A Study About the Effects of an Economic Trading Agreement in the International Trade Network

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1 Introduction

Trade may be as old as human history. Humans have always interacted with each other, this is nothing new. However, the importance and complexity of these interactions and connections may be more important and more rapidly evolving than ever before. According to Hidalgo (2015), *"economies become distributed computers, made of networks of people, and the problem of economic development becomes the problem of making these computers more powerful"* by building more valuable networks. Economic development and a nation's ability to grow its GDP and compete in the world economy may be very dependent on the networks in which a nation participates and their position in those networks. Advancing understanding of those networks could have broad relevance to a host of domains and activities.

This project paper uses network analysis and a simulation model to study the statistical properties of the trade relationships among the existing countries between 1947 and 2014. First, the properties of the international trade network over time are studied and summarized. Afterwards the network will be enriched by adding additional information to the nodes such as the GDP of the country. Finally, a simulation algorithm trained and tested on the network data is assigned to the network to analyze the introduction of free trade agreements (FTA).

2 Literature Review

Globalization affecting nearly all the areas of human being like politics, culture, environment, communication and the economy for individuals, society and nations. One of the main reasons for this is the technical progress especially in communication and transport technologies. Due to this the different nations get closer to each other and start trading more and more products with each other. To account for these major changes over time

Davis and Weinstein (2001) already hoped for a more empirical shift in the discipline of the analysis of global trade network. Which is still ongoing but nearly fully filled as the scientist now have the computing power to analyze those networks. So, Kastelle et al. (2006) investigated the effects of globalization on the trade network by performing a binary network analysis between 1938 and 2003. They discovered that the World Trade Network (WTN) hasn't reached a steady state yet in terms of a fully-globalized network. But it's much likely to evolve further over time and reach these state in the future. Most of the research in the field of trade network analysis in the early 2000s is based on a binary approach. This means the analysis of the graph is based on the existence of an edge between the different nodes in case weight is bigger as a defined threshold. Garlaschelli and Loffredo (2004) modeled their networks as a binary directed graph, where Serrano and Boguñá (2003) selected a binary undirected graph model. Both detected a negative correlation between node degree distribution and connectedness distribution. Where Garlaschelli and Loffredo (2005) proof this evidence to be stable over time. Fagiolo et al. (2013) used these results to question if the economic integration has really changed in the last 20 years or if only a few countries have really taken their advantages out of the globalization. An important result of the globalization and the connectedness of the countries are the developing dependencies between them and the impact on the stock market. Kali and Reyes (2005) analyzed these dependencies in their network by assigning connectedness measures to the countries. By this they identified the reason why certain crises in highly connected countries affect the global market much more then other crises in countries with a lower value. The most recent studies now also account for the intensity of the relationship between the different countries. So most of these studies use a weighted directed or undirected network approach, where the weights of the edges are representing the intensity of trading between the nations. Fagiolo (2006) discusses the need for special statistics for directed weighted trade networks. He illustrates that in such cases not only the weighted dimension of the edges should be taken into account, but also the direction of the flows between the countries. In recent years researchers started to investigate the reasons for cluster formation in the WTN. Lee and Bai (2013) used the concept of transitivity and homophily to determine the most important attributes of a country to be part of a FTA. They proved that economic attributes, regionalism, and political institutions are the crucial attributes of a country which determine the association to a specific FTA. Also they proved transitivity in FTA networks referring that an FTA partner of an FTA partner is likely to be an FTA partner.

	1950	1960	1970	1980	1990	2000	2010
Total trades	2614	4429	7461	9568	13026	20014	22867
Total countries	178	180	181	183	184	216	213
Trading countries	92	153	173	179	181	203	207
Mean trade partners	29.37	49.21	82.44	104.57	141.59	185.31	214.71
Size of giant component	72	103	137	134	161	181	182
Avg. node connectivity	4.0739	8.8571	19.9611	27.4548	43.6860	59.9339	74.0951
Avg. deg. of nearest neigh.	145.133	197.179	246.650	274.941	316.945	365.276	354.918
Avg. shortest path	390471.44	464965.59	95208.00	108572.32	36713.06	14577.55	57241.25
Maximum distance	inf	inf	inf	inf	inf	inf	inf

Table 1: Graph Summary of the World Trade Network between 1950 and 2010

3 Dataset

The data about the International Trade Network is provided by the International Monetary Fund[1] and covers 184 countries with annual data starting in 1947. The Direction of Trade Statistics (DOTS) present the value of export and imports to a country's primary trading partners. Imports are reported on a cost, insurance and freight (CIF) basis and exports are based on reported free in board (FOB) basis. GDP[2] and Capita[3] data are provided by the World Bank. As the dataset contained import and export data from all continents and certain other detailed information such as the oil import/export rate, EU and partly quarterly and monthly data, the dataset was cleaned before using it.

4 Network

Where every node N in the graph G_i will be a country which is importing or exporting goods in the particular year i. An edge $E_{a,b}$ is a connection between two different nodes N_a and N_b, where the nodes have zero, one or two connecting edges depending on the exchange direction of goods between the nodes. So the two nodes could have zero connecting edges if they don't trade goods in that year, if only one node e.g. N_a imports goods from node N_b or vice versa the nodes would be connected by one edge. Ceteris paribus if both nodes import and export goods will have to directed Edges $E_{a,b}$ and $E_{b,a}$. Where imported and exported goods are reported in US Dollar., the weight w($E_{a,b}$) is the sum of the actual value of imported goods of node N_b from node N_a and exported goods of node N_a from node N_b divided by two. This normalization of the directed edges is needed as sometimes the data of imports and exports of the different country combination is not perfectly aligned.

$$w(E_{a,b}) = \frac{(\text{import}(N_b, N_a) + \text{export}(N_a, N_b))}{2}$$

Every node $N \in G_i$ will be enriched by the information about the GDP_i, $Capita_i$ and GDP_i / $Capita_i$ over the different years of the dataset.

5 Statistics Summary

To get an understanding of the network changes over time in the underlying graph certain central metrics of the graph were analyzed in imitation to Newman (2004) such as the number of trades, total listed countries likewise the number of trading countries in the network (Table 1). Comparing the degree distribution in Figure 1 of the World Trade Network in the year 1950 to the year 2010 on a log-log scale it can be determined that the countries increased the number of trading partners since 1950. One reason for this can be the reduced costs of transporting goods or the change in the composition of the basket of goods towards digital and more light weighted goods. The reason for the not existence of a scale-free network can be found by comparing the network of 1950 and 2010. A reason for this can be lead back to the existence of trade between countries for several centuries. The displacement of the degree between 10^1 and 10^2 can be traced back to the Globalization which took place in this period.

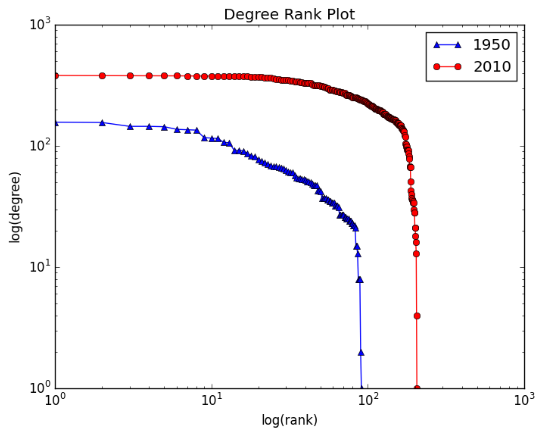

Figure 1: Degree distribution of World Trade Network in 1950 and 2010 (log, log)

[1] data.imf.org
[2] http://data.worldbank.org/data-catalog/GDP-ranking-table
[3] http://data.worldbank.org/data-catalog/health-nutrition-and-population-statistics

Rank	Degree[4]	Betweenness[5]	Closeness[6]	Eigenvector[7]
1.	USA (0.904)	USA (0.0158)	USA (0.4861)	USA (0.5983)
2.	Netherlands (0.887)	Netherlands (0.0133)	UK (0.4808)	Canada (0.5324)
3.	UK (0.8814)	UK (0.012)	Netherlands (0.4704)	UK (0.35)
4.	France (0.8192)	France (0.0099)	France (0.4375)	Germany (0.1715)
5.	Germany (0.8192)	Canada (0.009)	Germany (0.4375)	France (0.1593)
6.	Italy (0.8136)	Germany (0.0089)	Canada (0.4289)	Australia (0.1438)
7.	Canada (0.774)	Italy (0.0084)	Italy (0.4289)	Netherlands (0.1206)
8.	Sweden (0.7684)	Switzerland (0.0067)	Switzerland (0.4248)	Italy (0.1181)
9.	Switzerland (0.7627)	Sweden (0.0064)	Sweden (0.4167)	Brazil (0.1176)
10.	Japan (0.661)	Japan (0.0045)	Japan (0.4089)	Mexico (0.1135)

Table 2: Centrality Measures of Top 10 countries in World Trade Network in 1950

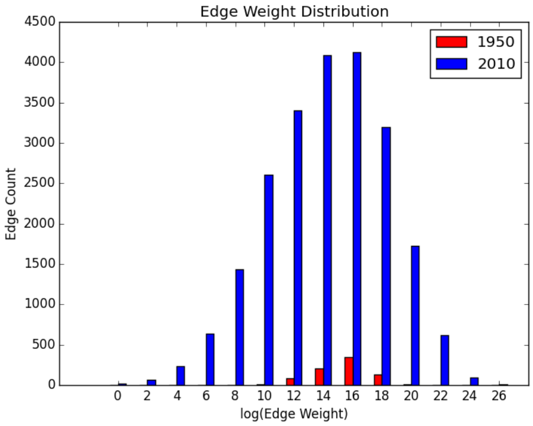

Figure 2: Edge weight distribution of World Trade Network in 1950 and 2010

Not only the number of trading partners increased. Looking at the distribution of edge weights in the directed graphs of 1950 and 2010 (Figure 2) reveals that the distribution changed significantly. The Kurtosis of the network in 2010 is much higher, meaning the log(edge weight) ranges from 0 up to 26 which is about USD 196,000,000,000 in trading volume.

Comparing the degree centrality, betweenness centrality, closeness centrality and eigenvector measurements of countries mostly developed countries can be found in these metrics as centrality in the directed graph accounts for both the import and export of goods. We can clearly identify the increase of China's trading power by looking at the eigenvector centrality in 2010. One effect of China's increase in economical power is the increase of the betweenness centrality of the connected countries Malaysia and Indonesia as is the increase of trading partners of India. Latter being a well connected country to these two countries.

6 Model a FTA in the WTN

However, a trading agreement affects not only member countries but also those countries, which are not in the agreement. The trading flows are reorganized and some countries could benefit while others could be prejudiced. For example, a country which, provides a specific product, could lose its clients when consumers are encouraged to buy from other providers who are members of the agreement and whose taxes are reduced. The purpose of this work is to model the impact of an economic trading agreement, such as the European Union (EU, 1993) or the Asia-Pacific (APTA, 1975) on global commerce and the wealth of the countries. The underlying model is represented by a network, where countries are characterized by nodes and the directed edges express the trading flows between two countries. In the beginning, the model will be initialized by using real data about international commerce before the trading agreement begin.

Rank	Degree	Betweenness	Closeness	Eigenvector
1.	UK (1.8066)	Malaysia (0.0102)	Denmark (0.9532)	USA (0.6243)
2.	Germany (1.7972)	Indonesia (0.0076)	UK (0.9532)	China (0.3313)
3.	Denmark (1.7925)	UK (0.0069)	Germany (0.9532)	Canada (0.3074)
4.	Netherlands (1.7925)	India (0.0069)	Netherlands (0.9442)	Germany (0.2514)
5.	India (1.7877)	Germany (0.0067)	India (0.9398)	Mexico (0.2237)
6.	Switzerland (1.7877)	Japan (0.0066)	Malaysia (0.9398)	Japan (0.2109)
7.	Canada (1.7877)	Denmark (0.0065)	France (0.9398)	Hong Kong (0.1933)
8.	France (1.783)	Netherlands (0.0063)	Switzerland (0.9398)	UK (0.1718)
9.	Malaysia (1.7783)	Korea, Rep. (0.0063)	Japan (0.9398)	France (0.169)
10.	USA (1.7783)	Canada (0.0062)	Korea, Rep. (0.9354)	Netherlands (0.1641)

Table 3: Centrality Measures of Top 10 countries in World Trade Network in 2010

[4] Opsahl, Agneessens, and Skvoretz (2010)
[5] Freeman (1977)
[6] Freeman (1979)
[7] Bonacich (1986)

After that, the network will be evolved for several rounds by using the rules of the model. When the experiment is completed, a qualitative study will be performed by analyzing the graph before and after the experiment. The results will be compared against the real data with the objective of measuring the quality of our model.

6.1 Network setup

A sets of nodes, which represent the countries will be created:

$N=\{n_1,n_2\ldots n_n\}$ countries in the global network
$N_T=\{n_{T1},n_{T2}\ldots n_{Tx}\}$ countries in the FTA
Where $N_T \subset N$ and $x<n$

Additionally every node will be enriched by the balance of trade (NX) in the first round. The NX will be used at the end of the simulation to determine how beneficial the trading agreements was for the certain country. Network edges will be created by using the information about trading flows between countries before the international agreement, let us define:

$$W_t = \{w_{12,t}, w_{22,t}, \cdots w_{ij,t} \cdots w_{nn,t}\}$$

Where w_{ij} the trading weights for every couple of nodes (n_i,n_j) where n_i is the seller (exporter) and n_j is the buyer (importer). Weights in the initial round will be used from real data in order to have a benchmark to compare our results later after simulation. Thus, define the total weights of the nodes n_i for importing $(I_{i,t})$ and exporting $(E_{i,t})$ goods at time t as follows:

$$I_{i,t}=\sum_{j=1}^{n} w_{ij,t-1} \text{ and } E_{i,t}=\sum_{j=1}^{n} w_{ji,t-1}$$

Thresholds for importing and exporting will be applied for all countries in the network, so countries can't buy or sell more than (1+q) of there previous total edge weights. The different thresholds are defined by $T^b_{i,t}$ as the buying threshold for node n_i and $T^s_{i,t}$ as the sales threshold for node n_i where :

$$T^b_{i,t}=(1+q)\times I_{i,t-1} \text{ and } T^s_{i,t}=(1+q)\times E_{i,t-1}$$

For example, if q=.10, it means that countries can sell or buy at most 10% more that they were in the previous round t. Under the assumption exports and imports cannot exceed the thresholds $T^s_{i,t}$ and $T^b_{i,t}$, define the values of the total sales and buying as:
3

$$w^s_{i,t}=\sum_{j=1}^{n} w_{ij,t} \text{ and } w^b_{i,t}=\sum_{j=1}^{n} w_{ji,t}$$

6.2 Network Development

The model will be evolved by several rounds, where each round represents a year. Given that, the trading agreement has increased its number of members, the model will include the country from the year in which this became a member. In the first part of each round the countries in the trading agreement will modify their flows favoring trading with their partners. For this purpose we used a random parameter to determine if the member will modify its flows.
The amount of the trading flow, which is out of the trading zone, will be transferred to the agreement countries, as follows: For each node $n_i \in N_T$, such as $w^s_{i,t}<T^s_{i,t}$ look with a probability p for a neighbor node $n_k \in N_T$ and with $(1 - p)$ for a non neighbor node where $n_k \notin N_T$ to generate a new edge e_{ik} with $w_{ik,t}=0$.

$$\mathbf{Pr}(e_{ik}) = p,\ e_{ij}=1 \text{ and } \mathbf{Pr}(e_{ik}) = 1-p,\ e_{ij}=0$$

If n_k is capable to import more, which means that $w^b_{k,t} < T^b_{k,t}$, then the weight of the edge (n_i, n_k) can increase. Given that the nodes n_i and n_k can't exceed the thresholds $T^s_{i,t}$ and $T^b_{k,t}$ respectively, the maximum weight the edge (n_i, n_k) can increase is:

$$\mathbf{max}(\Delta w_{ik,t})=\mathbf{min}\ (T^s_{i,t}-w^s_{i,t},\quad T^b_{k,t}-w^b_{k,t})$$

To decide the sales increase, we generate a random number $\varphi \in (0,1)$, which will be rounded to 1 digit, thus the new weight of sales for the edge (n_j, n_k) will be

$$w_{ik,t+1}=w_{ik,t}+\varphi\times\mathbf{max}(\Delta w_{ik,t}),$$
$$n_i \in N_T \wedge n_k \in N_T$$

Given that n_i is selling more to its partner n_k, then n_i must reduce selling to other countries which are not in the agreement. Thus, we decrease the amount of exporting goods to countries outside of the trade network by $d^s_{i,t}$. Where $d^s_{i,t}$ is defined by:

$$d^s_{i,t}=\frac{\sum_{k=0}\varphi\times\mathbf{max}(\Delta w_{ik,t})}{\sum_{j=0} e_{ij}},\ n_j \notin N_T \text{ and } e_{ij}=[0,1]$$

Analogously, the country n_k is buying more from country $n_i \in N_T$, thus n_k needs to buy less from countries which are not in the agreement. Vice versa we decrease the amount of importing goods to countries outside of the trade network by $d^b_{k,t}$. Where $d^b_{k,t}$ is defined by:

$$d^b_{k,t}=\frac{\sum_{i=0}\varphi\times\mathbf{max}(\Delta w_{ki,t})}{\sum_{j=0} e_{jk}},\ n_j \notin N_T \text{ and } e_{jk}=[0,1]$$

The objective of the second part is to distribute the lost sales/buying weights between the nodes that are not in the agreement. The countries, which are not in the agreement, may have lost exports (sales deficit), these will try to look for new clients in countries that are outside of the trading agreement, as follows: For each node $n_j \notin N_T$, such as $w^s_{j,t} < E_{j,t-1}$ [8] interact with $\mathbf{Pr}(e_{kd})$ with a node $n_d \notin N_T$ if n_d can buy more, which means that $w^b_{d,t} < T^b_{d,t}$, the edge (n_j, n_d) can rise given that, the nodes n_j and n_d cannot exceed the thresholds T^s_j and T^b_d respectively, then the maximum amount that edge (n_j, n_d) can rise is by $\mathbf{max}(\Delta w_{jd,t})$. For calculation of the new weight of the edges there is a need to account for additional cost ($C(w_{jd,t})$), which occur if one of the trading countries is not part of the FTA.

$$C(w_{jd,t}) = \lambda \times w_{jd,t},\ \lambda \in (0,1)$$

The net sales increase and hence the new weight of the edge (n_j, n_k) between those two countries will be

$$w_{jd,t+1} = w_{jd,t} + \varphi \times \mathbf{max}(\Delta w_{jd,t}) - C(\varphi \times \mathbf{max}(\Delta w_{jd,t})),\quad n_j \notin N_T \vee n_d \notin N_T$$

First, this procedure will be repeated until $w^s_j = T^s_j$ or node n_j has asked all the nodes $n_d \notin N_T$ to buy. If any node $n_i \in N_T$ has fulfilled it's trades and $n_d \notin N_T$ as well the nodes are allowed to trade with each other by accounting for $C(w_{id,t})$. After every round the we will recalculate the new balance of the trade (NX) of each country and add the balance of trade.

$$NX(n_i, t) = w^s_{i,t} - w^b_{i,t} + NX(n_i, t-1)$$

This will be used to compare our models to the real world happenings as well as calculate the impact of a FTA on the different countries.

The following parameters were used to conduct the experiment:

Parameter	Value
MemberProbAction	0.30
NoMemberProbAction	0.30
MemberProbPrefMem	0.70
MemberProbNewAdq	0.60

Table 4: Input parameters for simulation

The first parameter is used to indicate the activity of members to change their trading flows, since they are member of an agreement they will take advantage of its benefits. The *NoMemberProbAction* indicates that no members take an action to change their trading flows. The parameter *MemberProbPrefMem* is used to encourage the preference for members instead of no members.

6.3 Experiment Results

After the experiment is complete, a qualitative study was performed to measure the performance of our model against the real data, we propose to use three metrics; a) the normalized internal flows, which is the percentage of the transactions between two members of the agreement. 2) The percentage of importations, it means the commercial flows between a non-member country (seller) and a member country (buyer) and 3) the percentage of exportations, which is measured by the commercial trading between a member (seller) and a non-member (buyer). The two last measures play an important role in the model, since it is expected that these decrease in comparison to the first metric.

Table 4 and Figure 3 show the measure values for the real data. The annual metrics were calculated for different years. The measures show the behavior of the 28 current members, which joined the agreement in different years.
As can be observed the interaction between them has been increasing over time, from 1960 the members trade between them the 32% while in 2014 this rise to 47%, it means an increase of 45%. importations and exportations, from/to other countries which are not in the agreement, have decreased, these are currently the 77% and the 78% of these used to be in 1960.

Definitely, there are many economic and political factors that may influence the model, such as financial crises, the constitution of another trading agreement, wars, creation of new products, external alliances, changes in political divisions among many other factors. As can be seen, the factors that can influence the economic behavior of a trading group are many and some of them are complex to model.

	Internal Trading	Exportation	Importation
1960	0.3269	0.3392	0.3339
1965	0.3912	0.2940	0.3148
1970	0.4197	0.2905	0.2898
1975	0.4185	0.2925	0.2890
1980	0.4244	0.2745	0.3011
1985	0.4047	0.2891	0.3061
1990	0.4809	0.2498	0.2694
1995	0.4774	0.2728	0.2499
2000	0.4942	0.2443	0.2615
2005	0.4977	0.2414	0.2609
2010	0.4820	0.2462	0.2717
2014	0.4751	02617	0.2632

Table 5: EU Normalized Trading Flows Real data (1960 to 2014)

[8] Amount of sales of country n_j has decreased in comparison with the previous round *t-1*

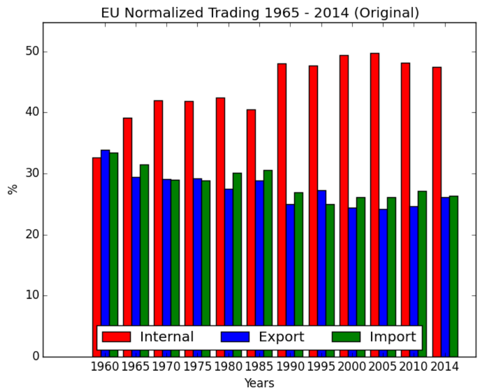

Figure 3: Histogram of normalized trading agreement indicators for member of the EU (Real)

	Internal Trading	Exportation	Importation
1960	0,3175	0,3107	0,3719
1965	0,3042	0,2876	0,4082
1970	0,3196	0,2788	0,4017
1975	0,3722	0,2562	0,3716
1980	0,3686	0,2580	0,3734
1985	0,4272	0,2343	0,3385
1990	0,4535	0,2209	0,3256
1995	0,4483	0,2147	0,3370
2000	0,4626	0,1952	0,3422
2005	0,4676	0,1809	0,3515
2010	0,4719	0,1770	0,3511
2014	0,4627	0,1664	0,3708

Table 6: EU Normalized Trading Flows Model data (1960 to 2014)

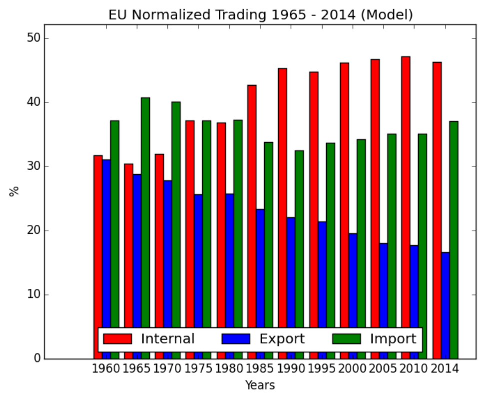

Figure 4: Histogram of normalized trading agreement indicators for member of the EU (Model)

Comparing the data in tables 5 and 6 we can observed a great similitude in the internal flow, which in both cases have increased 45% in the last 54 years. On the other hand, some work need to be done to balance the importations and exportations

7 Conclusion

The main objective of this project is to apply the network analysis and the simulation model to understand the international trading flows, the study is focused on a special case which is the trading agreement of the European Union.

In the first part of this work a literature review about international trading by using networks was provided. After that , a summary of the international trading network over time, was given. We proposed a model to simulate the process of member's integration in a commercial agreement. The main idea was to represent the preferencial election of partners, which in the real life is motivated by the advantage of reducing the amount of taxes. The idea behind this model is to slowly but constantly reduce the flows with no-members and as the same time increasing the trading with the agreement members. Every round is represented by a year and the members are incorporated in the year that these joined to the agreement. The results were compared against the real data by using three indicators which are the normalized internal flows and the normalized importations and exportations. From the experiment results we can coclude that the overall behavior of the agreement network can be modeled. However, a deeper analysis has to be performed in order to find out if the individual conduct can be represented.

Finally, there is a large list of economic and political factors that, in real life, affect the conduct of international trading networks.

8 Additional Work

This work studied the impact of a FTA based on the general value of goods traded between countries. For further insights a look on the different kind of products would be essential. By this a simulation of a shortage inside of a FTA could be simulated. Also by setting up basic value chains the generated value inside of a country and the Free Trade Agreement could be studied. Further insides on a preferential attachment could be investigated by analyzing the distance between the different countries inside and outside of the different FTA. Since the model integrates each of the members exactly in the year that these joined to the agreement, part of the future work is to perform a study of centrality in the network of the EU. This analysis would explain how the oldest members have acquired more benefits over time than the newest partners. Other pending study is to analyze the external agreements with the EU. This study would explain an important part of the importations and exportations of the EU. Finally, one of the major challenges is to model geographic changes, which have been very frequent in the last decades.

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