October 27, 2023

1. INTRODUCTION

TERRA - imporT ExpoRt netwoRk Analysis - is a tool built to enable exploratory analysis of open data from Eurostat sources on international trade through dynamic and interactive tools. The system enables exploration of phenomena related to the dynamics of global value chains (GVCs). The advantage of this new economic organization is well known, firms gain economic benefits through foreign direct investment or by outsourcing production, relocating some production stages to countries where high specialization or an advantageous labor market create more opportunities. However, the GVC structure has proven to be highly susceptible to shock transmissions and supply chain disruptions associated with geo-political events or epidemiological crises as in the case of Covid-19. In this context, through Graph Analysis, TERRA offers researchers and policy makers the opportunity to explore the dynamics of trade flows, with the possibility of focus on specific products and transport modes, tracing the critical phases of recent years. It also makes it possible to simulate flow disruptions or closures of specific logistics hubs or transport routes, giving a way to outline possible scenarios of modification or relocation of global chains capable of mitigating the risk of transmission shocks (changes in bilateral relations between countries, logistics or transport investments, increased foreign investment, etc.).

TERRA features graphic sections that illustrate the evolution of trade flows not only in trade volumes, but also in terms of the composition of the basket of traded goods.

1.1 EUROPEAN BIG DATA HACKATHON

The European Big Data Hackathon is an international competition (hackathon) organized by Eurostat as part of the *New Techniques and Technologies for Official Statistics* (NTTS) conference. Teams of experts (data scientists, researchers, methodologists, domain experts) from different European statistical institutes participate in the competition with the aim of creating innovative products that integrate traditional data sources and Big Data sources.

As part of the competition, teams must produce a product that responds to a *policy question* related to a pressing issue in the European context (e.g., COVID-19) and/or a statistical problem (integration of Big Data sources, use of new data collection tools, increasing the quality of outputs of certain production processes, etc.).

The Team that represented Istat created an open-source interactive dashboard (Cosmopolitics later modified and renamed TERRA) using modern javascript frameworks for the client component and a micro-services architecture for the server component.

TERRA provides a set of features to analyze international trade relations at both macro and micro levels. At the macro level by using *social network analysis* techniques (implemented in Python) we studied the impact of shocks in the means of transportation and the effects of disruptions in trade relations between countries. At the micro level by analyzing Google mobility data, we provided an indicator (implemented in R) representing the restriction imposed by the COVID-19 pandemic. This mobility analysis is not present in the current version of the dashboard.

2. DATASETS AND PREPROCESSING

This section explains the datasets and their classifications used by TERRA, and briefly describes the automatic process of downloading and processing monthly and annual COMEXT data.

2.1 DATASET

TERRA processes statistical domain data on international trade in goods (ITGS) produced by Member Countries and made available in Eurostat's COMEXT database accessible at:

http://epp.eurostat.ec.europa.eu/newxtweb/

COMEXT's *bulk download* feature allows users to massively download data in *.dat* format so that they can be easily imported for further analysis in tools such as, for example, R, SAS, or Python. The datasets contain metadata (classifications, data availability information.) and methodological notes.

COMEXT data are organized in different folders, TERRA is fed from the folders:

1) **PRODUCTS:** containing data on EU countries' monthly and annual trade interchange with each partner country in value (euro) and quantity (kg and any additional units) for products classified according to Combined Nomenclature, SITC, CPA (2002, 2008 and 2.1).
2) **TRANSPORT_NSTR:** containing data on monthly trade interchange of EU countries with non-EU partner countries in value (euro) and quantity (kg) by means of transport. Products are detailed according to NSTR classification.

Monthly frequency data and annual data are made available in each folder of the *bulk download* section, with the same characteristics in terms of variables and classifications.

2.2 AUTOMATIC DATA PROCESSING

The system is fed from foreign trade data from Eurostat sources, available as open data in the bulk download section of Eurostat, by accessing monthly at the link:

https://ec.europa.eu/eurostat/estat-navtree-portlet-prod/BulkDownloadListing?sort=1&dir=comext

At each monthly access, around the 21st of the month, the database used by TERRA is updated with the most recent data available (covering the previous 3 months) and fully updated for the previous reference periods, which are subject to revisions with non-harmonized frequency among different Member Countries. Data consolidation is generally conducted 10 months after the end of the year, as per Eurostat recommendation.

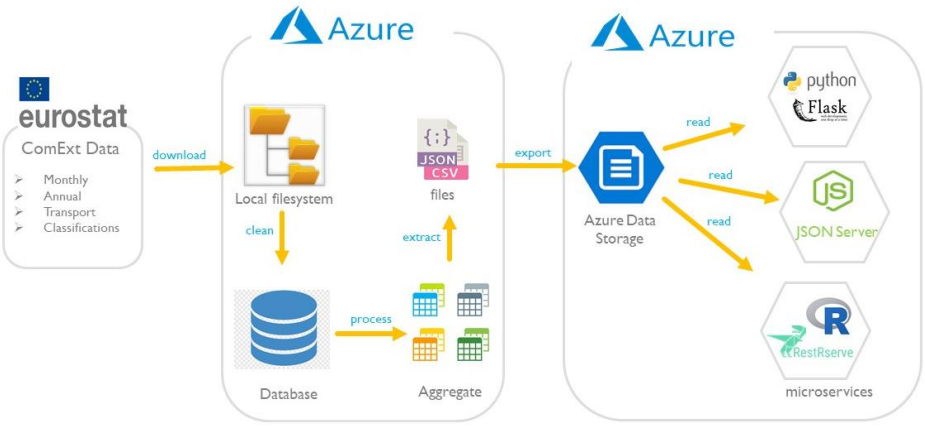


Figure 1: TERRA data processing workflow

The data are pre-processed to produce the time-series and statistical indicators needed to feed the different sections of TERRA.

Figure 1 models schematically:

i) the process of downloading data from Eurostat portal

ii) the process of data integration and aggregation.

Automatic datasets download process.

The first process is implemented through a *batch* script, which is started automatically once a month. This process performs the complete download of data, metadata and classifications, which are necessary to feed the various sections of TERRA, in total about eighty gigabytes of data are downloaded.

Specifically, 136 monthly *products* files are downloaded, for reconstructing the last 10 years of the historical series and for the basket of products; the last two useful files, annual *products*, for annual reports; the last three years, i.e., 36 monthly *transport_nstr files*, for the graph sections; the relevant files for product classifications. Finally, the process accesses various sections of the Eurostat portal to retrieve annual data on *Population*, *Unemployment* and *Industrial production* to construct the macro-economic indicators shown on the interactive map page.

Automatic dataset integration and aggregation process

Files downloaded from the *bulk download* section of Eurostat are compressed, consequently a preliminary decompression step is required. For this purpose, the data are preliminarily saved on a file system and, subsequently, extracted in their original format. These operations are performed in the Azure cloud environment (central panel in Figure 1)

After an initial cleaning phase, variables useful for subsequent processing are stored in a relational database. Processing and aggregation operations are performed in the database (*Aggregate* section, central panel Figure 1). To automate this process, a script has been implemented that automatically generates the data processing and aggregation queries. The script receives as input a set of environment variables, which specify a set of information, such as, date of the last dataset to be extracted, reference period of the time series, etc. The last step in the process is to extract the production data in *json* and *csv* formats.

2.3 ARCHITECTURAL ELEMENTS

The Figure 1 schematizes the main components of TERRA's *cloud* architecture. The main elements of the server components are illustrated below:

Pre-processing component:

the functional aspects of this component were described in the previous section. Architecturally, the script responsible for downloading data, creating relational tables, and cleaning and extracting data is implemented in Python and uses a *cloud* component (Azure Batch) optimized for performing batch operations on large amounts of data. The data, initially saved on a temporary file system, is imported into a performant and scalable relational database, which is activated (once a month) when queried by the script. At the end of the monthly batch operations, the database shuts down, waiting to perform the next processing.

Data storage component and micro-services:

the files produced in the previous step, are exported to the shared storage service, *Azure Data Storage*. This shared space is accessed by the three micro-services, *Json-Server*, *R-Server* and *Python-Server*, which provide data to the TERRA web component (right panel Figure 1). Each micro-service is responsible for one functional aspect of TERRA, more specifically:

- *Json-Server*: contains structural metadata (reference period, last data processing date, classifications, etc.).
- *R-Server*: exposes micro-services, implemented in R, that allow calculation of 10-year time series, on foreign trade data
- *Python-Server*: exposes micro-services, implemented in Python, to perform Graph Analysis and scenario analysis on COMEXT foreign trade data.

3. FEATURES OFFERED BY TERRA

The source code of the application is *open-source* and is available in the following github repository:

https://github.com/istat-methodology/terra

The repository is structured into folders, each folder containing source codes related to a specific component of the application:

- **terra-frontend**: this folder contains the web application code, implemented using the open-source frameworks Vue.js (https://vuejs.org/)
- **terra-backend**: this folder contains the code for the server component, implemented in Python and R. Specifically, the *Graph Analysis* functions (described in section 3.3) are implemented in Python, while the functionality offered by the time series section (described in section 3.4), is implemented in R.
- **terra-datafactory**: this folder contains the script responsible for automatic data loading and processing.

The following sections describe in detail the features made available by TERRA.

3.1 APPLICATION LANDING PAGE

The application can be accessed at the following web address:

https://www.terra.istat.it/

TERRA does not require authentication and offers a set of features for analyzing and visualizing Comext data. In Figure 2 the application's landing page is shown.

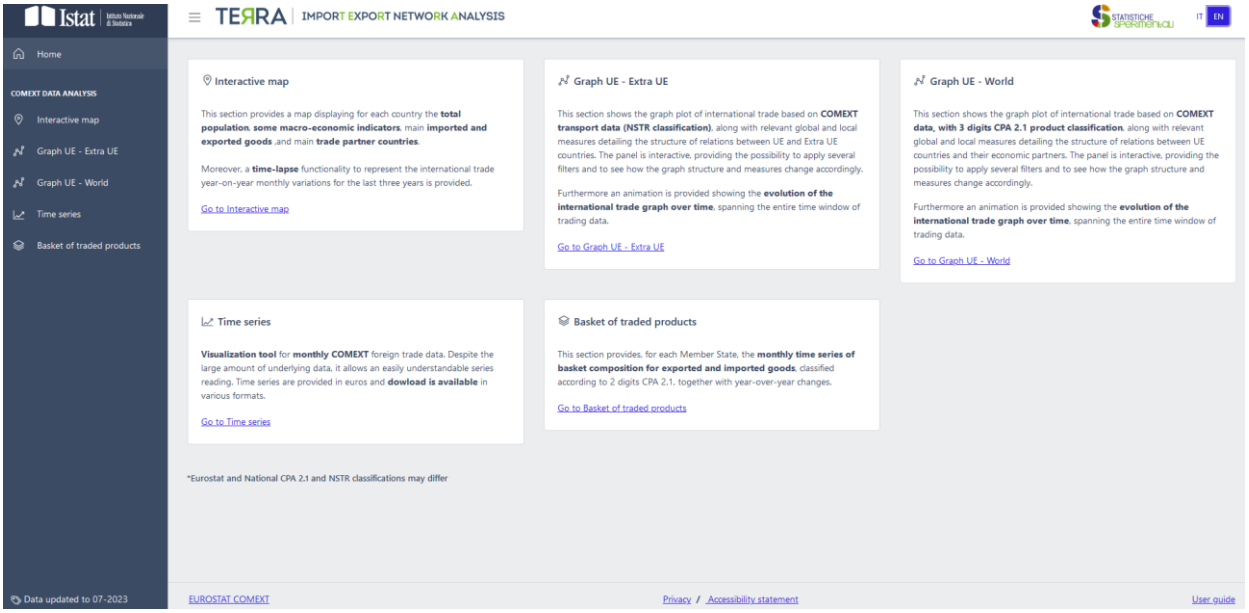


Figure 2: TERRA landing page

The landing page is structured as follows:

- **Header:** In this section you can change the language of TERRA (by clicking the button at the top right IT EN). Currently the application allows the textual content to be displayed in Italian and English. On the left side there is a button (☰) that allows you to hide the side navigation bar (recommended choice on small monitors). The header shows the most recent dataset downloaded from the Comext portal.
- **Side navigation bar:** in this section of the application you can find links to the different features made available to the user (the detailed list is given below). The *Home* link allows you to return to the login page of the application. Below is the date of the most recent dataset downloaded from the Comext portal.
- **Central section:** this section contains five cards, each presenting a brief description of the features offered by TERRA and the link to the feature itself.
- **Footer**: this section contains the link to Eurostat COMEXT data, the link to the Privacy and accessibility statements. Further the footer contains a link to the user manual.

The features offered by TERRA are as follows:

- **Interactive map**: This section provides a map showing for each country the total population, some macroeconomic indicators, major imported and exported products, and major trading partner countries. In addition, a time-lapse feature is provided to depict monthly trend changes in international trade for the past three years.
- **Graph EU - Extra EU**: This section displays graphs representing international trade by product (NSTR classification, see annex Classifications) and mode of transport from COMEXT source, along with relevant global and local measures detailing the structure of trade relations between EU and Extra-EU countries. The panel is interactive and provides the ability to apply various filters and see how the graph structure and measures change accordingly. In addition, an animation is provided showing the evolution of the international trade graph over time.
- **Graph EU - World**: This section displays graphs representing international trade by product (CPA 2.1 classification, see Annex Classifications) from COMEXT source, along with relevant global and local measures detailing the structure of trade relations recorded by EU countries to/from each trading partner country. The panel is interactive and provides the ability to apply various filters and see how the chart structure and measures change accordingly. In addition, an animation is provided showing the evolution of the international trade graph over time.
- **Time Series**: A visualization tool for COMEXT monthly foreign trade data series. This section allows for easy and understandable reading despite the volume of underlying data. Useful as an outreach tool. Series are provided in value and quantity and download is available in various formats.

- **Basket of traded products**: This section provides, for each Member State, monthly time series of trend changes in the composition of the basket of exported and imported goods, classified according to the divisions of the CPA 2.1 classification.

3.2 INTERACTIVE MAP

The interactive map is one of the components of TERRA that allows visualization of "Economic and International Trade Indicators" of EU countries.

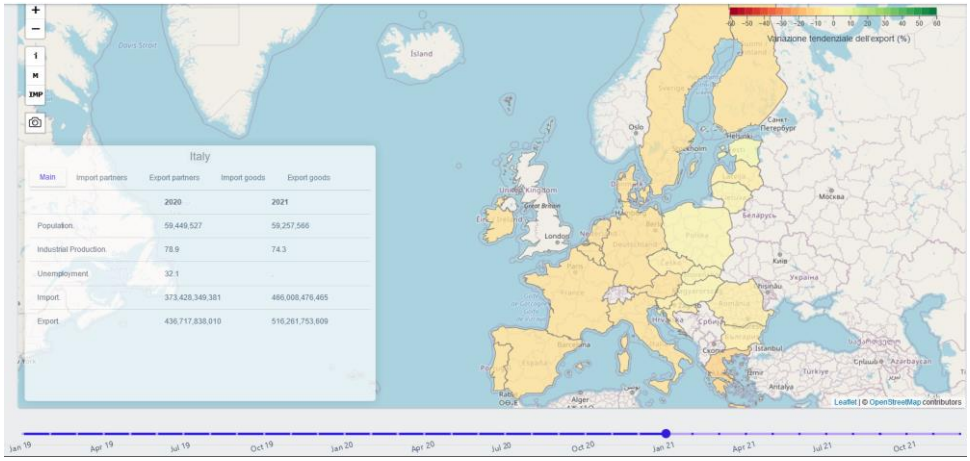


Figure 3: Interactive map

The map allows you to view trend changes, on a 2019 basis, in import and export for each EU country. By default, the application shows export data, you can view import data by clicking the IMP button, located at the top left of the map.

The visualization of countries in the geographic map has a twofold mode of representation: one through "Circular Markers," positioned according to the coordinates that identify that given country (Fig.3a), and the other through the application of a layer of "Features geojson," which highlight the contours of the geographic boundaries of each individual country (Fig.3b).

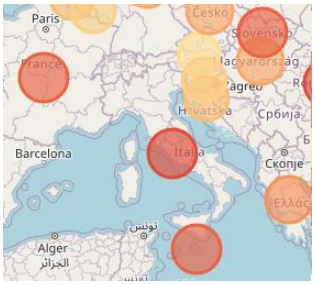


Figure 3a: Marker



Figure 3b: Features

For each country also, "moving the mouse" over the different circular markers or features activates a popup that displays the trend change in export or import based on the selected data (Fig.3c). Depending on the value of a given country, a color is assigned to the respective markers or features according to the positive/negative color/value scale. This scale is shown in the legend in the upper right corner present in the map (Fig.3d).



Figure 4c: Popup

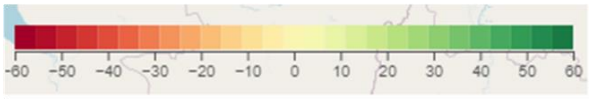


Figure 5d: Legend

Also, for each country, another feature of the interactive component is that of displaying a box on the lower left side of the map itself of data on total population and a set of macroeconomic indicators such as major imported and exported products and major trading partner countries (Fig. 3e).



Figure 3e: Macroeconomic indicators

In addition, a time-lapse feature is available in TERRA's map, using a slider, to display monthly trend changes in international trade over a given time period (Fig.3f).



Figure 3f: Time-lapse

Finally, there are a series of buttons (Fig.3g):

- The zoom of the map (**+/-**)
- The display of a help that quickly illustrates information about the interactive map and data(**s**)
- The selection of the type of display you want to activate (**F** = features, **M** = Marker)
- The data you want to view (IMP = import, **EXP=** export)
- The export of the map displayed as a graphic file



Figure 3g

3.3 FOREIGN TRADE ANALYSIS THROUGH GRAPH ANALYSIS TECHNIQUES

There are two panels in the application dedicated to the results of *Graph Analysis* applied to trade relations between nations: the “Graph EU - Extra EU” panel and the "Graph EU - World" panel.

Both panels show business relationship graphs with associated centrality measures describing the relationship structure, offering the user the opportunity to highlight various parameters of interest.

The difference between the two sections, which are similar, lies in the dataset used:

- In the **"Graph EU - Extra EU"** section, international trade data by product and mode of transport from COMEXT source are used, limited to trade occurring between EU and non-EU countries (*trade between EU countries and non-EU countries are excluded*)
- **"Graph EU - World"** section uses international trade data by product from COMEXT source for trade between all countries (*trade between non-EU countries is excluded*).

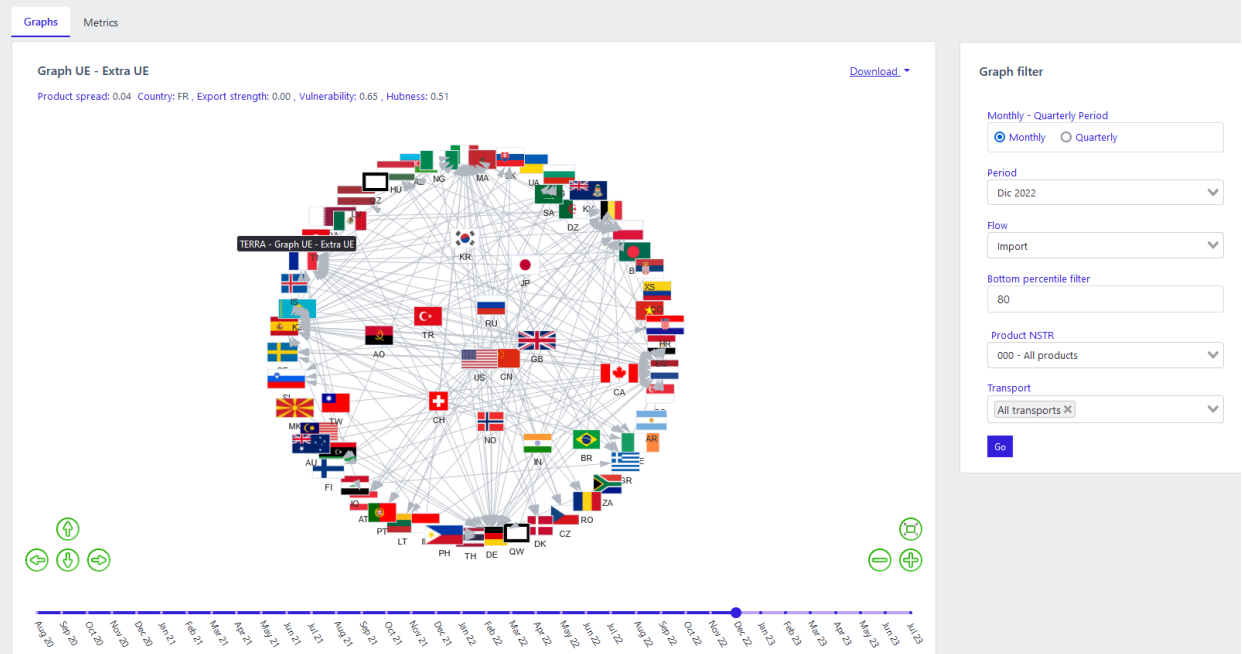


Figure 6: Graph visualization

The structure of the two sections is shown below.

Graph Analysis

The section has a central window in which the graph is displayed (Fig.4) and a side menu to the right with filters that allow selection of data analysis parameters. The nodes of the graph are represented by the flag icons of the indicated countries while the arcs are displayed through arrows that connect the countries to each other and represent traded goods. The relative positions of the countries within the graph are defined through the "*Spring layout*" algorithm, implemented in the Networkx python library (see section *Methodology for Graph Construction*)

Above the graph appear the centrality measures calculated for the graph itself, while the sliding bar at the bottom indicates the reference time-period. Through the sliding bar, it is possible to study the evolution of the graph over time and detect changes in the structure of trade relations.



Figure 5: Arrows and buttons for navigating the graph

The green arrows in Fig.5 allow you to move the view relative to the graph, while the icons allow you to zoom or center the graph in the window. For proper visualization, after selecting parameters and running the analysis with the "Run" button, it is important to always click on the icon to center the graph in the window.

To the right of the panel name above the graph, the "Download" button appears, which allows you to export the obtained graph and its centrality measures. The calculated measures are derived from the standard *Graph Analysis* centrality measures and are:

- **Diffusion of goods**: *density of* the graph. It represents how widespread the commodity is within the network of relationships represented by the graph; specifically, it equals 1 when all countries are connected to each other.
- **Export strength**: is *outdegree centrality* for each country.
- **Vulnerability*:*** is calculated as (1 - *indegree centrality*) for each country. Vulnerability reflects the fact that a country that receives a product from several distinct supplier countries is less dependent on a single country for the supply of that product.
- **Hubness**: is *closeness centrality* for each country.

In the side section, through drop-down menus, the user can instantiate the analysis parameters. The window is called "Search Filters," and based on the values chosen for the filters, the graph is created and the respective centrality measures are calculated.

Below is a description of the filters in the section:

- **Monthly-Three Monthly Period:** selects the relevant time window, monthly or quarterly.
- **Reference period:** selects the reference time period to which the data represented by the graph refer (a specific month/year or quarter/year).
- **Flow:** select "import" or "export," which means whether the data are taken from the database of declared imports or declared exports from EU countries.
- **Bottom Percentile Filter:** with respect to a selected network of trades among countries relating to the filters set by the user (Period, Flow, Product and Means of Transport), the "Bottom Percentile Filter" allows to remove a certain percentage of minor exchanges (in terms of Euros) from the visualization. With respect to the series of data sorted in ascending order, this filter (an integer value between 0 and 100) represents the trades below a chosen percentile which are removed from the graph. By selecting 10, the 10% of the minor trades are removed from the graph and the 90% of the major trades are displayed. Selecting 0 the dashboard displays all exchanges.
- **Products NSTR/CPA 2.1 - 3 digits:** selects data against the traded product, the user can select a single product, or all products considered together. In the "Graph EU - Extra EU"

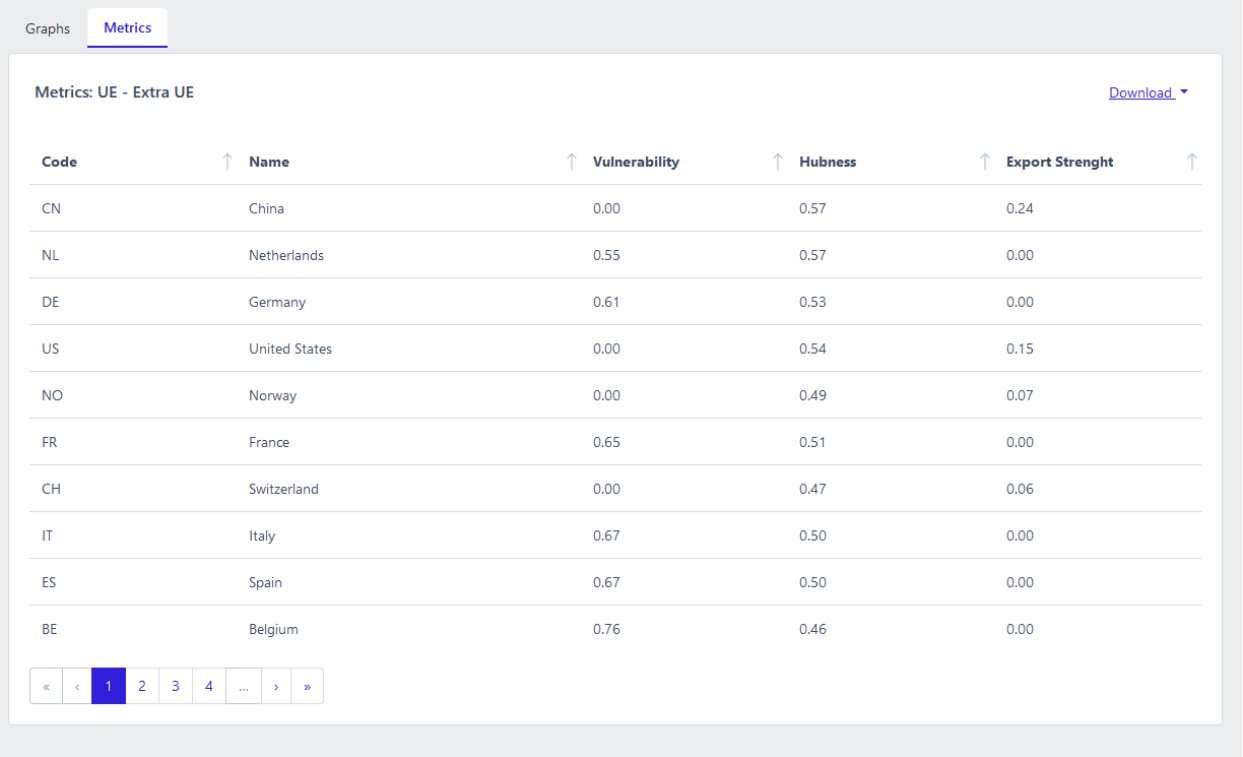
panel, products are listed according to the "NSTR" classification, and in the "Graphs EU - World" panel according to the "CPA 2.1 - 3 digits" classification.

- **Means of transport*:*** selects data with respect to the means of transport used in the exchange. Means of transport are "unknown," "sea transport," "rail transport," "road transport," "air transport," "postal consignments," "fixed transport facilities," "water transport," "own propulsion" (this filter is available only in the "EU - Extra EU graphs" panel).

In all graphs displayed in the application, regardless of the option you select for the "Flow" parameter, the country from which the arrow starts (country of origin) is always the country that exports the good, while the country to which the arrow points (country of destination) is always the country that imports the good.

Metrics panel

This panel shows, in tabular form, the graph metrics for each country: "Vulnerability," "Hubness," and "Export Strength" (Fig.6). The user can sort the results by clicking on the arrows next to the column names. In addition, results can be filtered by code and country name.



Code	Name	Vulnerability	Hubness	Export Strenght
CN	China	0.00	0.57	0.24
NL	Netherlands	0.55	0.57	0.00
DE	Germany	0.61	0.53	0.00
US	United States	0.00	0.54	0.15
NO	Norway	0.00	0.49	0.07
FR	France	0.65	0.51	0.00
CH	Switzerland	0.00	0.47	0.06
IT	Italy	0.67	0.50	0.00
ES	Spain	0.67	0.50	0.00
BE	Belgium	0.76	0.46	0.00

Figure 6: Graph metrics panel.

Scenario analysis

One of the features provided by the application, in relation to *Graph Analysis* is the ability to do scenario analysis by visualizing the changes that the disruption of one or more trade relationships between countries brings to the structure of the international trade network.

Scenario analysis can be performed in two ways: by acting on all trade in a given country or by acting only on a specific trade (link/arrow) between two countries. In the first case, the functionality is accessed by clicking on the icon of a specific country in the graph; in the second case, the functionality is accessed by clicking on a specific arrow linking two countries. All scenario analyses modify the graph generated from the search filters. In the following we will see in detail how to use this functionality.

Scenario analysis - world

In the "Graph Analysis EU - World" panel, clicking on the icon of a country in the graph opens a screen that shows the detail information, that is, information about all the trade affecting the selected country. Specifically, a list is displayed describing the characteristics of each arrow departing from or arriving at the selected country: the country of origin of the exchange ("Origin"), the country of destination of the exchange ("Destination"), the value in Euros of the exchange between the country of Origin and Destination ("Value in Euros"), the weight in percentage of the exchange compared to the total incoming or outgoing exchanges affecting the selected country ("Percentage"), and the direction of the exchange with respect to the selected country, ("Flow"), i.e., whether it is outgoing, "Export," or incoming, "Import." The list can be exported in csv format by clicking Download at the top head of the screen.

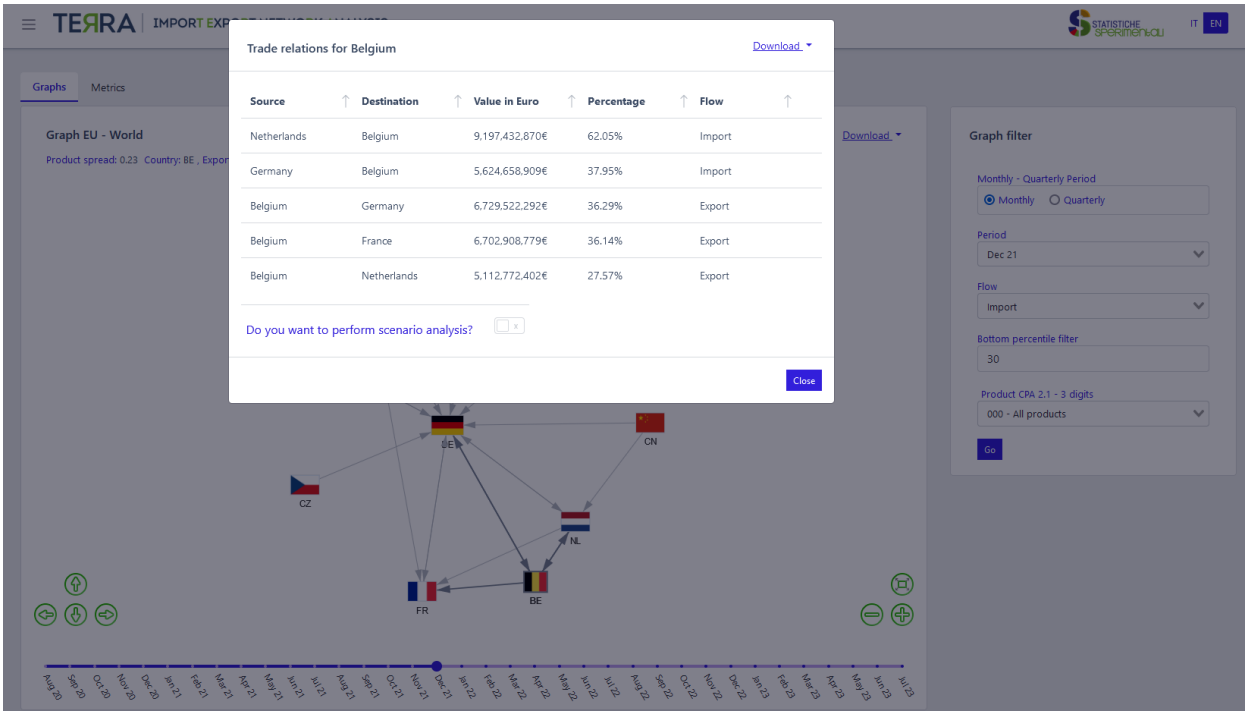


Figure 7: Scenario analysis, detailed information panel

Scenario analysis is activated by clicking on the switch labeled, "do you want to perform scenario analysis?" After activating the switch, new scenarios can be created in which unidirectional exchanges between countries are discontinued. To delete an exchange from an origin country to a destination country, one simply clicks on the cross that appears at the end of each row and clicks on "Update Graph." The graph for the new scenario is recalculated again by editing the graph generated by the search filters, in the new scenario the metrics and detail information are then recalculated.

Instead, by clicking on a specific arrow in the graph, a "business relations" screen appears with the detail information containing only the row for the selected arrow and direction.

Again, scenario analysis can be done by activating the switch labeled "do you want to delete this flow?" and clicking on update graph. Again, the graph for the new scenario is recalculated again by editing the graph generated by the search filters; in the new scenario, the metrics and detail information are then recalculated.

Scenario analysis - extra

As described above, for the "Graph Analysis EU - Non-EU" panel, the scenario analysis functionality can also be accessed by clicking on the icon of a specific country in the graph or on a specific arrow. In this case, however, checking the switch next to "Do you want to change the means of transport in this country's exchanges?" will take you to a new section of the window that allows you to change the means of transport participating in the exchange. The left pane "Current graph" lists the means of transportation that were requested in the search filter. The new analysis is built through *drag and drop* functionality by moving the transportation means that you want to consider in the new scenario to the right window named "New Scenario." The means of transportation in the new scenario are applied to all the trades in the origin and destination countries that appear in the window. The graph for the new scenario is then constructed again by editing the graph generated by the search filters, and the metrics and detail information are then recalculated.

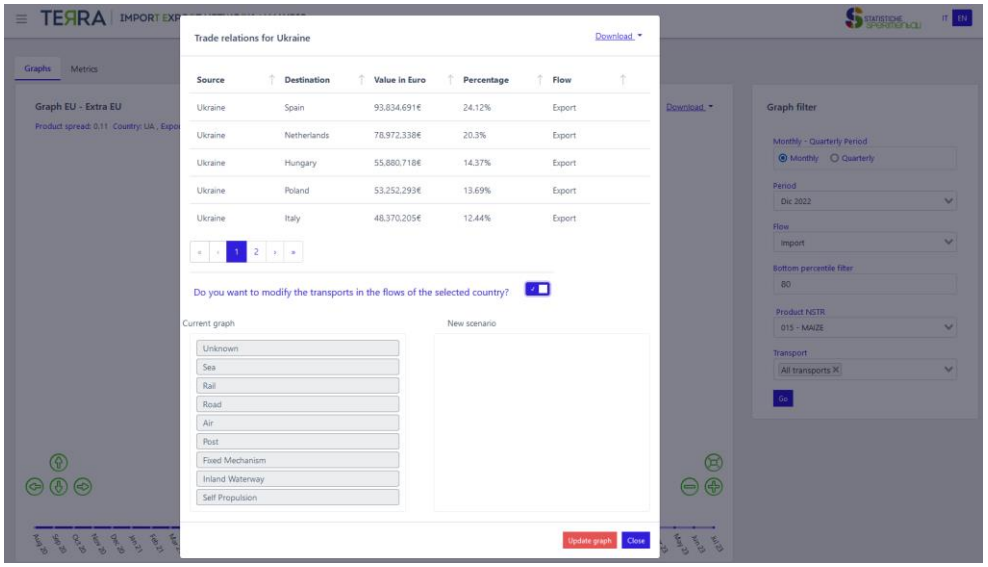


Figure 8: Scenario analysis for the Ukraine node.

We show an example below:

Let's look at the gas market by **third quarter of 2020**, for imports related to **"All means of transportation**." A scenario analysis that we can perform is proposed to show what would happen to the graph and related metrics if the exchange from Russia through sea transport and with oil pipelines was stopped. We consider 98% of the market. As a flow variable we choose *import*, in fact the exports of Russia in which we are interested, appear as imports in COMEX being a non-European country. As a metric we analyze the "Export Strength" of Russia: 0.41, this indicates the centrality and importance in the gas market of this country.

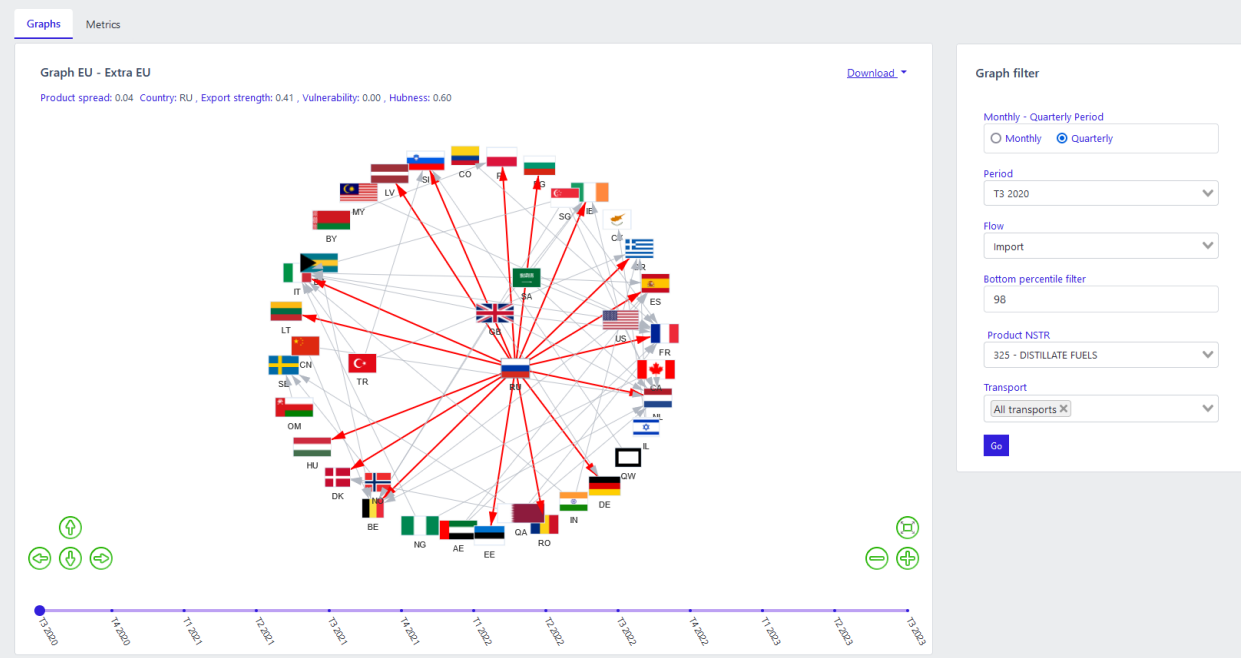


Figure 9: Scenario analysis: Russia with all means of transportation active

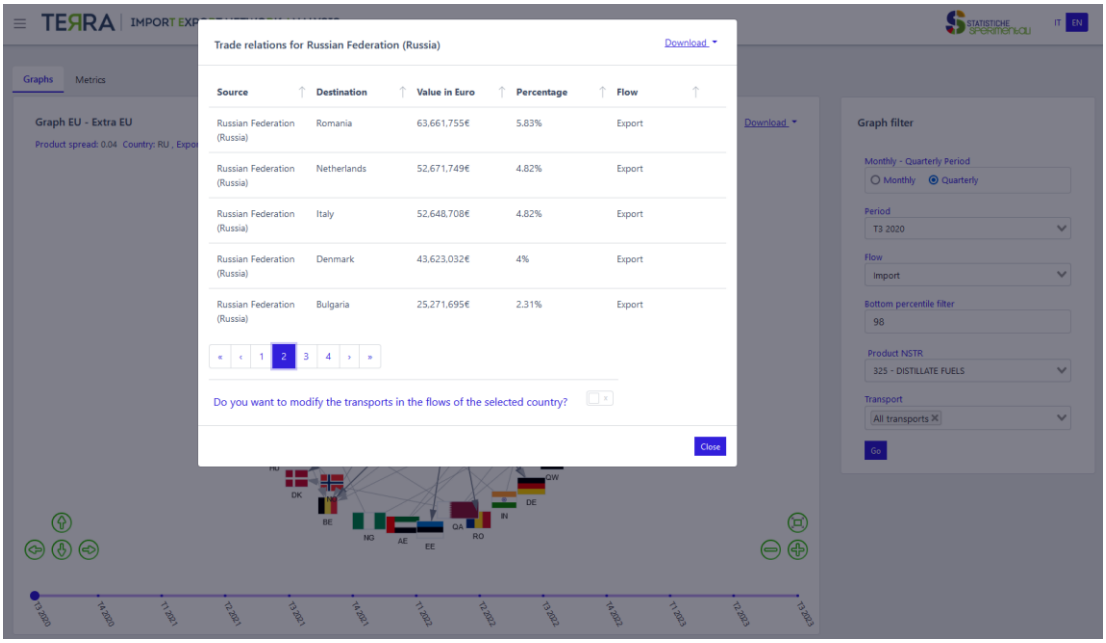


Figure 9: Scenario analysis, Russia detail panel.

As seen above, the scenario analysis related to transportation means can be accessed by clicking on a country (node). In the selected period we see that Russia exports 4.82% of gas to Italy. Let's consider the scenario in which Russia interrupts pipeline and maritime flows: after clicking on the switch, through the drag and drop functionality we move from the "Current graph" window to the "New scenario" window all transport media minus "Maritime transport" and "Fixed transport installations," then click on the red "Update graph" button.

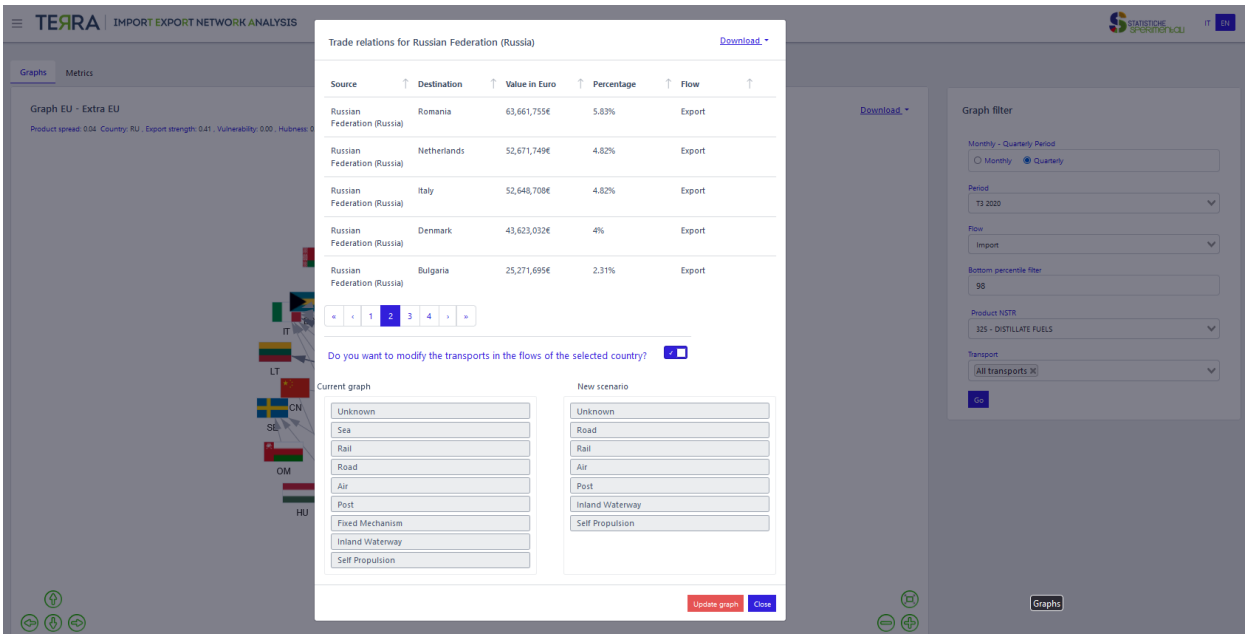


Figure 10: Scenario analysis-new scenario for transportation means.

Below will appear the new graph related only to gas trade for the new scenario. This involves a different reorganization of the graph structure with different measures of centrality, as can be seen in Fig.11, also it is interesting to note that the "Export Force" related to Russia decreases to 0.03, with the shift in the graph to peripheral position.

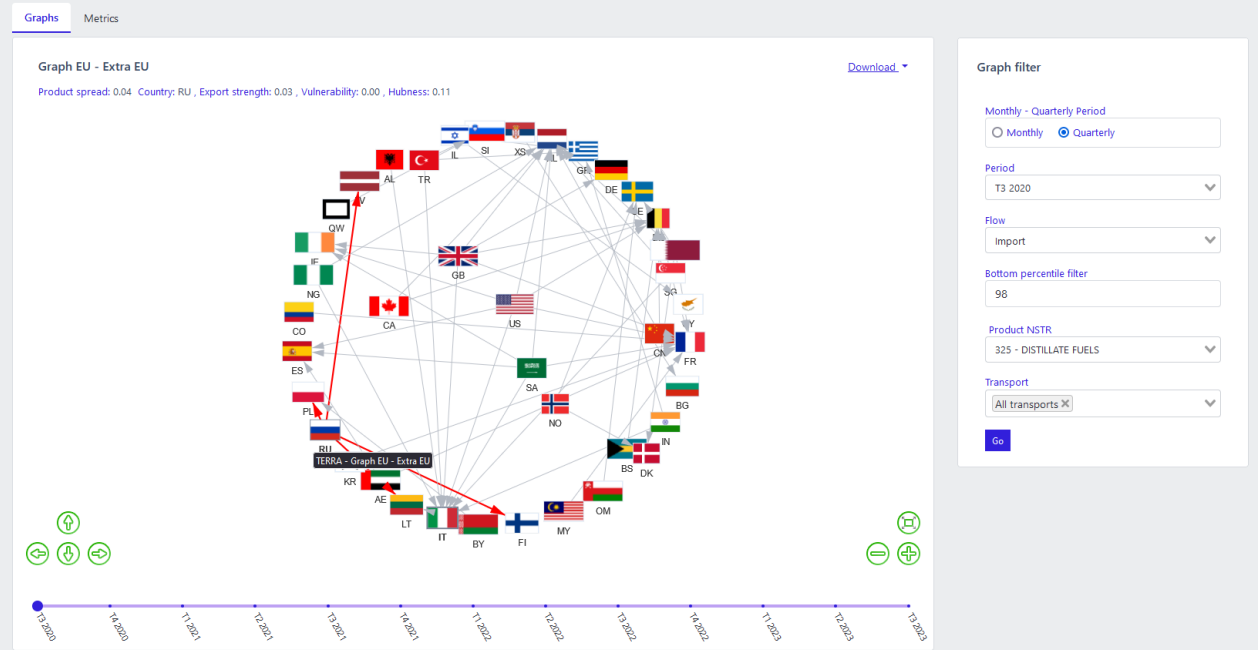


Figure 11: Scenario analysis, message for the user "Scenario analysis carried out successfully"

Methodology for graph construction

The Spring Layout or **Fruchterman-Reingold** algorithm is used to generate the relative position of nodes (countries) in the displayed graph. The position is obtained by using the following model as a representation of the system: the nodes, i.e., the countries, are represented as masses (all equal to each other) that repel each other; the arrows, i.e., the euro value of goods exchanged between the countries, are represented as springs that bind the countries together, with the greater the attractive force the greater the value exchanged. Based on this model, the algorithm then involves running a simulation from a causal distribution of countries in space. The simulation, which applies the model's attractive and repulsive forces to the initial configuration of countries, continues until an equilibrium state is reached, in which all forces are balanced. For reasons of graph readability, however, the configuration that is displayed in the application shows a solution that does not reach total convergence. For further technical details of the algorithm, see the documentation of the Networkx python library (https://networkx.org).

3.4 TIME SERIES

This section allows visualization of monthly COMEXT data from the PRODUCTS folder of the Eurostat bulk download. The data are updated monthly. As of the TERRA update date, which appears in the dashboard header, the most recent month displayed in this section represents the most up-to-date data available.

The user has a set of filters available to choose a single data set to display with a graph. The filters are as follows:

- **Type of series:** raw data series or trend change series (value at month t minus the value in the same month of the previous year).
- **Data type:** in value or quantity.
- **Flow:** Import or Export.
- Country**:** EU country.
- **Partner:** EU and non-EU country.
- **Products:** 2-digit CPA product classification (classification can be found in the Annex Classifications).

This section can returns the following graph:

- **Graph of user-selected data series** (Fig.12).

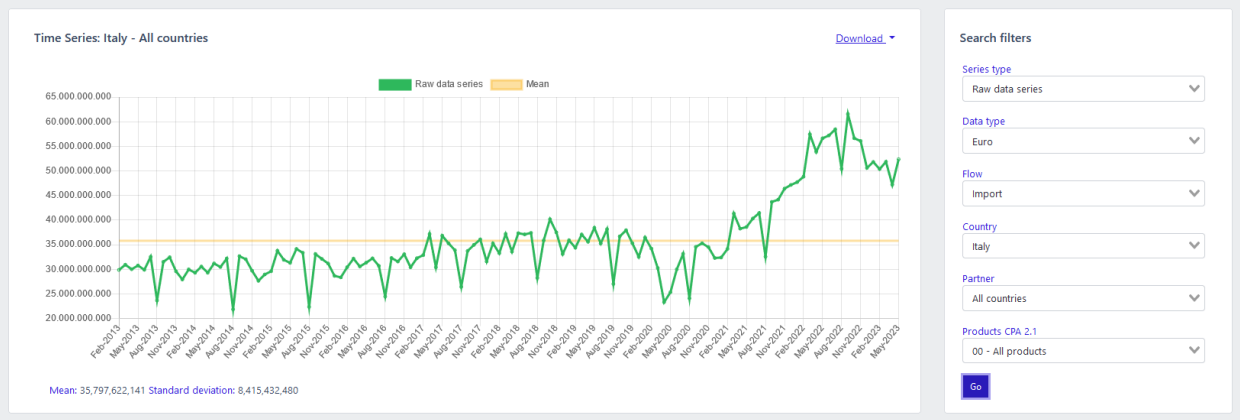


Figure 12: Series view

When the filters selected by the user do not meet any series in the Eurostat dataset, it means that there is no trade relationship between the selected countries for the product category and flow. In this case TERRA returns the following error message, "No data are available for the selected filters."

By clicking on the "Download" button it is possible to download the data series, graphs and related values with which they are constructed. Downloading is possible in *jpg, png, pdf, json, csv* formats. The first three export the graph image, the others allow downloading the data.

3.5 BASKET OF TRADED PRODUCTS

In the graphical section on the basket of traded products, trends in the monthly shares, in value or quantity, of imported and exported products defined according to the two-digit breakdown of the CPA 2.1 classification are displayed for each Member Country, together with their trend changes (Figs. 15 and 16).

The interest of the section lies in the possibility of monitoring which types of products are mainly in demand during periods of market imbalance associated with times of crisis and subsequent economic recovery.

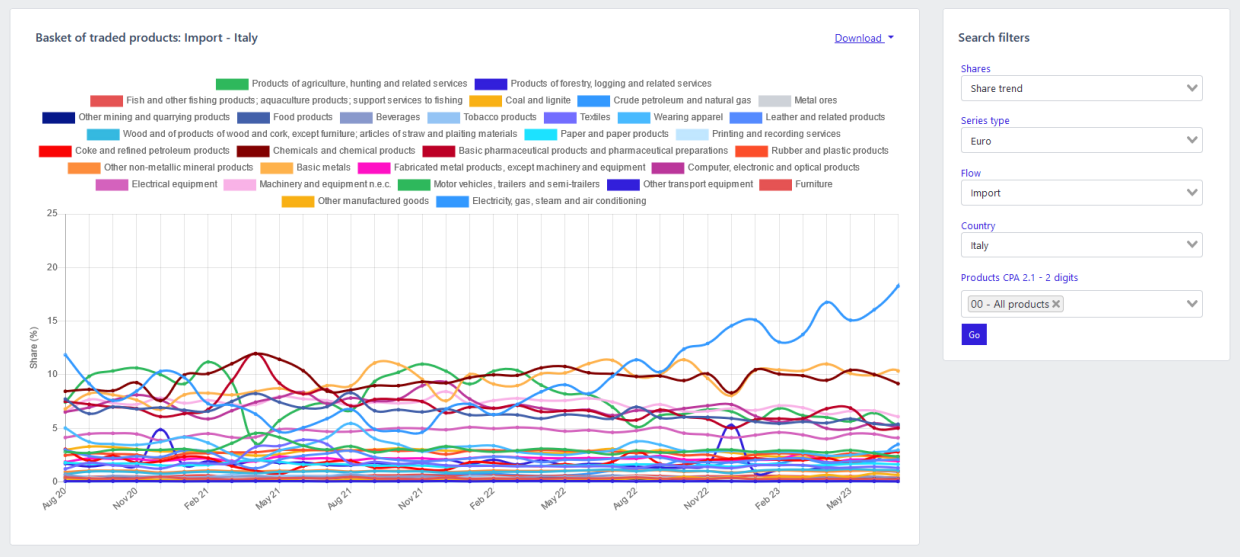


Figure 15: TERRA basket of products, shares of trade interchange by product

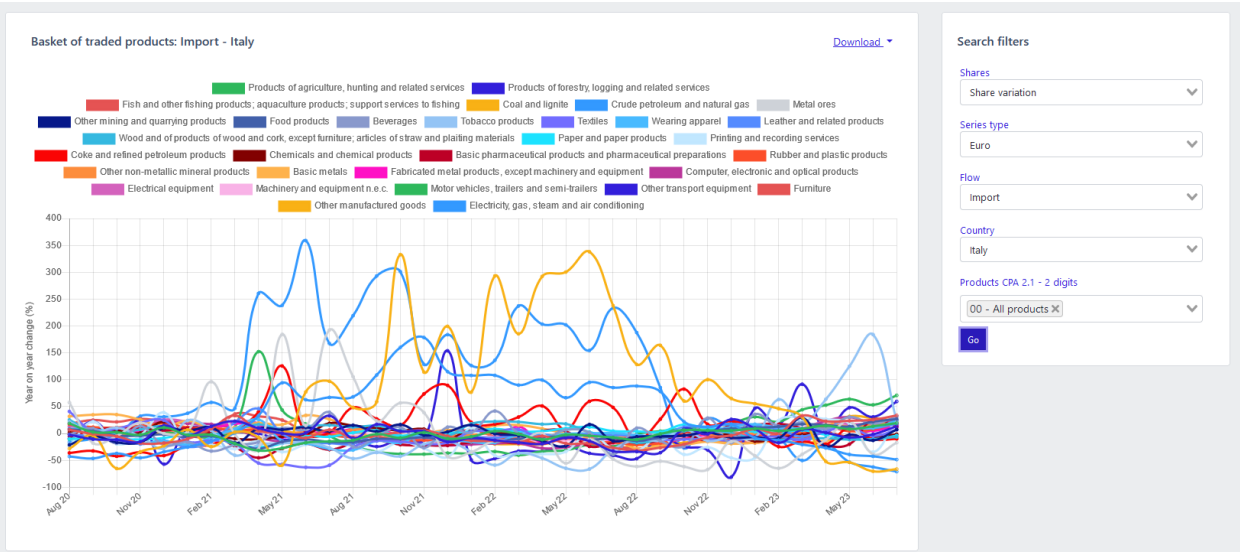


Figure 16: TERRA basket of products, trend changes in shares

In the panel there is a form on the right that allows the following fields to be selected:

- **Variation:** in value or quantity.
- Country**:** EU country.
- **Product:** the product of interest, according to the two-digit CPA 2.1 classification. The user can select a set of products or can select the "All products" product. In this case, the application will present all products in the graph.
- **Flow:** Import or Export.

In addition, the chart in the middle section of the page allows the user to deselect products of interest by clicking on the relevant labels shown at the top of the chart. The user can export the graph in different formats *jpg, png, pdf* by clicking the "Download" button. In addition, one can download the data shown in the graph in *csv* and *json* formats, again by pressing the " Download" button.

Fig.17 shows the graph where the user has deselected a set of products, identified by a line on the label.

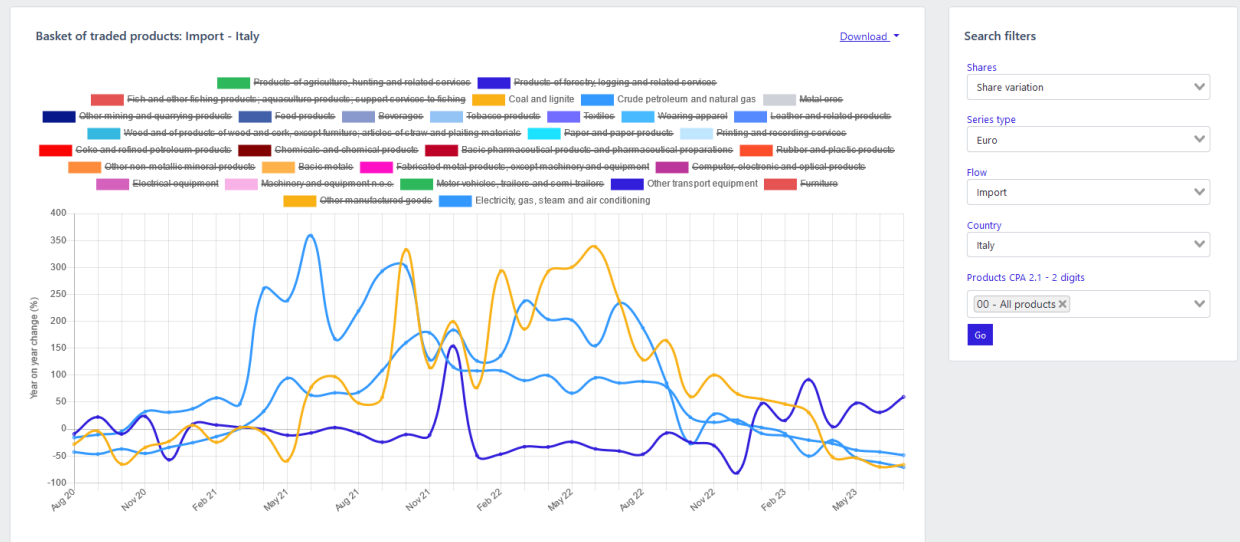


Figure 17: TERRA basket of products, trend changes in shares

The user can achieve a similar result by directly selecting a list of products to be represented in the "Products" select in the form (see the example in Fig.18).

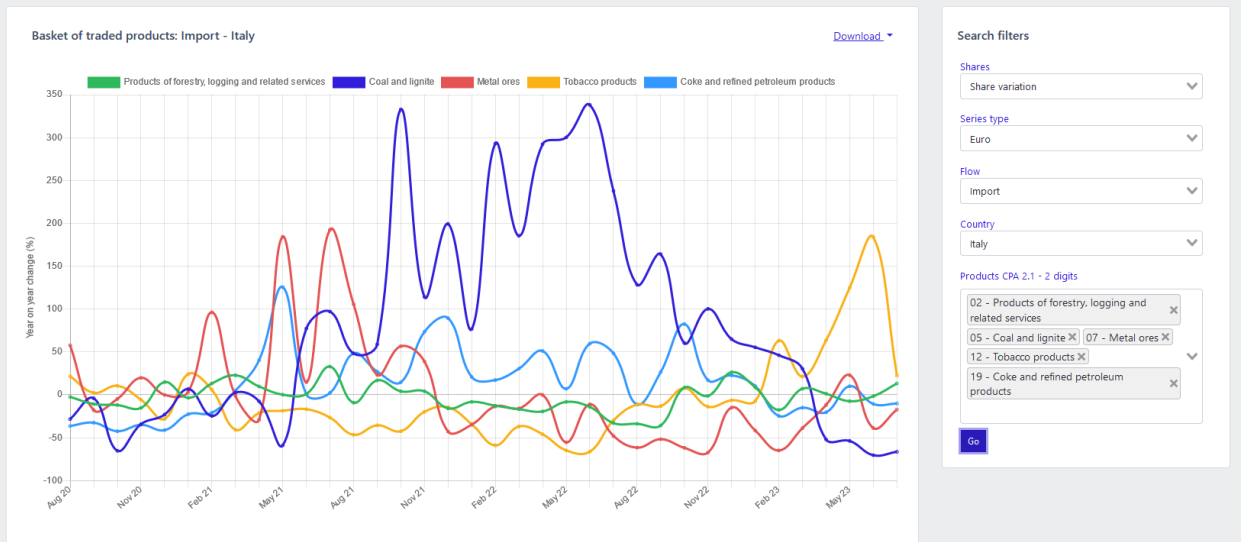


Figure 18: TERRA basket of products, trend changes in shares

The following collaborated in the production and analysis of the TERRA experimental statistics:

F. Amato, F. Brogi, M. Bruno, M.S. Causo, E. Cerasti, F. De Fausti, B. Guardabascio, P. Pizzo

BIBLIOGRAPHICAL REFERENCES

Lorenzo De Lauretis, 2019. *From Monolithic Architecture to Microservices Architecture2019*, IEEE International Symposium on Software Reliability Engineering Workshops (ISSREW), DOI: 10.1109/ISSREW.2019.00050

M. R. Mufid; A. Basofi; M. U. H. Al Rasyid; I. F. Rochimansyah; A. Rokhim, 2019. *Design an MVC Model using Python for Flask Framework Development,* 2019 International Electronics Symposium (IES)*,* DOI: 10.1109/ELECSYM.2019.8901656

N. Chen, 2004. *Intra-national versus international trade in the European Union: why do national borders matter?*, Journal of International Economics, Volume 63, Issue 1, May 2004, Pages 93-118.

Barlow P., van Schalkwyk MPH M.C., McKee DSc M., Labonté Rom, Stuckler D. 2021. *COVID-19 and the collapse of global trade: building an effective public health response*, The Lancet Planetary Health, Volume 5, 2, Pages 102-107

L. De Benedictis, S. Nenci, G. Santoni, L. Tajoli, C. Vicarelli, 2013. *Network Analysis of World Trade using the BACI-CEPII dataset*, CEPII Document de travail N 2013 - August 24.

OECD, 2021. *Global Value Chains: Efficiency and Risks in the Context of COVID-19*, OECD Tackling Coronavirus (COVID-19) Contributing to Global Effort, February 11, 2021. OECD Publishing, Global value chains: Efficiency and risks in the context of COVID-19 - OECD (oecd-ilibrary.org)

Lin B., Zhang Y. Y., 2020. *Impact of the COVID-19 pandemic on agricultural exports*, Journal of Integrative Agriculture, Volume 19, Issue 12, Pages 2937 - 2945.

M.R. Surugiu, C. Surugiu, 2015. *International Trade, Globalization and Economic Interdependence between European Countries: Implications for Businesses and Marketing Framework*, Procedia Economics and Finance, Volume 32, 2015, Pages 131-138

UNCTAD, 2020. Impact of the CO*VID-19 pandemic on trade and development: transitioning to a new normal*, United Nation (2020), ISBN: 978-92-1-113000-3. UNCTAD Publishing, Impact of the COVID-19 pandemic on trade and development: transitioning to a new normal | UNCTAD

4. ANNEX: CLASSIFICATIONS

TERRA uses the European classifications specific to the statistical domain on foreign trade in goods. The full system of European statistical classifications is available at the link

https://ec.europa.eu/eurostat/web/metadata/classifications

CPA Product Classification 2.1

CPA 2.1 (Classification of Products by Activity) is a classification of products (goods and services) adopted at the European Union (EU) level. The classification follows the criterion of the economic origin of products and for this reason is closely related to the European Classification of Economic Activities (NACE). In some cases, versions adopted at the national level by member countries may differ.

For the purposes of TERRA, the CPA classification has been limited to those codes most relevant to statistics on trade in goods, namely divisions '01' to '35'.

Cod	Description
01	Products of agriculture, hunting and related services
011	Non-perennial crops
012	Perennial crops
013	Planting material: live plants, bulbs, tubers and roots, cuttings and slips; mushroom spawn
014	Live animals and animal products
016	Agricultural and animal husbandry services (except veterinary services)
017	Hunting and trapping and related services
02	Products of forestry, logging and related services
021	Forest trees and nursery services
022	Wood in the rough
023	Wild growing non-wood products
024	Support services to forestry
03	Fish and other fishing products; aquaculture products; support services to fishing
05	Coal and lignite

Cod	Description
051	Hard coal
052	Lignite
06	Crude petroleum and natural gas
061	Crude petroleum
062	Natural gas, liquefied or in gaseous state
07	Metal ores
071	Iron ores
072	Non-ferrous metal ores
08	Other mining and quarrying products
081	Stone, sand and clay
089	Mining and quarrying products n.e.c.
09	Mining support services
091	Support services to petroleum and natural gas extraction
099	Support services to other mining and quarrying
10	Food products
101	Preserved meat and meat products
102	Processed and preserved fish, crustaceans and molluscs
103	Processed and preserved fruit and vegetables
104	Vegetable and animal oils and fats
105	Dairy products
106	Grain mill products, starches and starch products
107	Bakery and farinaceous products
108	Other food products
109	Prepared animal feeds

Cod	Description
11	Beverages
110	Beverages
12	Tobacco products
120	Tobacco products
13	Textiles
131	Textile yarn and thread
132	Woven textiles
133	Textile finishing services
139	Other textiles
14	Wearing apparel
141	Wearing apparel, except fur apparel
142	Articles of fur
143	Knitted and crocheted apparel
15	Leather and related products
151	Tanned and dressed leather; luggage, handbags, saddlery and harness; dressed and dyed fur
152	Footwear
16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
161	Wood, sawn and planed
162	Products of wood, cork, straw and plaiting materials
17	Paper and paper products
171	Pulp, paper and paperboard
172	Articles of paper and paperboard
18	Printing and reproduction services of recorded media

Cod	Description
181	Printing services and services related to printing
182	Reproduction services of recorded media
19	Coke and refined petroleum products
191	Coke oven products
192	Refined petroleum products
20	Chemicals and chemical products
201	Basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms
202	Pesticides and other agrochemical products
203	Paints, varnishes and similar coatings, printing ink and mastics
204	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
205	Other chemical products
206	Man-made fibers
21	Basic pharmaceutical products and pharmaceutical preparations
211	Basic pharmaceutical products
212	Pharmaceutical preparations
22	Rubber and plastic products
221	Rubber products
222	Plastic products
23	Other non-metallic mineral products
231	Glass and glass products
232	Refractory products
233	Clay building materials
234	Other porcelain and ceramic products

Cod	Description
235	Cement, lime and plaster
236	Articles of concrete, cement and plaster
237	Cut, shaped and finished stone
239	Other non-metallic mineral products
24	Basic metals
241	Basic iron and steel and ferro-alloys
242	Tubes, pipes, hollow profiles and related fittings, of steel
243	Other products of the first processing of steel
244	Basic precious and other non-ferrous metals
245	Casting services of metals
25	Fabricated metal products, except machinery and equipment
251	Structural metal products
252	Tanks, reservoirs and containers of metal
253	Steam generators, except central heating hot water boilers
254	Weapons and ammunition
255	Forging, pressing, stamping and roll-forming services of metal; powder metallurgy
256	Treatment and coating services of metals; machining
257	Cutlery, tools and general hardware
259	Other fabricated metal products
26	Computer, electronic and optical products
261	Electronic components and boards
262	Computers and peripheral equipment
263	Communication equipment
264	Consumer electronics

Cod	Description
265	Measuring, testing and navigating equipment; watches and clocks
266	Irradiation, electromedical and electrotherapeutic equipment
267	Optical instruments and photographic equipment
268	Magnetic and optical media
27	Electrical equipment
271	Electric motors, generators, transformers and electricity distribution and control apparatus
272	Batteries and accumulators
273	Wiring and wiring devices
274	Electric lighting equipment
275	Domestic appliances
279	Other electrical equipment
28	Machinery and equipment n.e.c.
281	General-purpose machinery
282	Other general-purpose machinery
283	Agricultural and forestry machinery
284	Metal forming machinery and machine tools
289	Other special-purpose machinery
29	Motor vehicles, trailers and semi-trailers
291	Motor vehicles
292	Bodies (coachwork) for motor vehicles; trailers and semi-trailers
293	Parts and accessories for motor vehicles
30	Other transport equipment
301	Ships and boats

Cod	Description
302	Railway locomotives and rolling stock
303	Air and spacecraft and related machinery
304	Military fighting vehicles
309	Transport equipment n.e.c.
31	Furniture
310	Furniture
32	Other manufactured goods
321	Jewellery, bijouterie and related articles
322	Musical instruments
323	Sports goods
324	Games and toys
325	Medical and dental instruments and supplies
329	Manufactured goods n.e.c.
33	Repair and installation services of machinery and equipment
331	Repair services of fabricated metal products, machinery and equipment
332	Installation services of industrial machinery and equipment
35	Electricity, gas, steam and air conditioning
351	Electricity, transmission and distribution services
352	Manufactured gas; distribution services of gaseous fuels through mains

NSTR Product Classification

Cod	Description
0	AGRICULTURAL PRODUCTS AND LIVE ANIMALS
00	LIVE ANIMALS
001	LIVE ANIMALS
01	CEREALS
011	WHEAT, SPELT AND MESLIN
012	BARLEY
013	RYE
014	OATS
015	MAIZE
016	RICE
019	OTHER CEREALS N.E.S.
02	POTATOES
020	POTATOES
03	OTHER VEGETABLES, FRESH OR FROZEN, FRESH FRUIT
031	CITRUS FRUIT
035	OTHER FRUITS AND NUTS, FRESH
039	OTHER VEGETABLES, FRESH OR FROZEN
04	TEXTILES, TEXTILE ARTICLES AND MAN-MADE FIBERS
041	WOOL AND OTHER ANIMAL HAIR
042	COTTON
043	MAN-MADE FIBRES
045	SILK, FLAX, JUTE, TRUE HEMP AND OTHER VEGETABLE TEXTILE MATERIALS

Cod	Description
049	RAGS AND WASTE OF TEXTILE MATERIALS
05	WOOD AND CORK
051	PAPER PULP WOOD
052	PIT PROPS
055	OTHER WOOD IN THE ROUND
056	RAILWAY OR TRAMWAY SLEEPERS OF WOOD AND OTHER WOOD ROUGHLY SQUARED, HALF SQUARED, OR SAWN
057	FUEL WOOD, WOOD CHARCOAL, WOOD WASTE, UNWORKED CORK, WASTE CORK
06	SUGAR BEETS
060	SUGAR BEETS
09	OTHER RAW ANIMAL AND VEGETABLE MATERIALS
090	OTHER RAW ANIMAL AND VEGETABLE MATERIALS
091	RAW HIDES AND SKINS, RAW FURSKINS, WASTE
092	RUBBER, NATURAL AND SYNTHETIC, RAW OR RECLAIMED
099	OTHER NON-EDIBLE RAW VEGETABLE AND ANIMAL MATERIALS N.E.S.
1	FOODSTUFFS AND ANIMAL FODDER
11	SUGARS
111	RAW SUGAR
112	REFINED SUGAR
113	MOLASSES
12	BEVERAGES
121	WINE OF FRESH GRAPES, GRAPE MUST
122	BEER MADE FROM MALT

Cod	Description
125	OTHER ALCOHOLIC BEVERAGES
128	NON-ALCOHOLIC BEVERAGES
13	STIMULANTS AND SPICES
131	COFFEE
132	COCOA AND CHOCOLATE
133	TEA, MAT+, SPICES
134	UNMANUFACTURED TOBACCO AND TOBACCO REFUSE
135	MANUFACTURED TOBACCO
136	GLUCOSE, DEXTROSE; OTHER SUGARS; SUGAR CONFECTIONERY; HONEY
139	FOOD PREPARATIONS N.E.S.
14	PERISHABLE FOODSTUFFS
141	MEAT, FRESH, CHILLED OR FROZEN
142	FISH, CRUSTACEANS AND MOLLUSCS, FRESH, FROZEN, DRIED, SALTED OR SMOKED
143	MILK AND CREAM, FRESH
144	BUTTER, CHEESE, OTHER DAIRY PRODUCTS
145	MARGARINE, LARD AND EDIBLE FATS
146	EGGS
147	MEAT, DRIED, SALTED, SMOKED; PREPARED OR PRESERVED MEAT
148	FISH, CRUSTACEANS AND MOLLUSCS, PREPARED OR PRESERVED
16	NON-PERISHABLE FOODSTUFFS AND HOPS
161	FLOUR, CEREAL MEAL AND GROATS
162	MALT
163	OTHER CEREAL PREPARATIONS

Cod	Description
164	FRUIT, FROZEN, DRIED, DEHYDRATED; PREPARED AND PRESERVED FRUIT
165	DRIED VEGETABLES
166	PREPARED AND PRESERVED VEGETABLES
167	HOPS
17	ANIMAL FEEDINGSTUFFS AND FOODSTUFF WASTE
171	CEREAL STRAW, HAY AND HUSKS
172	OIL-CAKE AND RESIDUES RESULTING FROM THE EXTRACTION OF VEGETABLE OILS
179	BRAN, CEREAL BY-PRODUCTS AND OTHER ANIMAL FEEDINGSTUFFS N.E.S.; WASTE FROM FOOD INDUSTRIES
18	OIL SEEDS AND OLEAGINOUS FRUITS AND FATS
181	OIL-SEED FATS, OILNUTS AND OIL KERNELS
182	ANIMAL AND VEGETABLE FATS AND OILS, AND PRODUCTS DERIVED THEREFROM
2	SOLID MINERAL FUELS
21	COAL
211	COAL (ECSC)
213	COAL BRIQUETTES (ECSC)
22	LIGNITE AND PEAT
221	LIGNITE (ECSC)
223	LIGNITE BRIQUETTES (ECSC)
224	PEAT
23	COKE
231	COKE AND SEMI-COKE OF COAL (ECSC)

Cod	Description
233	COKE AND SEMI-COKE OF LIGNITE (ECSC)
3	PETROLEUM PRODUCTS
31	CRUDE PETROLEUM
310	CRUDE PETROLEUM
32	FUEL DERIVATIVES
321	MOTOR SPIRIT
323	KEROSENE, JET FUEL AND WHITE SPIRIT
325	DISTILLATE FUELS
327	RESIDUAL FUEL OILS
33	GASEOUS HYDROCARBONS, LIQUID OR COMPRESSED
330	GASEOUS HYDROCARBONS, LIQUID OR COMPRESSED
34	NON-FUEL DERIVATIVES
341	LUBRICATING OILS AND GREASES
343	PETROLEUM BITUMEN AND BITUMINOUS MIXTURES
349	OTHER NON-FUEL PETROLEUM DERIVATIVES
4	ORES AND METAL WASTE
41	IRON HOURS
410	IRON ORE AND CONCENTRATES; EXCEPT ROASTED IRON PYRITES (ECSC)
45	NON-FERROUS ORES AND WASTE
451	NON-FERROUS METAL WASTE
452	COPPER ORE AND CONCENTRATES; COPPER MATTE
453	BAUXITE AND CONCENTRATES
455	MANGANESE ORE AND CONCENTRATES (ECSC)

Cod	Description
459	OTHER NON-FERROUS ORES AND CONCENTRATES
46	IRON AND STEEL WASTE AND BLAST-FURNACE DUST
462	IRON AND STEEL WASTE FOR REMELTING (ECSC)
463	IRON AND STEEL WASTE NOT FOR REMELTING (NON-ECSC)
465	IRON SLAG FOR REMELTING (NON-ECSC)
466	BLAST-FURNACE DUST (ECSC)
467	ROASTED IRON PYRITES (NON-ECSC)
5	METAL PRODUCTS
51	PIG IRON AND CRUDE STEEL; FERRO-ALLOYS
512	PIG IRON, SPIEGELEISEN AND CARBURIZED IRON-MANGANESE (ECSC)
513	FERRO-ALLOYS OTHER THAN CARBURIZED FERRO-MANGANESE (NON-ECSC)
515	CRUDE STEEL (ECSC)
52	SEMI-FINISHED ROLLED STEEL PRODUCTS
522	SEMI-FINISHED ROLLED STEEL PRODUCTS (BLOOMS, BILLETS, SLABS, SHEET BARS, COILS) (ECSC)
523	OTHER SEMI-FINISHED STEEL PRODUCTS (NON-ECSC)
53	BARS, SECTIONS, WIRE ROD, RAILWAY AND TRAMWAY TRACK CONSTRUCTION MATERIAL OF IRON OR STEEL
532	HOT-ROLLED OR -SHAPED STEEL (ECSC)
533	COLD-ROLLED OR -SHAPED OR FORGED STEEL (NON-ECSC)
535	WIRE ROD (ECSC)
536	STEEL IRON AND STEEL WIRE (NON-ECSC)
537	STEEL RAILS AND RAILWAY AND TRAMWAY TRACK-CONSTRUCTION MATERIAL (ECSC)

Cod	Description
54	STEEL SHEETS, PLATES, HOOP AND STRIP
542	SHEETS AND PLATES OF STEEL FOR RE-ROLLING; UNIVERSAL PLATES (ECSC)
543	OTHER STEEL PLATES AND SHEETS (NON-ECSC)
545	STEEL HOOP AND STRIP, TINPLATE (ECSC)
546	OTHER STEEL HOOP AND STRIP (NON-ECSC)
55	TUBES, PIPES, IRON AND STEEL CASTINGS AND FORGINGS
551	TUBES, PIPES AND FITTINGS
552	IRON AND STEEL CASTINGS AND FORGINGS
56	NON-FERROUS METALS
561	COPPER AND COPPER ALLOYS, UNWROUGHT
562	ALUMINIUM AND ALUMINIUM ALLOYS, UNWROUGHT
563	LEADS AND LEAD ALLOYS, UNWROUGHT
564	ZINC AND ZINC ALLOYS, UNWROUGHT
565	OTHER NON-FERROUS METALS AND ALLOYS THEREOF, UNWROUGHT
568	FINISHED AND SEMI-FINISHED PRODUCTS OF NON-FERROUS METALS (EXCEPT MANUFACTURES)
6	CRUDE AND MANUFACTURED MINERALS, BUILDING MATERIALS
61	SAND, GRAVEL, CLAY AND SLAG
611	SAND FOR INDUSTRIAL USE
612	ORDINARY SAND AND GRAVEL
613	PUMICE STONE, INCLUDING PUMICEOUS SAND AND GRAVEL
614	CLAY AND CLAY EARTH
615	SLAG NOT FOR RECOVERY OF METALS; ASH; DROSS

Cod	Description
62	SALT, IRON PYRITES, SULPHUR
621	SALT, CRUDE OR REFINED
622	UNROASTED IRON PYRITES
623	SULPHUR
63	OTHER STONES, EARTHS AND MINERALS
631	CRUSHED OR BROKEN STONE; PEBBLES, MACADAM, TARRED MACADAM
632	BUILDING AND MONUMENTAL STONE, UNWORKED
633	LIMESTONE FOR INDUSTRIAL PURPOSES
634	CHALK
639	OTHER CRUDE MINERALS
64	CEMENT, LIME
641	CEMENT
642	LIME
65	PLASTERS
650	PLASTERS
69	OTHER MANUFACTURED BUILDING MATERIALS
691	PUMICE STONE AGGLOMERATES; CONCRETE, CEMENT AND SIMILAR BUILDING MATERIALS
692	BRICKS, ROOFING TILES AND OTHER CERAMIC BUILDING MATERIALS, REFRACTORY BUILDING MATERIALS
7	FERTILIZERS
71	NATURAL FERTILIZERS
711	SODIUM NITRATE, NATURAL
712	PHOSPHATES, RAW, NATURAL

Cod	Description
713	POTASSIUM SALTS, RAW, NATURAL
719	OTHER NATURAL FERTILIZERS
72	CHEMICAL FERTILIZERS
721	BASIC SLAG (THOMAS SLAG)
722	OTHER PHOSPHATIC FERTILIZERS
723	POTASSIC FERTILIZERS
724	NITROGENOUS FERTILIZERS
729	COMPOSITE AND OTHER MANUFACTURED FERTILIZERS
8	CHEMICALS
81	BASIC CHEMICALS
811	SULPHURIC ACID; OLEUM
812	CAUSTIC SODA AND SODA LYE
813	SODIUM CARBONATE (SODA ASH)
814	CALCIUM CARBIDE
819	OTHER BASIC CHEMICALS
82	ALUMINIUM OXIDE AND HYDROXIDE
820	ALUMINIUM OXIDE AND HYDROXIDE
83	COAL CHEMICALS
831	BENZOLE
839	PITCH, MINERAL TAR AND OTHER CRUDE MINERAL CHEMICAL DERIVATIVES FROM COAL AND NATURAL GAS
84	PULP AND WASTE PAPER
841	PAPER PULP
842	WASTE PAPER AND SCRAP ARTICLES OF PAPER

Cod	Description
89	OTHER CHEMICAL PRODUCTS
891	PLASTIC MATERIALS, UNWORKED
892	DYEING, TANNING AND COLORING MATERIALS
893	MEDICINAL AND PHARMACEUTICAL PRODUCTS; PERFUMERY AND CLEANSING PREPARATIONS
894	MANUFACTURED EXPLOSIVES, FIREWORKS AND OTHER PYROTECHNIC ARTICLES, SPORTING AMMUNITION
895	STARCHES AND GLUTEN
896	OTHER CHEMICAL PRODUCTS AND PREPARATIONS
9	MACHINERY, TRANSPORT EQUIPMENT, MANUFACTURED ARTICLES AND MISCELLANEOUS ARTICLES
91	TRANSPORT EQUIPMENT
910	TRANSPORT EQUIPMENT, WHETHER OR NOT ASSEMBLED, PARTS THEREOF
92	TRACTORS, AGRICULTURAL MACHINERY AND EQUIPMENT
920	TRACTORS; AGRICULTURAL MACHINERY AND EQUIPMENT, WHETHER OR NOT ASSEMBLED; PARTS THEREOF
93	OTHER MACHINERY APPARATUS AND APPLIANCES, ENGINES, PARTS THEREOF
931	ELECTRICAL MACHINERY, APPARATUS, APPLIANCES AND ENGINES; PARTS THEREOF
939	NON-ELECTRICAL MACHINERY, APPARATUS, APPLIANCES AND ENGINES; PARTS THEREOF
94	MANUFACTURES OF MATERIAL
941	FINISHED STRUCTURAL PARTS AND STRUCTURES
949	OTHER MANUFACTURES OF METAL
95	GLASS, GLASSWARE, CERAMIC PRODUCTS

Cod	Description
951	GLASS
952	GLASSWARE, POTTERY AND OTHER MANUFACTURES OF MINERALS
96	LEATHER, TEXTILES AND CLOTHING
961	LEATHER, MANUFACTURERS OF LEATHER, OF RAW HIDE AND SKINS
962	TEXTILE YARN, FABRICS, MADE-UP ARTICLES AND RELATED PRODUCTS
963	TRAVEL GOODS, CLOTHING, KNITTED AND CROCHETED GOODS, FOOTWEAR
97	OTHER MANUFACTURED ARTICLES
971	SEMI-FINISHED PRODUCTS AND MANUFACTURED ARTICLES OF RUBBER
972	PAPER AND PAPERBOARD, UNWORKED
973	PAPER AND PAPERBOARD MANUFACTURES
974	PAPER MATTER.
975	FURNITURE, NEW
976	WOOD AND CORK MANUFACTURES, EXCLUDING FURNITURE
979	OTHER MANUFACTURED ARTICLES N.E.S.
99	MISCELLANEOUS ARTICLES
991	PACKING CONTAINERS, USED
992	CONSTRUCTION MATERIALS, FAIRGROUND VEHICLES AND EQUIPMENT, USED
993	REMOVAL EQUIPMENT
994	GOLD, COINS, MEDALS

Cod	Description
999	OTHER MANUFACTURED GOODS NOT CLASSIFIED ACCORDING TO KIND
TOT	TOTAL

Transportation classification

Code.	Description
0	Unknown
1	Sea
2	Rail
3	Road
4	Air
5	Post
7	Fixed Mechanism
8	Inland Waterway
9	Self Propulsion