With the help of a bargaining game with alternating offers, we illustrated the profit space in which the players can move. The exact parameters of this were determined using our trade oligopoly model. As a result, we concluded that the abolition of tariffs could lead to higher revenues for the parties in the long run, so it is not justified economically to maintain restrictions. In the case of the United States and the European Union, each applied trade tightening to the other during the examined period rather than offering a bargain, which was usually met with retaliation. However, there is a tendency for a possible shift between the parties, due to geopolitical interests in any case. We also highlighted that many points in the draft TTIP differ from the expectations of participants. By refining these, we believe that the agreement can be successfully concluded. The end result of our bargaining predicts a positive outcome based on economic theories.

Our arguments are also as follows:

- ◆ None of the players would accept a payment worse than the original setting (*pre*) after the conclusion of the agreement (*post*), thus we expect $\pi_{EU}^{post} > \pi_{EU}^{pre}$ and $\pi_{US}^{post} > \pi_{US}^{pre}$ to be true, respectively.
- ◆ The deal also ultimately ensures that without agreement, the parties will not be able to otherwise access the π^{post} level. (Possible reasons for this are, for example, the size of the buying market, etc.)
- ◆ We have proved that it is not worthwhile economically for either party to have the alternative which would follow in the absence of an agreement, thus proving that our first statement is true for the specified parameters.
- ◆ If they do not agree, tariff levels will increase over time to such an extent that trade between the two economies will become unreasonable.

The probability of other interests was not addressed in our research. There are several reasons for this. The probability of the forecast occurring could not be set narrowly enough due to too many conditions, so our trading model does not show clear directions. At this point, we draw attention to the fact that if there is no way to quantify factors, economic theories are unable to give an accurate prediction (Kreps 2005). Due to this, we could not prescribe an extensive form of play. Even if we had written it down, due to the enormous number of steps and counter-steps, we get a diverse decision tree that cannot be analysed with the usual game theory method. We note that we consider both methods to be suitable for estimating more complex trade agreements, but only if we can arrange for appropriate uncertainties to be set up. In the case of TTIP, the parties have not made rational economic decisions so far, and since the outcome depends only in part on economic factors, we could only predict the outcome of this situation with a larger margin of error.

4. SUMMARY

In this article, we calibrated the Cournot model for the TTIP and determined the properties of the equilibrium situation.

During the simulation modelling, we determined the actors and set up the rules. Finally, we described payoffs. Rationality as the most important basic assumption was kept in mind in both time periods. In making our forecast, we relied heavily on past experience as well as the preliminary results of our simulation. Given that we have striven for the greatest possible accuracy and detail in defining the rules of the game, we believe that our results will not be affected by minor changes in parameters. So our equilibrium expectations can be considered constant. Thus, we have moved on to the problem of game theory that if processes are not clear, equilibrium situations become sensitive.

In a trade agreement, players make a deal with each other that can generate a number of equilibrium situations. In the introduction, we modelled the possible outcomes with a decision tree and at the same time proved that there can be an extremely large number of rational and feasible payoffs for a trade bargain. By adjusting the optimization options of parties to the set parameters, we eliminated the problem of choosing between too many equilibrium situations in game theory.

Equilibrium was generated with a time-constant model. The illustrations were prepared by specifying the parameters. We illustrated revenue and cost functions, reaction curves, and trade equilibrium. Where the equilibrium solution can be interpreted, we have given its exact location and the maximum amount of export profit with the corresponding tariff level. If more than one equilibrium situation existed, the one closest to the parameters was selected. We assumed that there could not be negative quantities and profits, but if they had provided the optimum in equilibrium, we would not have accepted this solution. For these reasons, it is a favourable point that our results cannot be refuted since the model was also tested experimentally.

Despite the results, we handle them critically, since many factors could not be included in the calculations. We also recognize that increasing variables can change equilibrium situations. Given that we used a formal mathematical and oligopoly theory to model a trade situation, we provide only approximate information for correct judgment and prediction. We believed that if we were careful, we would get closer to reality. On the other hand, we do not rule out the possibility that other methods could lead to different results.

Overall, we consider our results to be valid, and we believe the oligopoly theory to be ideal for examining free trade agreements. It is possible to extend our simulation with administrative and transport costs. Further, it is worth contemplating the inclusion of uncertainty variables if their values can be minimized.

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