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HOW RESILIENT WAS INTERNATIONAL TRADE TO COVID-19? INSIGHTS FROM CLUSTERS OF EUROPEAN COUNTRIES

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Abstract
The Covid-19 crisis spread worldwide at lightning speed mainly due to the interconnectedness of today's economies as evidenced by major disruptions in international trade. This article aims to assess the possible shifts that coronavirus disease has triggered in the trade activity of European countries in two particularly affected sectors, that is food and machinery and transport equipment. In this process, exploratory data analysis is conducted to accurately explain the patterns lying behind the observed variations in trade values. Furthermore, cluster analysis is performed on the sample of European countries by applying hierarchical and K-means clustering algorithms using Python's libraries. By examining clusters of countries with similar trade profiles, this article contributes to discussions on global value chains, and to which extent there is data-based evidence to indicate systemic changes and reconfiguration of global production processes.

Keywords: International trade, cluster analysis, Covid-19, Europe, programming models

JEL classification: C38, C80, F14

Introduction

The twin nature of both supply and demand shock from Covid-19 pandemic has led to a sharp decline in world trade (Baldwin and Tomiura, 2020; Liu, Ornelas and Shi, 2022). The severe drop was not only caused by the negative impact of declining global demand on international trade, but also by increased cross-border restrictions, port closures, and many other logistical disruptions. For any economy facing a pandemic, the economic contraction caused by domestic containment policies would lead to a reduction in demand, and thus to a drop in imports. From the supply side, a sudden break in production following the lockdowns and outright closure of firms would imply a contraction in exports

from the pandemic-affected country to its trading partners, or equivalently, the bilateral imports of partners (Baldwin and Freeman, 2022; Cerdeiro and Komaromi, 2020; Lafrogne-Joussier, Martin and Mejean, 2021). However, early expectations of a double-digit contraction turned out to be too pessimistic, as world trade has already started to recover in the second half of 2020. “Overall, global trade declined by about $2.5 trillion in 2020 (or by about 9 percent compared with 2019). According to UNCTAD data, as economic conditions improved in 2021, the value of global trade rebounded strongly, reaching a record high of about $28.5 trillion, equivalent to an increase of about 13 percent compared with pre-pandemic levels” (UNCTAD, 2022). What is also important to note is that there are significant differences in the effects of the pandemic on the trade performance of different economic sectors. Covid-19 pandemic has had an important contribution to both demand and supply disruptions in commodity markets, bringing about price volatility across various commodities. Over the last two years, food prices have recorded almost the same dynamics as global trade. “In January–September 2020, the UNCTAD monthly food index declined by 4 percent as the prices of most commodities in the group fell due to a combination of abundant supply in markets and decline in demand. From the last quarter of 2020, through 2021, to February 2022, the food index trended upwards, with short-term fluctuations” (UNCTAD, 2022). The upsurge in food prices was prompted by a rebound in demand and growing input costs driven by an increase in oil and gas prices, with the latter explaining the delayed effect. Basically, the dynamics of commodity prices during the coronavirus disease have affected both the economies dependent on commodity exports and many net importers (poor countries) of food and fuels. Additionally, the evidence suggests that companies involved in global value chains (GVCs) during the pre-crisis period have seen the highest drop in exports and a slower pace of recovery than non-GVC exporters (Lebastard and Serafini, 2023). However, the pandemic has affected global production networks to varying degrees, mainly depending on supply chain configuration as measured by the number of cross-border intermediate production steps (length) and the degree of participation in production processes across the countries (geographical distribution) (Kostoska, Stojkoski and Kocarev, 2020). The most exposed industries include value-chain-intensive sectors (e.g. machinery and equipment, automotive, electronics, and textile and apparel) “which account for about 20 percent of greenfield investment across all industries, but almost 50 percent when considering manufacturing investment only” (UNCTAD, 2022). The pandemic has offered several good lessons for companies and governments alike on how to make global value chains more resilient. Many governments emphasized the risk of excessive dependence on foreign suppliers, not only on account of the global economic shock but also in the current situation of shifting geopolitics. In addition, social problems related to employment increased during the pandemic, which in turn further argued the proposals for reshoring some of the manufacturing industries closer to consumers (Organization for Economic Co-operation and Development, 2021). Governments have also been increasingly focused on a combination of reshoring policies with nearshoring, which implies restructuring of the production networks towards geographically closer countries. Nearshoring could diminish the risks coming along with over-reliance on distant providers and decrease efficiency losses from reshoring, while still providing some diversification. However, what is important is that global value chains represent a backbone of industrialization strategies in developing countries, and thus any reconfiguration of networks could have significant development implications.

Given what has been said, this paper intends to examine the trade activity of European countries for the two key sectors (food and live animals; machinery and transport equipment) to draw appropriate information on where these countries stand concerning recovery, pre- and during the Covid-19 levels and whether new trajectories can be observed. For this purpose, exploratory data analysis is performed to precisely explain the patterns corresponding to observed variations in trade values of European countries. Further investigations are based on the application of certain techniques to identify clusters of countries according to their specificities. The cluster analysis is a multivariate technique that helps reorganize countries in a way that minimizes the distance of the clustering variables between countries belonging to the same cluster, whilst maximizing the distance among various groups. The purpose of the analysis is to construct groups with homogeneous characteristics out of heterogenous large samples (Hair et al., 2013) so that variables identifying each cluster would have smaller standard deviation and a higher mean contrasted to those of other clusters (Cornia and

Scognamillo, 2016). In this way, distinct shifts in how countries respond to pandemic-induced changes could be identified and potential recalibrations of country groups across the observed period can also be examined. Hence, the estimates made here will contribute to discussions on global value chains in terms of the extent to which there is data-based evidence of diversification, reshoring, and nearshoring as announced by policymakers.

The rest of the paper is organized as follows. Section 2 reviews the literature studying the impact of the pandemic on international trade. Section 3 refers to data and applied methods. Section 4 reveals the results obtained from various measurements. Discussions and conclusions are provided in Section 5.

Literature Review

The literature examining the effects of Covid-19 on international trade is fairly limited but is growing rapidly. In general, studies that refer to changes in trade patterns during the pandemic are divided into two groups, that is, those that examine the effects of Covid-19 on international trade across the supply chains or through the transmission of demand and supply shocks and studies that comprise the analysis within the product groups.

The first category includes, for instance, the article of Kejzar and Velic (2020), who estimate a gravity model using monthly bilateral trade data for EU member states over the period from June 2015 to May 2020. The authors confirm that supply chain disruptions have significantly contributed to the transmission of Covid-19 demand shocks. Additionally, Bonadio et al. (2020) have modeled the lockdowns as a labor supply shock that is transmitted across countries through the global value chains. Hayakawa and Mukunoki (2021a) examine the impact of coronavirus disease on global value chains by looking into bilateral trade flows of finished machinery products, while Espitia et al. (2022), using monthly disaggregated trade data for 28 countries and multiple trading partners, found that the negative trade effects of the pandemic differed widely across sectors and, more importantly, participation in global value chains amplified the traders' susceptibility to shocks experienced by trading partners. On the other hand, Eppinger et al. (2021) have examined whether decoupling from GVCs can increase a country's welfare by decreasing its exposure to foreign supply shocks. More specifically, by conducting simulations with a quantitative trade model, the authors have provided evidence that welfare losses from decoupling outweigh the benefits from less shock exposure. Considering that the economic effects of Covid-19 depend on the extent to which countries are connected in global production networks, Sforza and Steininger (2020) integrate the pandemic-induced production barriers into a Ricardian model with sectoral linkages, trade in intermediate goods and sectoral heterogeneity in production. The authors find that the coronavirus shock has significantly affected most economies around the world, especially if the share of the labor force is isolated. Friedt and Zhang (2020) estimated the effects of the coronavirus pandemic on Chinese exports and distinguished the hypothesized 'triple pandemic effect' across three components, that is the domestic supply shock, the international demand shock, and the effects of global value chain contagion. The authors found that all three shocks contributed to the fall in Chinese exports caused by the pandemic, but the GVC contagion had the largest and the most lasting impact explaining the losses. Finally, Simola (2021) examines the development of GVC trade during the pandemic mainly focusing on internal and external EU trade. The author provides evidence that trade overall has been hit hard by the pandemic, but not the GVC trade, in particular (with a remarkable exception of transport equipment). Moreover, the analysis suggests that the coronavirus crisis will not necessarily lead to a major restructuring of global value chains but may possibly reinforce several trends that determine the GVC development.

The second category of studies examines the sources of heterogeneity used within product data. For instance, Liu, Ornelas and Shi (2022) employ a gravity-like approach to examine how coronavirus deaths and lockdown policies have affected imports from China during 2020. The authors found that a country's own deaths and lockdowns have significantly diminished imports from China, indicating that the negative demand effects have outweighed the negative supply effects of the coronavirus disease. Quite the opposite, the pandemic deaths in the main trading partners of a certain country (excluding

China) bring more imports from China, partially offsetting the countries' own effects. Moreover, the authors underline that important sources of heterogeneity exist across products and countries. For example, the negative effects of Covid-19 disappear when the sample is restricted to medical goods and are significantly alleviated for goods with a high 'work-from-home' share, for products with a high contract intensity and for goods exported under processing trade. Durable consumption goods, on the other hand, exhibit more pronounced negative results. In the context of a gravity equation and using different Covid-19 proxies, Hayakawa and Mukunoki (2021b) examine monthly exports of 34 countries to 173 countries from January to August in 2019 and 2020. The authors confirmed the significant negative effects of the pandemic on international trade of both exporting and importing countries. They also found that these effects, especially for the importing countries, tended to become insignificant after July 2020 and were heterogeneous across industries. More specifically, the pandemic led to a decrease in imports of mineral products, leather products and transport equipment, whilst the impact on machinery products has become insignificant. Moreover, the authors found positive effects of the pandemic on some medical products of importing countries, whereas labor-intensive industries (e.g. textile) and transport equipment have suffered from the negative effects of Covid-19 in exporting countries. The heterogenous effects of the pandemic across sectors and product types were confirmed again by Caporale, Sova and Sova (2022), who estimated dynamic panel data models to examine how the coronavirus disease had affected the European trade patterns.
This article is rather a combination of both categories of studies, as it includes a sectoral analysis, but also contributes to discussions on global value chains. However, the paper differs from the reviews listed above as it takes a completely different methodological approach to examine the trade effects of Covid-19, and unlike most contributions, it focuses on a specific case of European countries.

Methodology

The cluster analysis performed here uses 1-digit SITC data on exports and imports of 42 European countries vis-à-vis the world in two product groups, namely "Food and Live Animals" and "Machinery and Transport Equipment". The reference period in the article refers to three separate years - 2019, 2020, and 2022-, that is the time frame before the outbreak of the pandemic until the time when many countries removed the measures. During the preprocessing phase for clustering, the values were standardized using Z-Score Normalization due to a wide range of data for different countries. This procedure is done to ensure that the values have a mean of 0 and a standard deviation of 1 (Normalized value = (x - mean) / standard deviation). The StandardScaler() function from Python's scikit-learn library was used for this purpose. The cluster analysis is performed by two different algorithms using Python's scipy and scikit-learn libraries. The first algorithm is the Hierarchical Clustering Model using Ward Linkage method, which is representative of the Connectivity Model. It determines the clusters based on the closeness of data points. Basically, hierarchical clustering represents a method for grouping data points in such a way that items in a certain group are more similar to each other and different from items in other groups. The second algorithm is K-means clustering, which is a representative of the centroid model. To group the data points, this algorithm calculates the distance between a specific data point and the centroid of the cluster.
It should be noted that cluster analysis requires independence between variables. The estimates here indicate that there is a high correlation between exports and imports in both industries, which would suggest that cluster analysis may provide biased results with respect to the inclusion of countries in a corresponding cluster. However, we have proceeded to perform this technique here, since our objective is not to identify which of the countries in the sample belong to a given cluster, but whether the countries, based on their trade profile, preserve stability, or maintain their position in the specific cluster during the selected period.

The following hypotheses are defined in the context of the research objectives:

Hypothesis 1: Impact of Covid-19
The pandemic has significantly affected the import and export growth of European countries in both sectors, that is "Food and Live animals" and "Machinery and Transport Equipment".

Hypothesis 2: Cluster Stability

The clusters exhibit a certain degree of stability across the selected years, indicating that countries tend to maintain similar trade patterns over time.

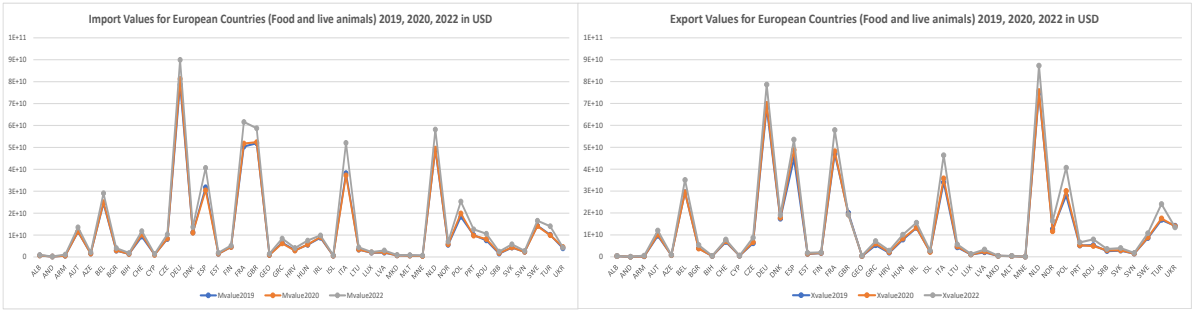
Results

The results of the study will be presented in two separate subsections. The first subsection refers to exploratory data analysis, while the other focuses on cluster analysis of the two types of products across the selected timeframe.

Exploratory Data Analysis

The analysis of the import and export values of "Food and Live animals" in 2019, 2020, and 2022 shows that there are no significant deviations among the respective countries, especially in the years prior to pandemic (2019) and during the pandemic (2020). In 2020, there was a decline in net values for both exports and imports across almost all countries in the sample. However, despite the higher values for "Food and Live animals" in 2022 compared to the previous years, exports and imports still follow a pattern of each respective country (Figure 1).

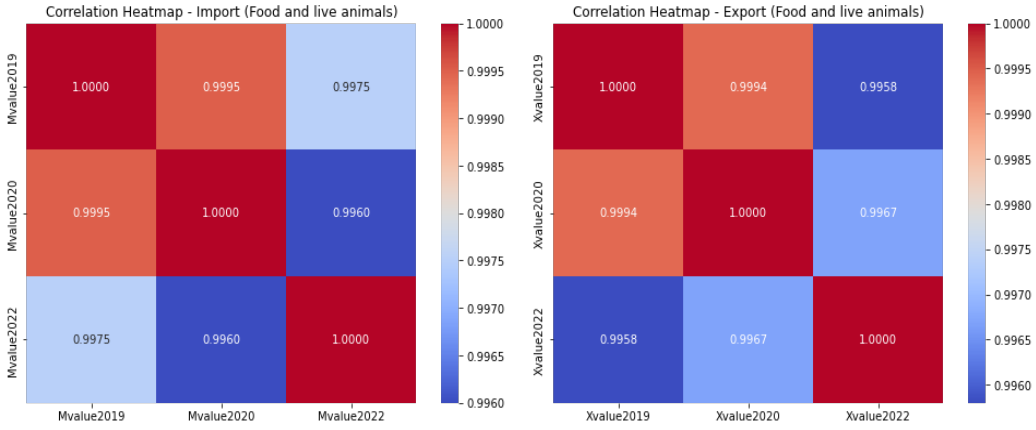
Figure 1. Import and Export Values for Food and Live Animals (2019, 2020, 2022)



Source: Author's calculation based on UN Comtrade Database

These claims are also supported by the high correlation between variables for imports and exports during the respective years (Figure 2).

Figure 2. Correlation between variables for Food and Live Animals

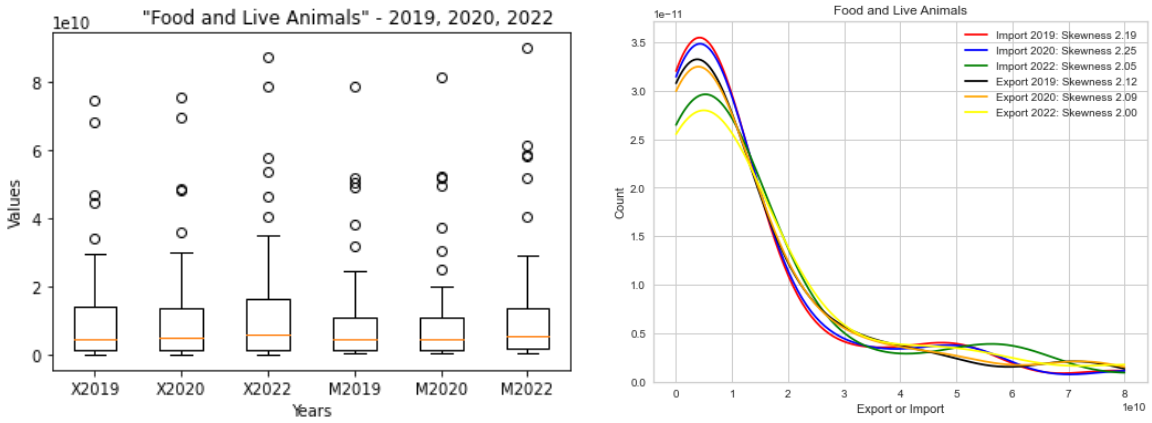


Source: Author's calculation based on UN Comtrade Database

The Interquartile Range (IQR) indicates that only a few countries stand out as outliers, which is also supported by the values of skewness (2.12 for export and 2.19 for import in 2019; 2.09 for export and 2.25 for import in 2020; 2.00 for export and 2.05 for import in 2022). In other words, distribution has a longer tail on the right side, which means that there are only a few countries with extremely high export and import values that contribute to the skewness of the overall distribution (Figure 3).

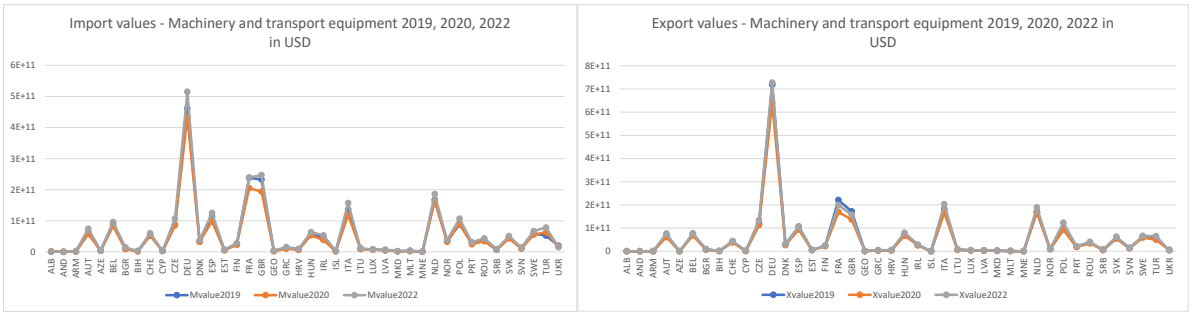
The examination of the import and export values of “Machinery and Transport Equipment” in 2019, 2020, and 2022 reveals that there are no notable discrepancies in the patterns among the individual countries. The import and export values of “Machinery and Transport Equipment” correspond to the trends observed in each specific country and year (Figure 4). Noticeable downward changes in the net values both in exports and imports are observed in 2020, followed by a significant increase in 2022, but with a strong correlation between the variables for imports and exports in different years (Figure 5).

Figure 3. The Interquartile Range (IQR) and skewness for Food and Live Animals



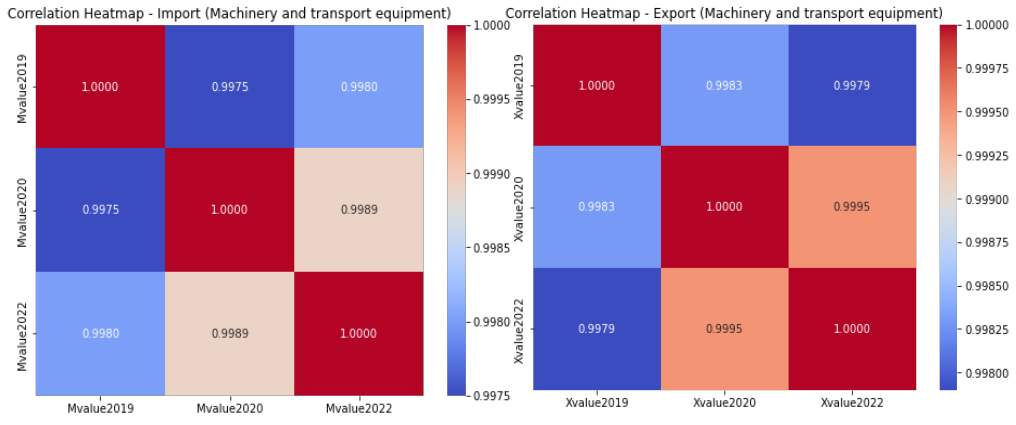
Source: Author’s calculation based on UN Comtrade Database

Figure 4. Import and Export Values for Machinery and Transport Equipment (2019, 2020, 2022)



Source: Author’s calculation based on UN Comtrade Database

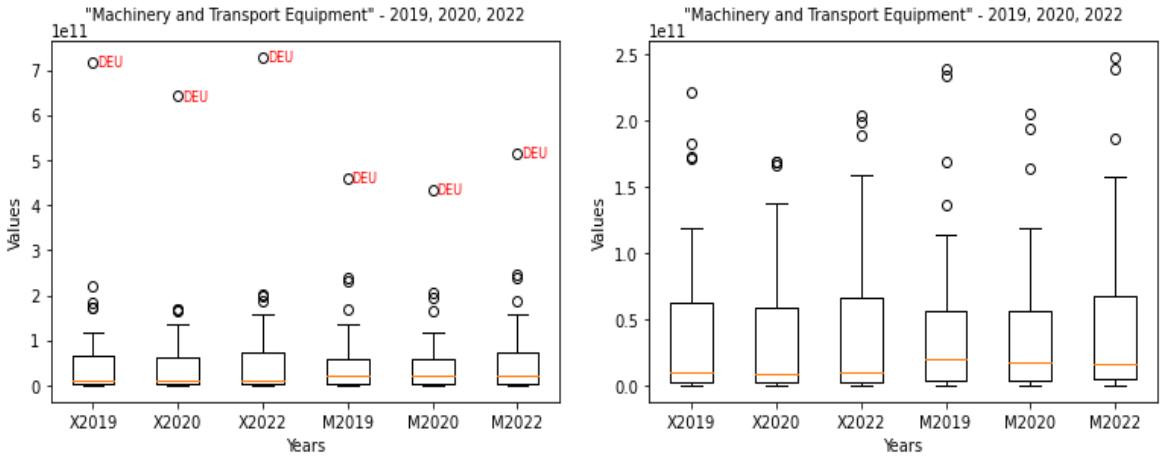
Figure 5. Correlation between variables for Machinery and Transport Equipment



Source: Author’s calculation based on UN Comtrade Database

Since the results showed that Germany is an outlier for both export and import values in "Machinery and Transport Equipment" for all three years, the subsequent cluster analysis will exclude this country as it would represent a separate cluster on its own (boxplot without values for Germany are shown on the Figure 6-right) (Figure 6).

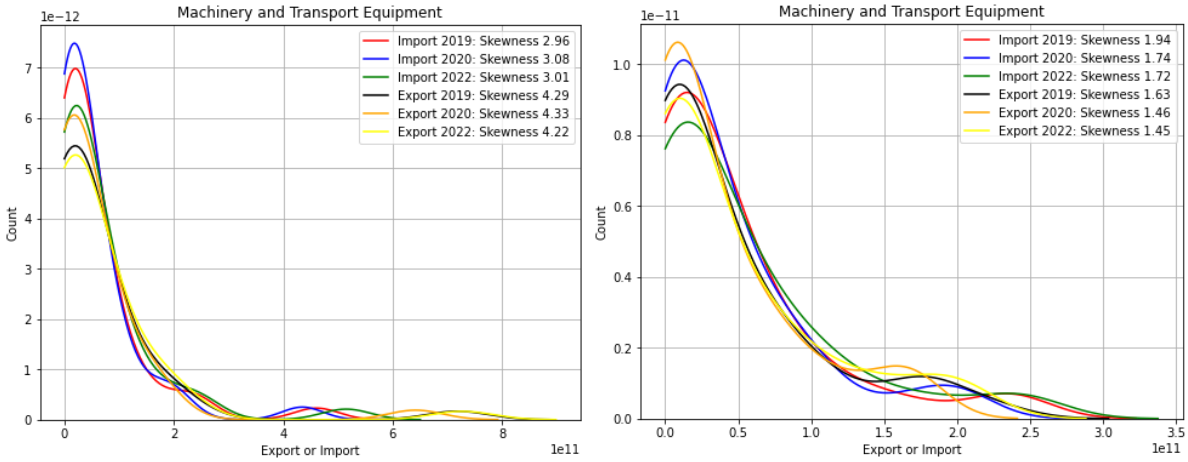
Figure 6. The Interquartile Range (IQR) for Machinery and Transport Equipment



Source: Author's calculation based on UN Comtrade Database

Figure 7 shows the data distributions both with (Figure 7 - left) and without Germany (Figure 7 - right) in the dataset. It is evident that the skewness values are significantly reduced, ranging from 2.96 to 4.33 before excluding Germany, and from 1.45 to 1.94 after excluding Germany from the dataset.

Figure 7. Distribution and Skewness values for Machinery and Transport Equipment



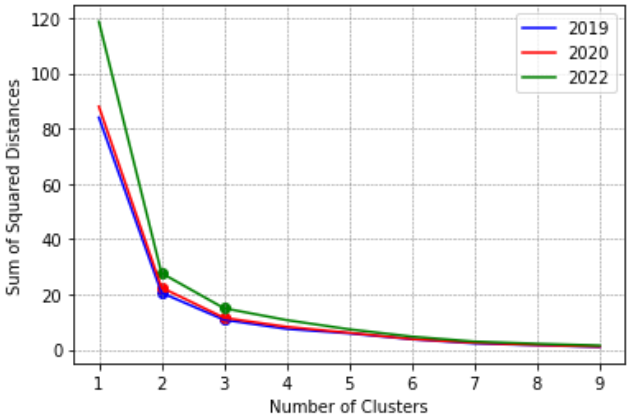
Source: Author's calculation based on UN Comtrade Database

Cluster Analysis

The cluster analysis for "Food and Live Animals" based on both a dendrogram for hierarchical clustering and the KMeans clustering algorithm shows that there are almost no differences in terms of the inclusion of countries in the respective clusters during the selected timeframe. More specifically, both the Elbow method for optimal cluster selection (Figure 8) and the distances in the dendrograms suggest that the dataset should be divided into two or three clusters. This decision is further supported by the relatively high values of the Silhouette coefficient for all three years (Silhouette Coefficient - 2019: 0.766 for two clusters and 0.738 for three clusters; Silhouette Coefficient - 2020: 0.761 for two

clusters and 0.738 for three clusters; Silhouette Coefficient –2022: 0.766 for two clusters and 0.722 for three clusters).

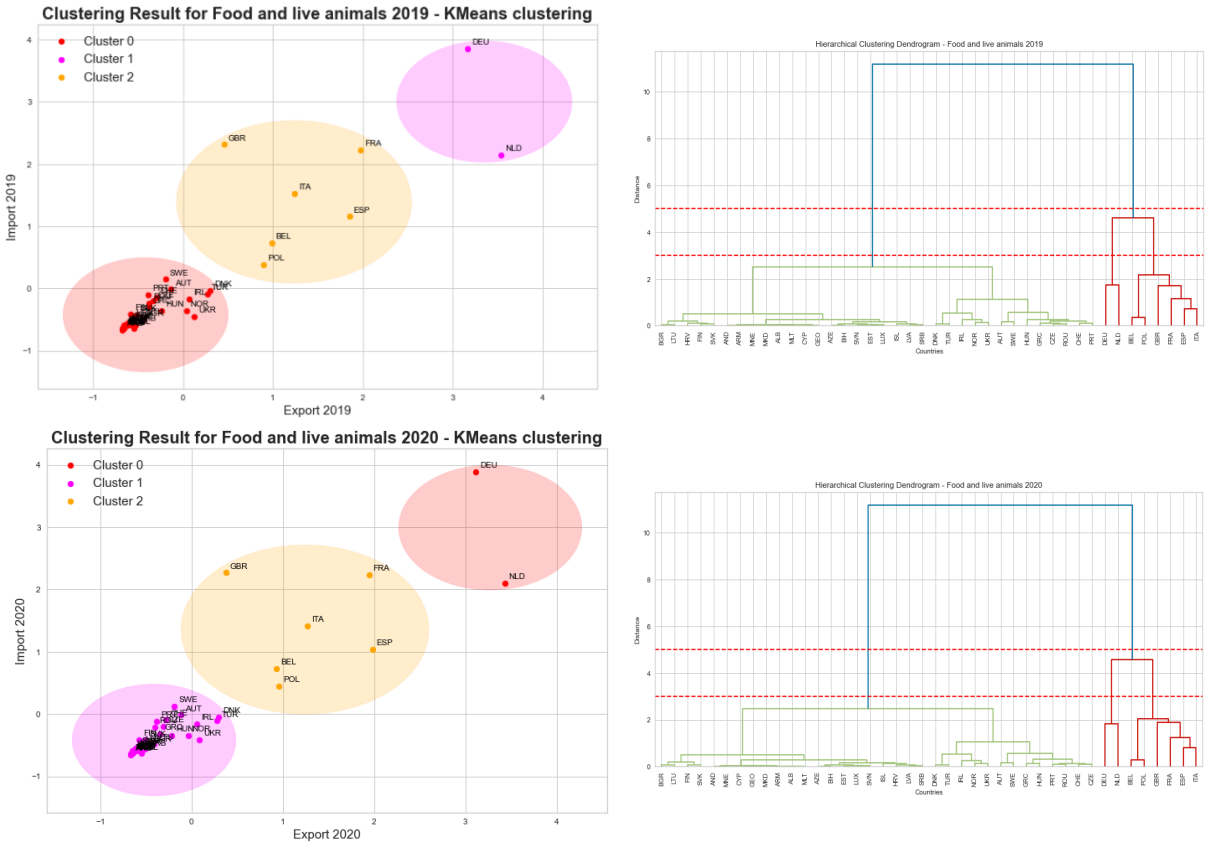
Figure 8. Elbow method for optimal number of clusters for Food and Live Animals



Source: Author's calculation based on UN Comtrade Database

In view of all these values, a final decision was made to consider 3 clusters (Figure 9).

Figure 9. Clustering results for Food and Live Animals KMeans Clustering and Hierarchical Clustering (2019, 2020, 2022)



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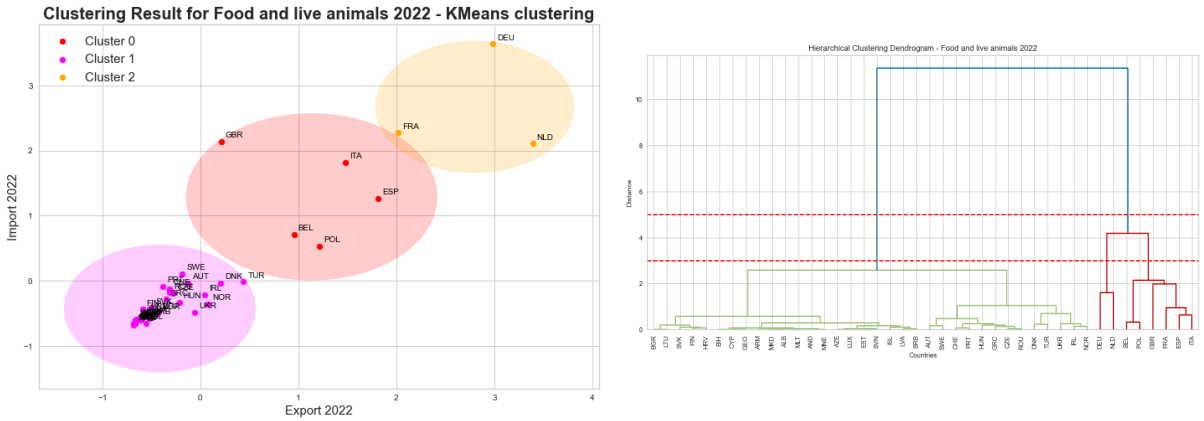
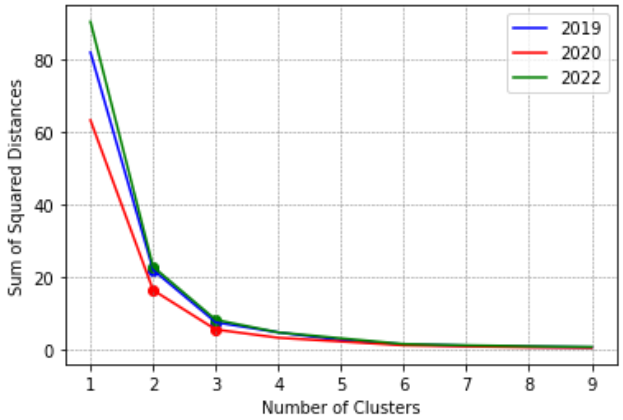


Source: Author's calculation based on UN Comtrade Database

As mentioned earlier, Germany is excluded from further cluster analysis because this country's values for exports and imports of "Machinery and Transport Equipment" deviate significantly when compared to the values of other countries. Taking into account the Elbow method for optimal cluster selection (Figure 10), the distances in the dendrograms, and the Silhouette coefficients (Silhouette Coefficient - 2019: 0,717 and 0.690 for two or three clusters, respectively; Silhouette Coefficient - 2020: 0.708 and 0.702 for two or three clusters, respectively and Silhouette Coefficient - 2022: 0.724 and 0.696 for two or three clusters, respectively), it was again decided to consider three distinct clusters (Figure 11).

Figure 10. Elbow method for the optimal number of clusters for Machinery and Transport Equipment



Source: Author's calculation based on UN Comtrade Database

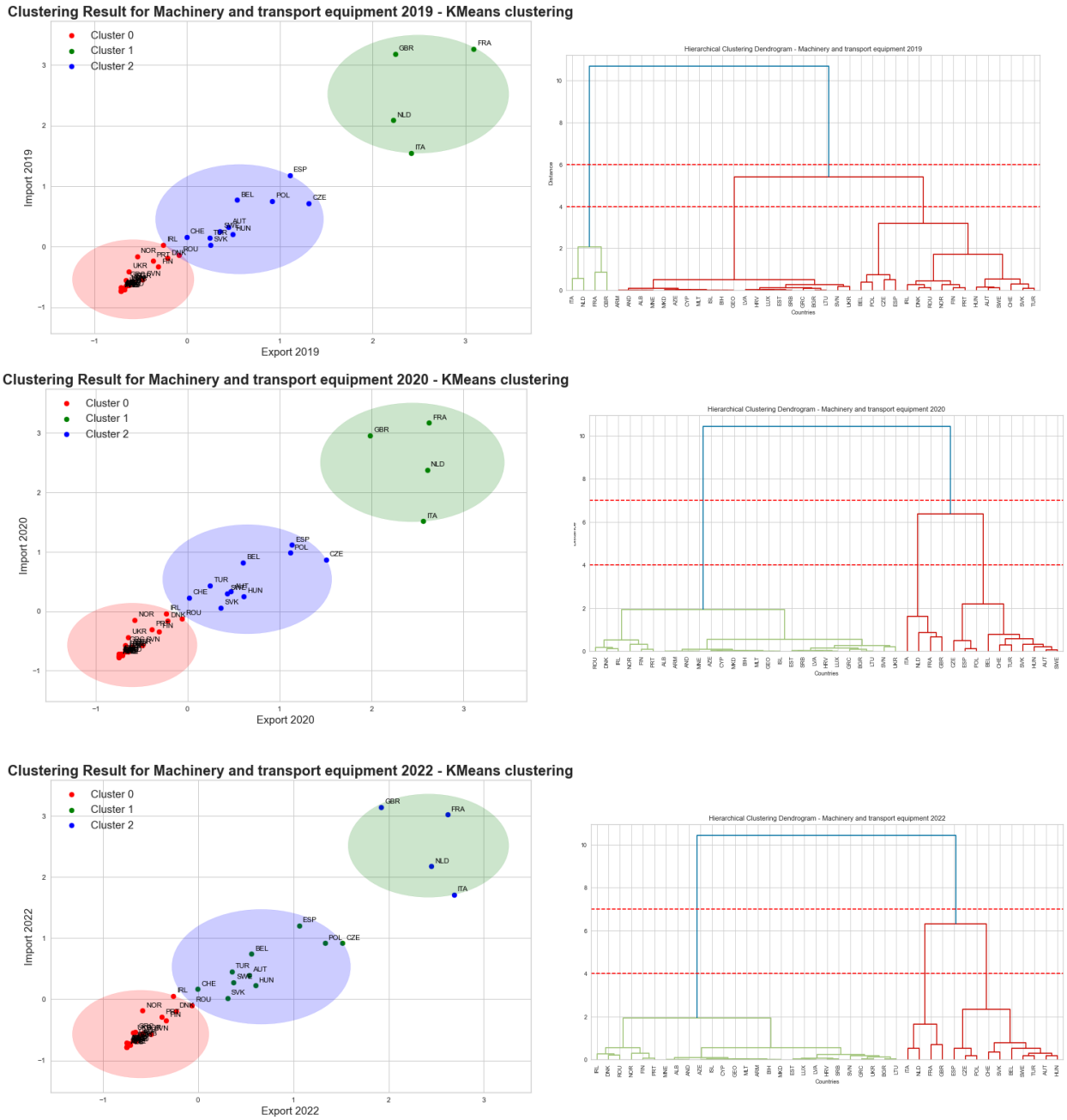
Discussion and Conclusion

Although the export and import values of "Food and Live Animals" follow a certain pattern for each country, there are significant differences in the growth of exports and imports over the years. More specifically, trade values in 2020, when the Covid-19 measures were introduced, were significantly lower than those recorded in 2019 (Figure 12). The F-statistics and p-value obtained from ANOVA suggest that there are significant differences in the mean values of the three groups of growth, both in the case of export and import growth of "Food and Live Animals" (export: F-statistic = 18.5508; p-value = 0.0000; import: F-statistic = 71.1256; p-value = 0.0000).

These results confirm the first part of Hypothesis 1 that the pandemic significantly affected the trade activities of European countries for "Food and Live Animals". In fact, the results are consistent with

findings that a large part of the effects of the pandemic on international trade flows have been contingent on changes in patterns of demand which, due to lockdown measures, decreased in most industries in the first half of 2020 (UNCTAD, 2022).

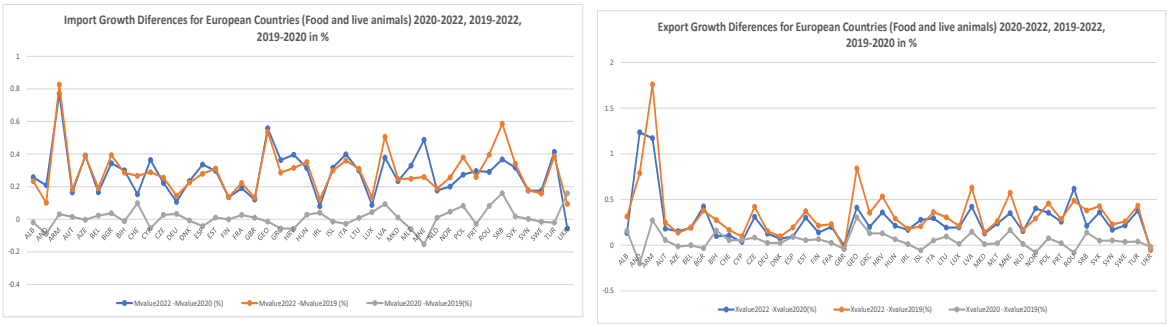
Figure 11. Clustering results for Machinery and Transport Equipment
KMeans Clustering and Hierarchical Clustering (2019, 2020, 2022)



Source: Author's calculation based on UN Comtrade Database

The ANOVA analysis for "Machinery and Transport Equipment" indicates that there are significant differences in mean values of the three groups in terms of import growth (import: F-statistic = 23.5997; p-value = 0.0000), but no significant differences were observed in the growth of exports (export: F-statistic = 1.4391; p-value = 0.2412).

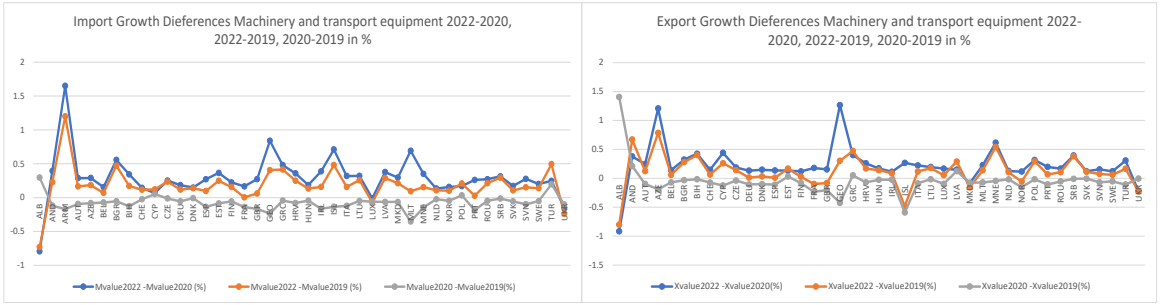
Figure 12: Differences in the growth of imports and exports for Food and Live Animals



Source: Author's calculation based on UN Comtrade Database

These results indicate that hypothesis 1 can be confirmed in terms of imports of "Machinery and Transport Equipment", but when it comes to exports the same hypothesis should be rejected (Figure 13). The result is most likely due to successful mitigation strategies at the beginning of the pandemic, which provided for a reopening of supply chains before other countries. At the same time, the production focus of these countries was on those products for which trade was significantly more resilient and there was growth in global demand due to lockdown measures.

Figure 13: Differences in the growth of imports and exports for Machinery and Transport Equipment



Source: Author's calculation based on UN Comtrade Database

The cluster analysis shows a high degree of stability over the years regarding the inclusion of countries in different clusters, both for "Food and Live Animals" and "Machinery and Transport Equipment". In other words, despite some minor repositioning of countries within the clusters, they predominantly remain in the same cluster to which they previously belonged. All this will confirm and validate the hypothesis of cluster stability, that is, countries tend to maintain similar trade patterns over the reference period used in the article - the time frame before the outbreak of the pandemic, during the coronavirus disease to the time when many countries lifted the measures. These findings could indicate that, despite the challenges of the pandemic, the network restructuring (reshoring or nearshoring) aimed at resilience was less pronounced than initially expected. The coronavirus crisis has certain particularities that may hinder historical comparisons, but previous crises may still provide insights into the potential consequences for global value chains this time around. The noticeable reference point is the global financial crisis which is closest to the latest crisis in terms of the magnitude of the economic consequences, especially when it comes to supply chain disruptions. Similar to our findings, the experiences from the global financial crisis also indicate that the Covid-19 crisis may not lead to a major restructuring of global value chains (Antras, 2020; Miroudot, 2020). At least at the aggregate level, there is no clear trend for greater geographic diversification or concentration across value chains in various industries after the global financial crisis. The trade downfall was mainly the result of a substantial decrease in demand. Although the current crisis has also been combined with a supply shock, the results indicate that the main attack has again come from the sharp decline in demand. In fact, supply chain problems have affected production processes across sectors, but most global value chains seem to have been pretty resilient. The short-term emergency restructuring would likely occur due to political pressures or concrete policy incentives to

prioritize supply chains for critical goods and strategic growth industries. In the absence of policy interventions, most companies are likely to focus on improving supply chain risk management practices that do not encompass the reconfiguration of production networks. In other words, the restructuring of global value chains, especially reshoring, is generally not considered an optimal strategy. For instance, OECD (2020) simulations indicate that a more localized regime, where economies are less interconnected via global value chains, would add further GDP losses to the economic downturn induced by the pandemic and such a regime is also more susceptible to shocks than the type of global production network currently in place. Bonadio et al. (2020) also advocate that, without global value chains at their current scale, the negative impact of the latest crisis on employment and production could have been even more oppressive for certain countries. More importantly, the long-term considerations of increased resilience will become part of a wider transformation process launched even before the pandemic and will mainly be in line with trends induced by technological changes (digitalization, automation, and robotization) (Angeleski and Kostoska, 2022; Angeleski and Kostoska, 2023), increased regionalization and protectionism, as well as the requirements for meeting sustainable development goals (Kostoska and Kocarev,, 2019). These trends do not inevitably involve substantial changes in existing global production networks, but instead affect the design of the future global value chains. In fact, deep transformation of the complex global value chains could be quite difficult as the network structures involve many fixed linkages. But then again, it is also important to note that the main proponents of the global dispersion of production seem to have faded considerably and the coronavirus disease has further fueled such trends. In a nutshell, although the development of global value chains will come to a halt in the future, the complexity and high restructuring costs of the global production networks are likely to prevent any large-scale cessation of existing GVCs.

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