Impact of Economic Blocs on International Trade Networks: A Case Study of the European Union Post-Euro Introduction and Brexit

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Abstract

This study looks into the impact of regional economic integration, specifically within the European Union (EU), on global trade networks, focusing on two major events: the introduction of the euro and the United Kingdom's exit from the EU (Brexit). We used comprehensive trade data from the BACI-CEPII dataset from 1995 to 2022 to create weighted directed graphs to simulate trade ties between countries. Then, using network analysis tools such as sparsification and community recognition, we investigate how these events can modify trade patterns and network architecture. Our findings illustrate significant changes in trade dynamics within and beyond the EU and highlight the larger impact of external economic factors on global trade connections, implying that alterations observed may be driven by a number of external pressure beyond the studied ones.

1. Introduction

The aim of our research is to determine how regional economic blocs can influence and shape the network of international trade, leading to changes in imports and exports among countries. In this paper, we will focus on the trade network of the European Union, by creating a network mapping imports and exports between countries and studying how it evolves in response to two major events related to the EU, namely, the introduction of the euro and the United Kingdom's decision to leave the Union, commonly referred to as Brexit.

The idea behind our research is to assess how the reality of the Union impacts the economic exchanges and trade relationships of the members and in general at a global level. We decided to do so by evaluating networks which allowed us to analyze the relationships between countries studying also how the whole structure influences them: it would be imprecise to consider each country by itself without determining the impact of the rest of the network. We used different network statistical measures to examine network's changes over time trying to highlight the effect of the two main events that we considered.

This allowed us to analyze the impact of the Union from multiple perspectives starting from our two main events.

The euro was established to facilitate easier and more efficient trade across borders, eliminate exchange rate uncertainties, and deepen economic integration among member

states. The introduction of the euro has had profound effects on trade, investment and economic policy within the Union and abroad. Our aim is to analyze how the euro has influenced trade relationships within the EU and beyond.

In contrast, Brexit represents a significant disintegration within the EU, due to the economic importance of the UK within Europe. Trying to extrapolate the effects of these 'opposing' events can enrich the research within this field.

2. Background

The study of international trade networks, particularly in the context of big economic events, has received a great deal of attention in the scientific community.

Network analysis offers a comprehensive perspective of trade linkages, surpassing traditional dyadic analyses in revealing the interconnection and complexity of global trade. In an interesting paper, Benedictis and Tajoli (2011) demonstrated how network analysis can capture structural changes over time using indices such as density, closeness, betweenness, and degree distribution; in particular, their analysis revealed how global trade has become increasingly interconnected, even as the disparity between countries' trade relations has grown, and how network analysis can also capture the impact of trade policies.

Further, studies like those by Shahnazi, Sajedianfard, and Melatos (2006) explored the resilience of trade networks to shocks, revealing vulnerabilities in the global oil trade network. Their research analyzed the stability and effective share of countries within the oil trade network, finding that major oil exporters and importers exhibit significant instability, which affects global trade network resilience. This analysis is crucial for understanding how geopolitical events and economic fluctuations can disrupt critical trade markets and how networks are able to embrace them.

Finally, De Benedictis et al. (2014) emphasized the importance of structural interdependence using the BACI-CEPII dataset (the one we decided to use, we will go deeper into it afterwards), providing a nuanced view of trade relationships that account for intermediary influences and overall network structure. Their work highlighted the importance of considering the structural dimension of trade relationships, where the effect of one country on another is mediated by their connections to third countries. This approach highlights the complexity of international trade and the need for comprehensive network analysis to understand the full implications of trade policies and economic events.

We can see how the literature on international trade networks provides a rich understanding of how global trade relationships are structured and how they respond to significant economic events.

Regarding the two events that we decided to approach, there are different studies who analyzed the main issue.

For example, Micco, Stein, and Ordonez (2003) examined the euro's trade impact, emphasizing its importance for both current Eurozone members and potential entrants. The researchers found that the Economic and Monetary Union (EMU) not only enhances trade among member countries but also with the rest of the world, supporting the broader benefits of currency unions in promoting global trade.

At the same time, as found by Rose (2000), the introduction of euro augmented trade volumes within and beyond the Eurozone, illustrating the currency's role in facilitating efficient cross-border trade. The paper introduces a gravity model which demonstrated that currency unions, such as the EMU, could triple trade volumes between member countries compared to those with different currencies. This effect highlights the profound impact of deeper economic integration facilitated by a common currency.

In contrast, research shows that Brexit has had a separating effect on trade relationships within Europe.

Janez Kren and Martina Lawless (2024) found substantial declines in EU-UK trade flows post Brexit. Their study utilized product-level trade flows to compare pre and post Brexit trade patterns, revealing a sharp decline in trade from the UK to the EU and significant reductions in trade from the EU to the UK.

The introduction of the euro and Brexit serve as two contrasting examples within the Union, each with profound implications for trade networks. Network analysis emerges as a powerful tool in these studies, offering insights into the interconnectedness, resilience, and structural properties of global trade. By examining these relationships through network theory and analysis, our aim is to better understand the dynamics of international trade, especially within Europe.

3. Data

3.1. ***Data Sources***

The data we used comes from a database of CEPII (Centre d'Etudes Prospectives et d'Informations Internationales), a major French center for research on the world economy, the BACI (Base pour l'Analyse du Commerce International), which includes international trade information for more than 200 countries and 5,000 products spanning from 1995 to 2022.

It is very difficult to find structured and verified data on international trade, however CEPII publishes and updates its database yearly. All the data comes from the United Nations Statistical Division, however, the CEPII elaborates the data from the COMTRADE database to improve the quality, which may cause discrepancies between the two of them. The need of improving the data derives from the fact that sometimes trade partners report different values in terms of total trade and, moreover, import values generally reported CIF (cost, insurance, and freight), while export values reported FOB (free on board); the BACI applies a harmonization process for each trade flow ensuring the reliability of the data.

For each trade flow, the database provides information about the exporter, the importer, the year, the product (through a six digits code based on a "Harmonized System" nomenclature), the quantity and the monetary value. For each year there were recorded from 5 million to more than 10 million trade flows between countries.

3.2. ***Data Preparation***

To guarantee that the dataset was properly formatted and ready for analysis, we conducted a thorough data cleaning and preparation process. Initially, we loaded the country

codes from a CSV file provided by CEPII, which was required for mapping numeric country codes to their corresponding countries. This step was critical to understanding the data appropriately.

We then created a function to clean and aggregate trading data. This function included renaming the columns for greater readability and combining the dataset with the nation codes, which replaced numerical numbers with country names. The merging process was repeated twice, once for exporters and once for importers, after which unnecessary columns were deleted. We also computed the total trade amount by importer and removed duplicate entries to verify the data was unique and properly aggregated.

Next, we combined the yearly trade data files into a single DataFrame. This procedure entailed iterating over individual CSV files for each year, adding a 'Year' column to each DataFrame, and finally concatenating them into a single, comprehensive DataFrame. This final dataset, which includes trade data from all years, was then saved into a new CSV file. After this process, we are now ready to undertake the analysis.

4. Network Construction and Analysis

To start our analysis, we decided to being with the construction of the network, which is represented as a weighted directed graph $G = (V, E)$, where V is the set of nodes representing countries, and E is the set of directed edges representing trade flows between countries. The weight of an edge w_{ij} denotes the trade volume from country i to country j. However, it generated an enormous and not so interpretable network, for which the analysis was not clear (Figure 1).

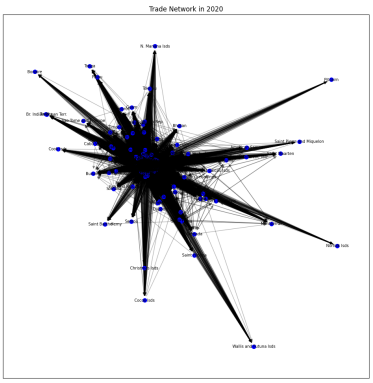


Figure 1: Total Trade Network in 2020

Given this result (Figure 1), we explored techniques to reduce the high network density. To achieve this, we implemented four different sparsification methods: a minimum amount of trade as a filtering threshold, local degree thresholding, betweenness centrality sparsification, and backbone extraction.

*4.1. **Network Reduction***

To start, we plotted a histogram of the 'Total by Exporter' values to understand the distribution of trade volumes and to identify a high percentile that would allow us to discard

low amount trades, which we figured not to be relevant for the scope of our research. This

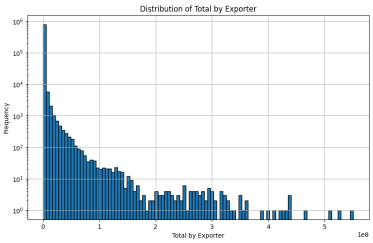


Figure 2

analysis helped us to understand the distribution of trade volumes and identify a threshold to filter out smaller, less significant trades. This step was important for ensuring that our sparsification methods effectively reduced network density without losing essential trade relationships that might be useful for the scope of our study.

First, we used local degree thresholding, restricting the number of outgoing edges per node to the top k edges depending on weight. This strategy assures that each country is only connected to its most important trading partners, lowering the overall number of edges while maintaining the most critical trade links.

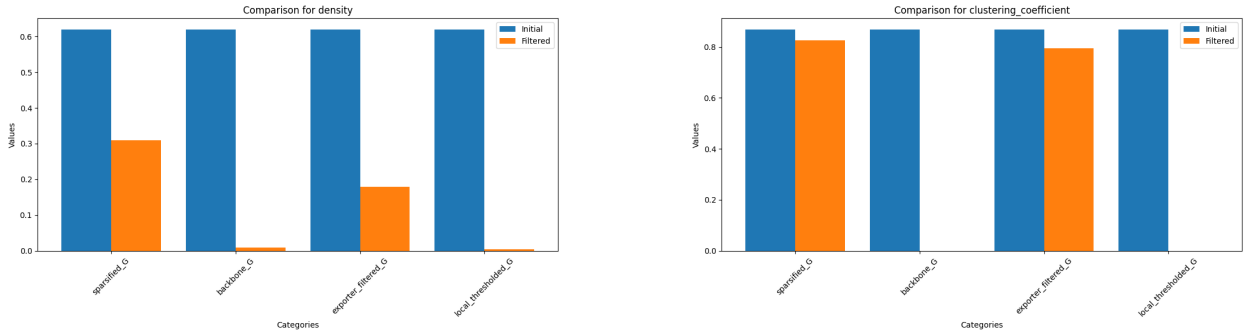
Second, we applied betweenness centrality sparsification. This strategy keeps only a subset of the edges with the highest betweenness centrality scores. This strategy seeks to preserve the structural integrity of the trade network while considerably lowering its complexity by focusing on edges that play a crucial role in the network's shortest pathways.

Finally, backbone extraction was carried out using the minimal spanning tree (MST) method. The MST was calculated using an undirected version of the network, which contains only the most critical edges that connect all nodes without producing cycles. This strategy assures that the final network is a simplified version of the original, emphasising the underlying structure of global trade.

4.2. ***Network Selection***

After applying these sparsification techniques, we analyzed the resulting networks. To rigorously evaluate the impact of our sparsification techniques, we compared several key metrics across the original and sparsified networks. These metrics included the number of nodes, number of edges, network density, clustering coefficient, and total edge weight. By comparing these metrics, we could quantitatively assess how each sparsification method altered the network structure and preserved critical trade relationships.

To justify our selection of the exporter filtered network (exporter_filtered_G where Amount by Exporter $>$ 35,000, which corresponds to the 75-th percentile), we examined two metrics: network density and clustering coefficient (Figure 3). Network density reflects the proportion of realized trade relationships compared to all possible relationships, while clustering coefficient measures the extent to which countries tend to cluster together based on their shared trade partners. The exporter filtered network, with a density of 0.179 and a clustering coefficient of 0.794, has the best balance between maintaining significant trade



(a) Network Density

(b) Clustering Coefficient

Figure 3: Key metrics used

connections and reducing network complexity. This choice ensures that while the network is substantially sparser than the original one, it still captures substantial trade interactions and maintains compact clusters of countries. These metrics indicate that the exporter filtered network effectively retains the meaningful trade relationships, making it suitable for further detailed analysis of global trade dynamics.

*4.3. **Community Detection***

4.3.1. Louvain Detection

The obvious next step given that we are analyzing trade networks was to explore the realm of communities created by trade flows. Considering the size and number of networks analyzed, we opted for the Louvain algorithm due to its efficiency and standard use with large datasets, having a complexity of O(nlogN). To guarantee that substantial trading routes were included, we maintained a criterion for overall commerce by exporter. This approach allowed us to discover four communities per year, with the exception of 2000-2005, when we identified five.

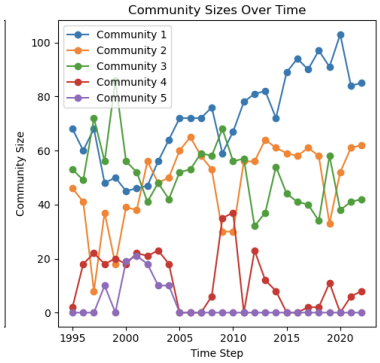


Figure 4

We then represented the various communities on a map to perform a detailed analysis, and we found some interesting results. (all the html files for interactive graphs can be found in this link)

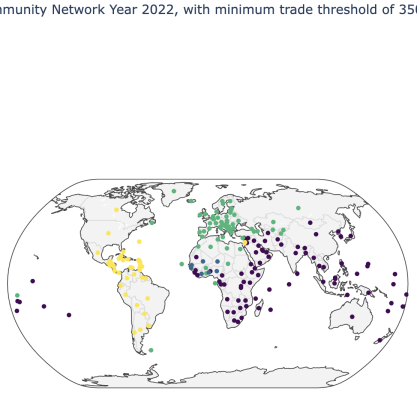


Figure 5: Network in 2020

As expected, the identified communities (Figure 5) in the international trade network are predominantly geographically close. Some communities evolve significantly over time, while others remain largely unchanged. In the visual representation, we observe distinct visions: one community for the Americas, another encompassing Europe and North Africa, and a third for the developing countries of the rest of Africa and Southeast Asia.

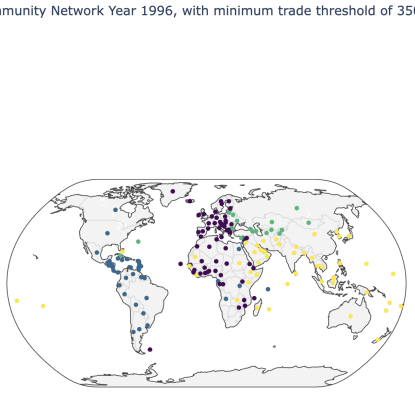


Figure 6: Network in 1996

In 1996 (Figure 6), the community structure was very different. The European community included practically all of Africa, while Eastern Europe and Russia, along with neighbouring countries, created their own community. This is consistent with the historical background, as it occurred only a few years after the collapse of the Soviet Union. We have noticed a number of trends over time. The European community has gradually lost nodes in African countries, focusing increasingly on Eastern Europe, notably Russia. Southeast Asia has rapidly become a cohesive community, extending its influence over practically all of West and South Africa. After further research, we believe that this Southeast Asian group may represent the BRICS countries. While not all BRICS countries continuously belong to this community, we relate this to their geographic location. For example, Brazil frequently

alternates between the Americas and Southeast Asian communities. In some years, Brazil's contacts with other BRICS nations are strong enough to tip the balances in its favour, allowing it to join the club.

5. Results

5.1. ***Brexit Analysis***

To assess the impact of Brexit, we mainly focused on the analysis of the trade relations of the UK over time to determine what were the effects of leaving the Union.

First, we observed how imports and exports within the EU changed from 1995 to 2022 (Figure 7), focusing on the filtered network. We measured for each year the export ratio over global exports, the import ratio with respect to overall global imports and the ratio between exports and imports for the UK; we then plotted how they changed in a graph.

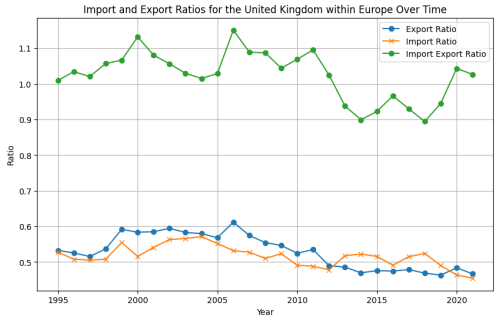


Figure 7

The import ratio is consistently below 0.6, indicating that imports from Europe, relative to total trade, were less significant compared to exports. There is a notable decline in the import ratio starting around 2015, which continues through to 2020 (probably due to the Covid crisis), suggesting a potential impact of the Brexit referendum in 2016.

The export ratio also shows a decreasing trend over time, in particular we notice a decrease after 2006.

The last ratio, export ratio over import ratio, generally stayed above 1.0 until around 2015, after which it shows a declining trend, indicating a relative decrease in the UK's role as an exporter within Europe after 2015.

However, the decreasing trends for both the import and export ratios may be due to a globalization phenomenon characterized by trade openness which facilitated interactions and trade relations between almost all countries of the world, diminishing the weight of big players around the globe.

Moving on, we analyzed how the betweenness centrality of the UK within the EU changed over time.

The betweenness centrality (Figure 8), which indicates UK's centrality in the European trade network, shows a significant decline from around 2000 to 2020. The most substantial drops occur between 2005 and 2010, and a further decrease is noticeable post 2015. From

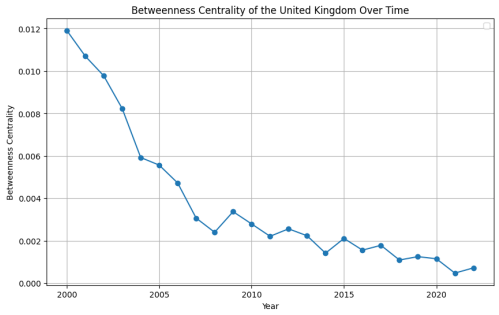


Figure 8

2016 onward, the UK's importance clearly decreased, probably as a result of the political and economic unpredictability surrounding Brexit as well as the modifications to trade agreements and connections.

The UK may have lost some of its centrality in the European trade network over time, as indicated by the drop in betweenness centrality. However, as we have previously stated, it is more reasonable to assume that the decline in UK centrality is caused by the removal of trade barriers both within and outside of the Union, which has facilitated easier international trade and reduced the significance of major exporters. This could be the result of changing trade policies or rerouting trade flows as businesses and nations adjusted to the new regulatory environment following Brexit.

Moreover, the UK had to adapt quickly to the situation by negotiating new trade agreements to mitigate negative impacts on its economy.

5.2. ***Euro Introduction***

To assess the impact of the Euro's adoption on trade dynamics within the Eurozone, we analyze the proportions of imports and exports between Eurozone countries and non-Eurozone partners. In particular, we compute the total trade volume between countries within our cluster and use it to compute two ratios: one by the aggregate of all imports from these countries and another by the aggregate of all exports to them. This allows us to determine the proportion of imports and exports that are internal to the Eurozone (Figure 9).

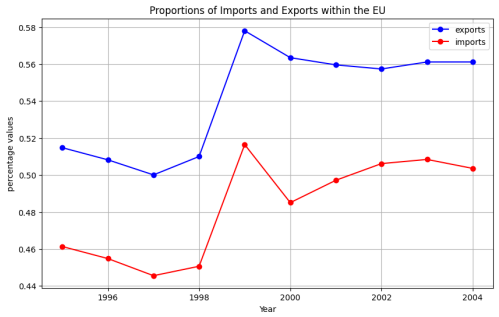


Figure 9

Our study shows a significant increase in both proportions with the introduction of the Euro: the blue line represents exports and the red line represents imports. After adoption, these proportions stabilise below their initial peak levels, although they nonetheless stay elevated. This implies that although the Euro first made intra-cluster commerce easier, this benefit faded with time.

Additionally, we use weighted network centralization to analyse the trade distribution (Figure 10), evaluating the degree of trade volume parity across the participating nations. While lower numbers indicate a more balanced distribution, higher values show that trade volumes are dominated by a small number of nations.

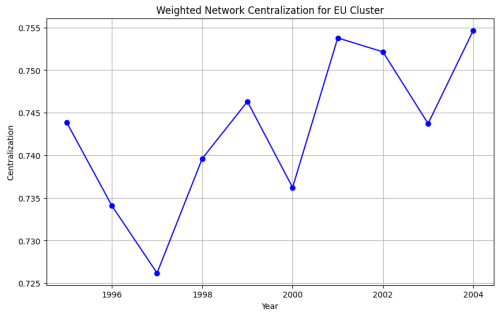


Figure 10

Interestingly, our analysis shows a gradual increase in centralization over the study period. Surprisingly, this trend does not seem to correlate with the introduction of the Euro, implying that while the currency influenced overall trade patterns, it did not significantly alter the distribution of trade volumes among participating countries.

6. Conclusions

Initially we analyzed the separation of the international trade network through the division in communities, which allowed us to find in our network a reflection of major geopolitical change, after having done so, we identified 2 main events that we thought would have been interesting to analyze: Brexit and the introduction of the euro.

Our analysis of the impact of Brexit on the UK's trade relations with the European Union reveals significant changes in trade patterns over time, however we do not associate the variations to the exit of the UK from the Union. We observed a general decline in the UK's import and export ratios with the EU and in the betweenness centrality, which was accentuated after 2015, although the trend was consistent and started much earlier, so we are not confident in linking the decrease to the event we are considering. Probably, the decrease has more to do with the development of a more open market and of trade relations between countries.

At the same time, our examination of the introduction of the euro did not reveal significant and persistent changes in trade patterns or network centralization within the EU. While there were initial increases in exports and imports following the euro's introduction,

these changes were not sustained, suggesting that the anticipated improvements in trade integration were not as pronounced as expected.

6.1. ***Moving Forward***

In the future, more investigation into particular commodities or industry sectors may be conducted to find more profound effects from these occurrences. Distinctive effects across industries may be shown by analysing sector-specific data, offering insights into how supply networks and market dynamics have changed or reorganised following Brexit and the adoption of the euro.

Furthermore, the application of measures to evaluate the stability of importers and exporters in trade networks may contribute to a better understanding of resilience and methods for adaptation in the wake of geopolitical and economic shifts. Trade concentration indices and network robustness metrics, for example, can provide insightful information about the adaptability of economies both inside and outside of regional blocs as well as the resilience of trade linkages.

By doing this, future research can advance our understanding of how global trade networks are shaped by geopolitical events and regional economic integration. Such insights can be crucial for policymakers and businesses navigating an increasingly interconnected global economy.

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