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# The impact of rising maritime transport costs on international trade: Estimation using a multi-region general equilibrium model

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ABSTRACT

This paper evaluates the impact of the 2021–22 surge in rates for containerized and bulk shipping costs. Employing a detailed transport database and applying a set of detailed shocks by transportation mode, regions and commodities in a multi-region general equilibrium model, the paper analyses the sectorial (agri-food sectors, manufacturing) and macroeconomic (trade, wide-economic indicators) impacts of the recent surge in shipping costs. Maritime transport costs are sensitive to imbalances between global demand and supply, which rose further after the Covid-19 pandemic. In a globalised world, an increase in shipping rates can have widespread repercussions on international trade, creating risks for the global economic activity. The results allow the analysis of how shocks in transport costs can affect prices in international trade and explain the short- and medium-term impacts on the economy. The main finding is that rising maritime transport costs tend to reverse the trend towards globalisation of international trade and favour localization.

## 1. Introduction

Maritime transport is crucial for international trade and the global economy. Over 50 % of the value and 80 % of the volume of international trade is carried by sea (UNCTAD, 2021). During the third quarter of 2020, after the economic downturn caused by the COVID-19 pandemic crisis, the global economy showed a sharp increase in activity. The rebound was driven by the re-activation of the manufacturing sector after the easing of the pandemic containment measures and the substantial policy support deployed by many governments. Following the collapse in global trade in the first half of 2020, the shipping industry entered a period of high volatility (Michail and Melas, 2020). Global maritime trade gradually recovered and reached pre-pandemic levels by November 2020. However, the rise in global demand for goods due to the reduced demand for services caused a strong rebound in manufacturing activity and resulted in several bottlenecks across the supply chain. One of the signs was the rise of ocean freight shipping costs, especially for containerized goods. Since the second half of 2020, global freight shipping costs had been on a steady recovery path from the lows reached during the pandemic. The strong rise in demand for intermediate inputs by the manufacturing sector raised the demand for Chinese exports and for container shipments. At the same time, shortages of empty containers at Asian ports and lack of sufficient personnel exacerbated supply bottlenecks and further increased shipping costs (P. Chowdhury et al., 2021a; Toygar et al., 2022). The rise in shipping costs was further accentuated by limited airfreight capacity as international flight volumes plunged due to travel restrictions and flight cancellations. The increase in shipping costs affected the economy globally and all traded sectors, from primary to manufacturing. While there are indications that the stress on global transport logistics is easing, developments are highly dependent on the future evolution of global markets and on the solution of structural problems in maritime transport.

UNCTAD has estimated the impact of the current surge in container freight rates, concluding that at the global level import price levels might rise by 10.6 % (UNCTAD, 2022) and global industrial production could be negatively affected. The impact would be heterogeneous by countries and sector according to the different economic structure and trade pattern of each country and commodity. The increase in trade costs and import price will also influence, even if with a lower magnitude, consumer prices via several channels. The price of final goods increases directly due to the increase in shipping costs, but they can also increase indirectly due to increased price of intermediate products strongly embedded in global supply chains such as selected raw materials or parts and components used in production processes. The possible quantitative effects of the 2021–22 surge in rates for containerized and

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bulk costs on the global economy has not yet been fully analysed.

The aim of this paper is to quantify the impacts of the increase of freight transport costs on the global economy and on selected regions using indicators such us world and domestic prices, international trade, and macroeconomic indicators. Building on a detailed transport database, a set of detailed shocks by transportation mode, region and commodity feed a multi-region, computable general equilibrium (CGE) model which analyses the sectorial (agri-food sectors, manufacturing) and macroeconomic (trade, wide-economic indicators) impacts of the recent surge in shipping costs. CGE models are a popular method for assessing the direct and wider economic impacts of transport shocks and policies, as they can determine the distribution of impacts among every market and agent in the economy (Robson et al., 2018). The sequential modelling framework is employed, where new shipping costs are implemented into the Modular Applied GeNeral Equilibrium Tool (MAGNET) (Woltjer et al., 2014). The designed scenarios capture the trade, macroeconomic and price impacts which arise in each region due to increase of transportation costs. The main finding of the paper suggests that rising maritime transport costs tend to reverse the trend towards globalisation of international trade and favour localization. The results show a generalised increase of CIF prices with an almost linear relationship with the shock applied to the model, a reduction of the volume of world trade by 0.42 % and of value by 0.23 % (which is equal to around 103 billion USD), compared to the 2020 values and a GDP decreases by 0.05 %, (around 45 billion US dollars) but with significant discrepancies among countries.

The paper contributes to the literature on modelling economic impacts of shocks on maritime transport on two fronts:

a) Improving the link between the Global Trade Analysis Project (GTAP) database and data transport to improve the creation of scenarios looking at change on the transport market;

b) Providing a detailed analysis of the impact of the recent increase of transport price on selected sectoral (agri-food sectors, manufacturing) and macroeconomic indicators (trade, GDP, prices) at global and regional level to show the direct and indirect links between the increase in shipping costs and main economic variables.

The rest of this paper is structured as follows. Section two sets the scene of the paper providing the background and the relevant literature review. Section three shows how detailed shocks by transportation mode, regions and commodities are estimated and how the shocks feed into the economy-wide global model to quantify the impacts of the increasing shipping costs i. Section four presents international trade, macroeconomic and domestic price impacts of the shocks on selected countries, regions, and commodities. The two final sections discuss how these findings can benefit policy debate present some of the caveats and add some concluding remarks.

## 2. Background

In 2020, lockdown measures and other impacts of COVID-19 suddenly cut the demand for containerized goods. In 2020, global container trade fell by 1.1 % to 149 million twenty-foot equivalent units (TEU). The container volumes bounced back quickly as consumer demand increased, boosted by stimulus packages and measures to support incomes during COVID-19. In the second half of 2020, demand for container shipping started to pick up and absorb spare capacity. As demand picked up, carriers released more capacity but by that time, the supply was being constrained by other factors, notably port congestion and equipment shortages that kept vessels waiting, especially in West Coast North America. The result was exacerbated disruption and inefficiency at ports. By the end of 2020, freight rates had surged to unexpected levels (UNCTAD, 2022).

Towards the end of 2020 and into 2021, container shortages and congestion at ports, along with other disruptions, led to record container freight rates, notably on the routes from China to Europe and the United States reflected in the Shanghai Containerized Freight Index (SCFI). In June 2020, SCFI spot rate on the Shanghai-Europe route was less than $1,000/TEU but by the end of 2020 had reached around $4,000/TEU and, by the end of July 2021, the SCFI has reached $7,395/TEU. Freight rates also escalated on the China-United States trade lane and extended across developing regions, including South America and Africa (UNCTAD, 2022).

This increase was also visible in other freight rate indices. According to the Freightos Baltic Index (FBX), a global container freight index, the freight rates in August 2021 reached $10,174 for a 40-foot container (FEU), an increase of 466 % on the previous year and plateau at around $9,000/FEU during 2022. While container fares were the most sensible to price increases, also dry bulk transport recorded a significant price increase, as shown by the Baltic Dry Index peaking at more than $5,500 in October 2021, however the price spike for dry bulk transport was shorter lived than for container transport.

An analysis of the United States case shows that the global shipping container disruptions meant a significant increase in port congestion and the considerable increase in the freight. The disruption caused the reduction of the containerized agricultural exports by 22 percent below the counterfactual from May 2021 to January 2022 and that this adverse trade effects translate into USD 10 billion in export losses (Carter et al., 2022).

The surge of freight costs might have an impact of domestic inflation rate. Although international shipping costs are not included in import price indices, importers can pass changes in shipping costs through to consumers in a manner that affects aggregate price growth. Empirical studies reveal that a one-standard-deviation increase in global shipping costs increases domestic headline inflation by about 0.15 percentage point, with the effect building up over the course of 12 months. Unlike many other pass-through that have been studied in the literature, this effect appears to have remained strong over time, reflecting the increased openness of countries to international trade. This implies that the increase in shipping costs observed in 2021 could have contributed to increase domestic inflation in 2022 by about 1.5 percentage points, particularly in countries where imports make up a bigger share of domestic consumption (Carrière-Swallow et al., 2023). The impact of the high freight charges would be greater for Small Island Developing States (SIDS), which could see import prices increase by 24 % and consumer prices by 7.5 %. In least developed countries (LDCs), consumer price could increase by 2.2 % (UNCTAD, 2022). Within the European Union, freight rates have a significant impact on the price of the sub-categories of Non-Energy Industrial Goods (NEIG). Following a shock in freight rates, the most hard-hit sectors are garments and major household appliances, items that have traditionally been manufactured outside the euro area. The relationship between freight rates and inflation tends to become positive once the former rise above $1,200-$1,500 (Michail et al., 2022). Empirical OECD estimates of these two relationships assess the implication for inflation of the average 50 % rise in container prices observed in the first quarter of 2021. If shipping costs stabilise at their current level for the rest of 2021, in the short run, the rise of 50 % in shipping costs observed in the first quarter of 2021 is estimated to raise quarter-on-quarter import price inflation by 2.5 percentage points. After one year, merchandise import price inflation is estimated to rise by 2 percentage points (OECD, 2021).

On the other hand, another analysis suggests that after one year, the pass-through of shipping prices into US Personal Consumption Expenditures (PCE) inflation is limited. Even a 50 % annual increase in the Harpex index of charter rates for container ships – like that experienced leading up to January 2021 – could raise annual PCE inflation by up to 0.25 percentage points one year later. The size of this effect is also explained by the fact that international shipping costs make up only a small share of the final cost of manufacturing output. Overall, given that supply challenges are driven by transportation rather than production constraints, the rise in transportation costs is expected to have only a modest impact on global economic activity (European Central Bank, 2021).

The costs of international maritime transport are frequently mentioned in the literature as an area of research interest (Chang and Talley, 2019). Supply chains become more international and complex, leading to a higher degree of dependence on maritime transportation (Calatayud et al., 2017), particularly pronounced in the case of less developed regions (Lin and Sim, 2013). As regards shipping connectivity, (Yap et al., 2023) carried out an extensive review and identified major limitations in the literature where the focus is on port-to-port or country-to-country connectivity without sufficient consideration of the dynamics between shipping lines involved in such linkages. International trade volumes have been repeatedly shown a high correlation with maritime transport connectivity (Lin et al., 2020; Lun and Hoffmann, 2016). Gravity models employed in the research included in (Bottasso et al., 2018; del Rosal and Moura, 2022; Márquez-Ramos et al., 2011). The latter estimated a gravity equation for Brazilian international maritime trade the period 2009–2012 and identified that an increase in port productivity is associated with large increases in exports and moderate increases in imports. For the Turkish economy, (Coşar and Demir, 2018) used micro-level export data to demonstrate that containerization and the drop in shipping costs it provoked has significantly contributed to the growth of international trade. The analysis of several types of disruptions in international maritime transport, however, suggests that specific regions and/or economic sectors can be highly vulnerable to the sudden shocks (Priyabrata Chowdhury et al., 2021b; Rousset and Ducruet, 2020; Vega et al., 2018).

The analysis of potential economy-wide impacts of shocks affecting the global transportation systems needs the development of quantitative global economic simulation models. One of the most popular approaches to assess transportation related applications is CGE modelling. While early combinations of CGE and transportation models encountered difficulties in interfaces, as well as sectoral and regional aggregation (Tavasszy et al., 2011), modern approaches are suitable for the assessment of the economic impact of transport, both direct and indirect (Shahrokhi Shahraki and Bachmann, 2018). Such models can simulate the distribution of impacts among every market and agent in the economy by reproducing the behaviour of households, firms and others based on microeconomic first principles (Robson et al., 2018). CGE have been applied to analyse infrastructure (road, rail) construction, transportation network changes (e.g., expansion, removal, and speed change), congestion costs, infrastructure investment/financing, land-use impacts, cross-border trade, transport cost change infrastructure interdependencies, trade facilitation and trade agreements (Betarelli et al., 2020; Gaus and Link, 2021; Hörcher and Tirachini, 2021; Shahirari et al., 2021). Most of the global studies dealing with the transportation sector relies on the GTAP database as their main economic data source. The GTAP model and all GTAP-based models, which represent transport cost using explicit approaches, have been widely employed for analysis related to the transport sector. For example, GTAP-E provided a quantitative evaluation of the economic impacts of a maritime carbon tax showing that imposing a maritime carbon tax on international container shipping is not expected to have a significant economic impact unless the amount of the carbon tax is extremely high (Lee et al., 2013). Similarly, the GTAP model has been used to show that investments in transportation infrastructure among 17 Belt and Road Initiative countries during 2014–2020 (Chen and Li, 2021) have an overall positive effect among the belt and road countries even if the impacts were found to vary among different countries and regions.

The current paper is part of the quantitative assessment of shocks on the global transportation system using CGE models. The paper, through an estimation of the recent increase in freight feeding a global economy-wide model, contributes to the literature on modelling the impact of transportation improving the link between the Global Trade Analysis Project (GTAP) database and data transport and providing a detailed analysis of the impact of the recent increase of transport price on selected sectoral and macroeconomic indicators at global and regional level.

## 3. Data and methods

This analysis employs the Modular Applied GeNeral Equilibrium Tool (MAGNET) model, a state-of-the-art multi-sector, multi-region CGE model (Woltjer et al., 2014). MAGNET is widely employed to simulate the impacts of agricultural policies (M'barek et al., 2017), land issues (Sartori et al., 2019), and free trade agreements (Ferrari et al., 2021; Simola et al., 2022) on the global economy. For this analysis, the model provides results of a comparative static analysis. Given its global coverage in terms of geography and sectors and the flexibility it allows for the treatment of transport costs, MAGNET can be considered as a suitable tool for the explorations of issues covered here.

MAGNET is based on the Global Trade Analysis Project (GTAP) model, which accounts for the behaviour of households, firms, and the government in the global economy and how they interact in markets (Corong et al., 2017). The model is a system of simultaneous equations where the number of endogenous variables equals to the number of equations. Shocking exogenous 'drivers' (e.g., taxes, technological parameters, or endowments), price and quantity adjust to reach a new equilibrium. Comparing the new scenario with the benchmark gives an indication of the market impact of the shock on selected indicators (e.g., international, and domestic prices, outputs, trade flows and real incomes). The model includes the food supply chain from "farms", as represented by agricultural sectors - via food processing industries and food service sectors – "to fork", considering bilateral trade flows for major countries and regions in the world. In the model, goods can be sold on the domestic market or to other regions in the world. Similarly, domestic intermediate, private household, and government demand for goods can be satisfied by domestic production or by imports from other regions in the world (i.e., the 'Armington assumption'). Sourcing of imports happens at the border, after which - based on the resulting composite import price - the optimal mix of import and domestic goods is derived. Demand for and supply of commodities and endowments meet in markets, which are perfectly competitive and clear via price adjustments.

International transport modes in the standard Global Trade Analysis Project (GTAP) model (Hertel, 1997) are handled by a global transport services industry that allocates a composite international transport good among exporting countries in direct proportion to their global export shares of a given product. The composite international transport good is a bundle of air, water (mostly vessel), and other (land, predominantly truck and rail) transportation services. The combination of the Free on Board (FOB) price at the country of origin with the composite international transport good generates a Cost, Insurance and Freight (CIF) price at the destination country. International margins are based on a bilateral dataset of modal transport shares that matches the country and product aggregation of the GTAP Data Base (Nuño-Ledesma and Villoria, 2019).

The GTAP database Version 10, contains a complete record of all economic activity (i.e., production, trade, primary factor usage, final and input demands, taxes, trade tariffs, and transport margins) for 65 activities and 141 regions for 2014 (Aguiar et al., 2019). The behavioural parameters of the model equations are 'calibrated' to replicate the initial equilibrium conditions provided by the benchmark database. The MAGNET model includes an additional provision of disaggregated sectors compared to the original GTAP database. The sectorial disaggregation includes 14 primary agriculture commodities, 10 Food and beverages and 16 other sectors (see Table A1 for details). The regional disaggregation comprises 22 regions including the EU, Australia, Canada, Japan, Mercosur, Mexico, New Zealand, United States, China, Ukraine, and Russia (see Table A2 for details).

A major improvement brought by the work presented here is the integration into MAGNET of the detailed international transport costs published by the United Nations Conference on Trade and Development (UNCTAD). The data include detailed figures for freight costs by transport mode (sea, air, road, and rail), at country origin–destination level and for WCO HS6 commodity level. The available indicators include

**Table A1**
Commodities included in MAGNET database.

| Number | GTAP code | Description | |
|---|---|---|---|
| 1 | Rice | Rice, husked and unhusked | Agriculture |
| 2 | Wheat | Wheat and meslin | Agriculture |
| 3 | Other cereals | Maize (corn), barley, rye, oats, other cereals | Agriculture |
| 4 | Fruits&veg. | Vegetables, fruits, nuts, potatoes, cassava, truffles, | Agriculture |
| 5 | Oilseeds | Oil seeds and oleaginous fruit; soybeans, copra | Agriculture |
| 6 | Sugarbeet: | Sugar cane and sugar beet | Agriculture |
| 7 | Plant fibres | Fibres crops | Agriculture |
| 8 | Wool | Wool, silk, and other raw animal materials used in textile | Agriculture |
| 9 | Other Crops | Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials | Agriculture |
| 10 | Live Cattle | Cattle | Agriculture |
| 11 | Live sheep | Sheep, goats, horses, asses, mules, and hinnies; and semen thereof | Agriculture |
| 12 | Live poultry | Poultry | Agriculture |
| 13 | Live pigs | Swine and other live animals; eggs, in shell (fresh or cooked), natural honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin, hides, skins and furskins, raw, insect waxes and spermaceti, whether or not refined or coloured | Agriculture |
| 14 | Raw milk | Raw milk | Agriculture |
| 15 | Beef meat | Fresh or chilled meat and edible offal of cattle. | Food |
| 16 | Meat: sheep, goats, horse | Fresh or chilled meat and edible offal of sheep, goats, horses, asses, mules, and hinnies. Raw fats or grease from any animal or bird. | Food |
| 17 | Poultry meat | Preserves and preparations of meat, meat offal or blood, flours, meals and pellets of meat or inedible meat offal; greaves | Food |
| 18 | Pig Meat | Pig meat and offal. | Food |
| 19 | Oils & meals | Refined oils of soya-bean, maize (corn), olive, sesame, groundnut, olive, sunflower-seed, safflower, cottonseed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu and linseed, perhaps partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised. Also, margarine and similar preparations, animal or vegetable waxes, fats and oils and their fractions, cotton linters, | Food |
| 20 | Dairy | Milk: dairy products | Food |
| 21 | Processed Rice | Rice, semi- or wholly milled | Food |
| 22 | Sugar | Sugar | Food |
| 23 | Feed | Preparations used in animal feeding | |
| 24 | Oilcake | Oilcake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes. | |
| 25 | Crude vegetable oils | Crude vegetable oils | |
| 26 | Other Food | Prepared and preserved vegetables, pulses and potatoes; prepared and preserved fruits and nuts; wheat and meslin flour; other cereal flours; groats, meal and pellets of wheat and other cereals; other cereal grain products (including corn flakes); other vegetable flours and meals; mixes and doughs for the preparation of bakers' wares; starches and starch products; sugars and sugar syrups n.e.c.;; lucerne (alfalfa) meal and pellets; bakery products; cocoa, chocolate and sugar confectionery; macaroni, noodles, couscous and similar farinaceous products; food products n.e.c. | Food |
| 27 | Beverages & tobacco | Beverages and tobacco products | Food |
| 28 | Forestry | Forestry, logging, and related service activities | |
| 29 | Fishery | Hunting, trapping, and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing | |
| 30 | Coal | Mining and agglomeration of hard coal, lignite, and peat | |
| 31 | Oil | Extraction of crude petroleum, service activities incidental to oil and gas extraction excluding surveying | |
| 32 | Gas | Extraction of natural gas, service activities incidental to oil and gas extraction excluding surveying | |
| 33 | Light manufacturing | Manufacture of textiles, wearing apparel, leather and related products, wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials, printing, and reproduction of recorded media. Manufacture of chemicals and chemical products, of pharmaceuticals, medicinal chemical, and botanical products, of rubber and plastics products | |
| 34 | Manufacturing | Manufacture of other non-metallic mineral products, Iron & Steel, Non-Ferrous Metals, Manufacture of fabricated metal products, of computer, electronic and optical products, of electrical equipment, of machinery and equipment n.e.c., of motor vehicles, trailers, and semi-trailers, of other transport equipment. | |
| 35 | Petroleum Products | Manufacture of coke and refined petroleum products | |
| 36 | Electricity | Electricity; steam and air conditioning supply | |
| 37 | Gas distribution | Gas manufacture, distribution | |
| 38 | Food Services | Food and service activities | |
| 39 | Services | Water supply; sewerage, waste management and remediation activities, Construction: building houses factories offices and roads, | |

(continued on next page)

**Table A1** (*continued*)

| Number | GTAP code | Description |
|---|---|---|
| | | Wholesale and retail trade; repair of motor vehicles and motorcycles, accommodation, Warehousing and support activities, Information and communication,,Other Financial Intermediation: includes auxiliary activities but not insurance and pension funding, Insurance, Real estate activities, Other Business Services, recreation & Other Services: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants), Other Services (Government): public administration and defence; compulsory social security, activities of membership organizations n.e.c., extra-territorial organizations and bodies, Education, Human health and social work, Dwellings: ownership of dwellings (imputed rents of houses occupied by owners). |
| 40 | Fertilisers | Fertilisers |
| 41 | Biodiesel | Biodiesel |
| 42 | Biogas | Biogas |
| 43 | Other Transport services | Land transport and transport via pipelines |
| 44 | Water transport services | Water transport |
| 45 | Air transport services | Air transport |

total transport costs, transport costs to FOB value, transport costs per unit, transport costs per 10 000 km, with year 2016 as a baseline. The structure of the UNCTAD data allows the aggregation of the indicators into the regions and commodity groups used by MAGNET. It also permits the parameterization of the transport cost variables used by the model and –as a result- the exploration of various scenarios.

A first set of exploratory analysis provides an evaluation of the overall impacts at regional and commodity level. Regions dependent on imports/exports of low value-to-weight ratio products suffer the highest relative price increases. The same holds for regions that trade with long-distance partners, or do not have efficient freight transport infrastructure or services. Higher value goods may find alternatives in air or road transport, if possible. Goods transported by containers -especially reefers- are more sensible to price increases, while the impact on goods transported in bulk is more limited.

To simulate the impact of increased maritime transport costs on the global economy, we applied a methodology that combines the integration of new data sources on transport costs and the transformation of the detailed transport costs into a structure compatible with MAGNET. The improved coverage of transport costs allowed the development of a sub-model linking final prices to transport costs and the estimation of the repercussion of increased rates in maritime transport. We applied the resulting changes in margins –for all commodity, origin, and destination combination in MAGNET to capture the potential impacts at sectoral and regional level (Fig. 1).

The main new data source is the UNCTAD Global Transport Costs Dataset for International Trade (UNCTAD, 2021). The dataset includes a set of six input and output tables, each distinguished by mode of transport. We use the raw data (input) tables for international trade transported by sea, with year 2016 as the reference.

The dataset contains bilateral trade data as reported by countries in UN ComTrade Plus and as edited/imputed by UNCTAD, World Bank and Equitable Maritime Consulting, based on a methodology specifically developed for the estimation of transport costs. Based on the bilateral trade flows of commodities for which traded volumes, Cost, Insurance and Freight (CIF), and Free on Board (FOB) value data exist, the dataset displays the related transport costs (incl. insurance costs) by country pair, commodity group and mode of transport. This dataset is the only available source of estimates of global maritime shipping costs for

**Table A2**
Countries and regions included in MAGNET database.

| Number | GTAP code | Name | Description |
|---|---|---|---|
| 1 | EU | EU | Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden |
| 2 | UK | United Kingdom | United Kingdom |
| 3 | ARG | Argentina | Argentina |
| 4 | BRA | Brazil | Brazil |
| 5 | PRY | Paraguay | Paraguay |
| 6 | URY | Uruguay | Uruguay |
| 7 | CAN | Canada | Canada |
| 8 | NZL | New Zealand | New Zealand |
| 9 | AUS | Australia | Australia |
| 10 | MEX | Mexico | Mexico |
| 11 | CHL | Chile | Chile |
| 12 | JPN | Japan | Japan |
| 13 | THA | Thailand | Thailand |
| 14 | PHL | Philippines | Philippines |
| 15 | IDN | Indonesia | Indonesia |
| 16 | MYS | Malaysia | Malaysia |
| 17 | VNM | Vietnam | Vietnam |
| 18 | USA | United States of America | United States of America |
| 19 | UKR | Ukraine | Ukraine |
| 20 | RUS | Russia Federation | Russia Federation |
| 21 | CHN | China | China |
| 22 | RoE | Rest of Europe | Switzerland, Norway, rest of the European Free Trade Association, Albania, Belarus, rest of eastern Europe, rest of Europe |
| 23 | RoAm | Rest of Americas | Rest of North America, Bolivia, Colombia, Ecuador, Venezuela, Peru, rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Caribbean |
| 24 | RoAs | Rest of Asia | Hong Kong, South Korea, Mongolia, Taiwan, rest of East Asia, Brunei, Cambodia, Laos, Singapore, Rest of South-East Asia, Bangladesh, India, Nepal, Pakistan, Sri Lanka, rest of South Asia |
| 25 | MENA | Middle East and North Africa | Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates, rest of western Asia, Egypt, Morocco, Tunisia, rest of North Africa |
| 26 | SSA | Sub-Saharan Africa | Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, rest of western Africa, rest of Central Africa, rest of South-Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, rest of eastern Africa, Botswana, Namibia, South Africa, rest of South African Customs Union |
| 27 | RoW | Rest of the world | Rest of Oceania, Kazakhstan, Kyrgyzstan, Tajikistan, rest of former Soviet Union, Armenia, Azerbaijan, Georgia, rest of the world |

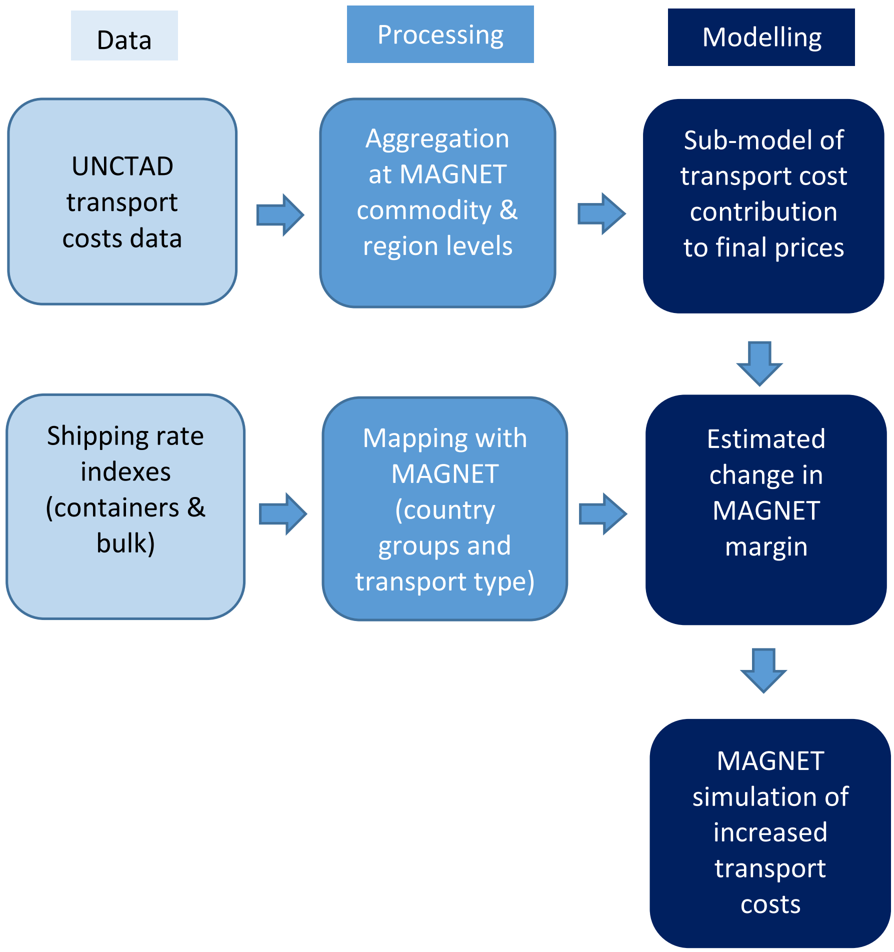



**Fig. 1.** Overview of modelling process.

bilateral trade flows at sectoral level, with the additional advantage of using region and sector classifications that are compatible with MAGNET. Moreover, the dataset is open and publicly accessible, allowing the unhindered replication of the findings.

The data cover 135 importing countries and 235 exporting countries (based on ComTrade Plus data) and include nearly 25 million trade records, at Harmonized Commodity Description and Coding System 6-digit (HS2012 HS6) commodity level, which can be directly mapped to the commodities used in the MAGNET model. Based on these the difference between CIF and FOB trade values per MAGNET commodity, Fig. 2 summarizes the ratio between transport costs (considered as the difference between CIF and FOB prices according to the UNCTAD definition) and FOB prices. The difference in values reflects a well-known effect in transport economics, an inverse relationship between the value-to-volume ratio and the transport costs per unit of value of the goods transported (Fig. 2).

For cattle meat (cmt), international transport costs represent an increase of 12.7 % to the FOB price, while for fertilizers (fert) they represent 12.2 %. In fact, most commodities for which transport costs represent more than 6 % of FOB price are low value to weight/volume products that are normally transported in bulk (crude oil and oil products, natural gas, coal, grains, etc.), or require special conditions for transport (meat, vegetables and fruits, live cattle, etc.). On the other extreme, higher valued commodities that are transported by sea such as wool or plant fibres have a minimal impact of transport costs (1.3–1.4 %). The comparison between light manufacturing (3.6 %) and manufacturing in general (5.4 %) is also indicative of the influence of the product value. Above a certain value to weight/volume (or when additional speed constraints are present) maritime transport is not the preferred mode of transport and shippers prefer land or air transport. This would be the case –for example- for higher value pharmaceuticals, technological products, or fresh flowers.

Transport distances also have a role in determining the impact of transport costs. Commodities with a high geographical concentration of either exporting or importing countries (e.g., sugar) may travel a higher average transport distance than products with more widespread global trade patterns (e.g., other food products). Summarizing the data at MAGNET region level (Fig. 3), the interplay of the product mix and geographical distribution is more evident. Depending on the type of commodities, each region imports/exports, and the geographic distance from the trade partner regions, the average impact of transport costs on prices varies significantly by region, as well as between imports and exports for the same region. China is an example of the difference between imports and exports. Since China's international maritime trade consists of importing raw material (usually in bulk) and exporting manufactured products (most frequently in containers), transport costs represent 7 % of the FOB value of imports but 4.5 % of the FOB value of exports. A similar imbalance can be observed for the European Union: 7.8 % for imports, 5.9 % for exports (the difference with China is due to the combination of different product mix and average distances for the EU). In contrast, USA and Australia show the opposite pattern: the repercussion of maritime transport costs is higher for exports than for imports, mainly because of the high share of commodities in their exports. Oil represents a high share of USA exports, while Australian exports record a high share of coal and iron ore (the latter included in the Manufacturing commodity group in MAGNET). The geographic location of their markets also influences, with Australia needing longer transport distances than the USA (or most other regions) on average.

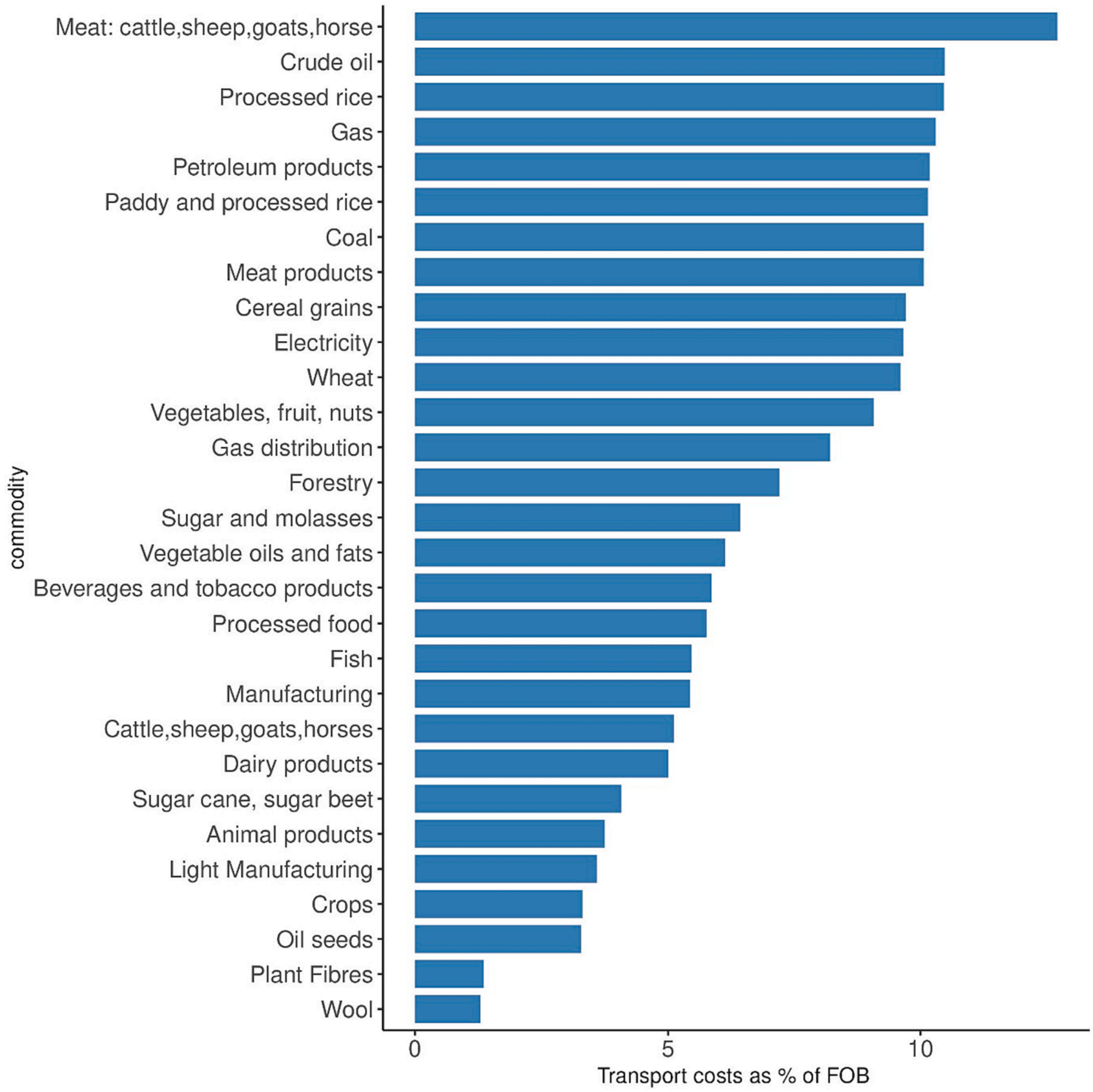



**Fig. 2.** Weighted average of maritime transport costs to FOB price per MAGNET commodity.

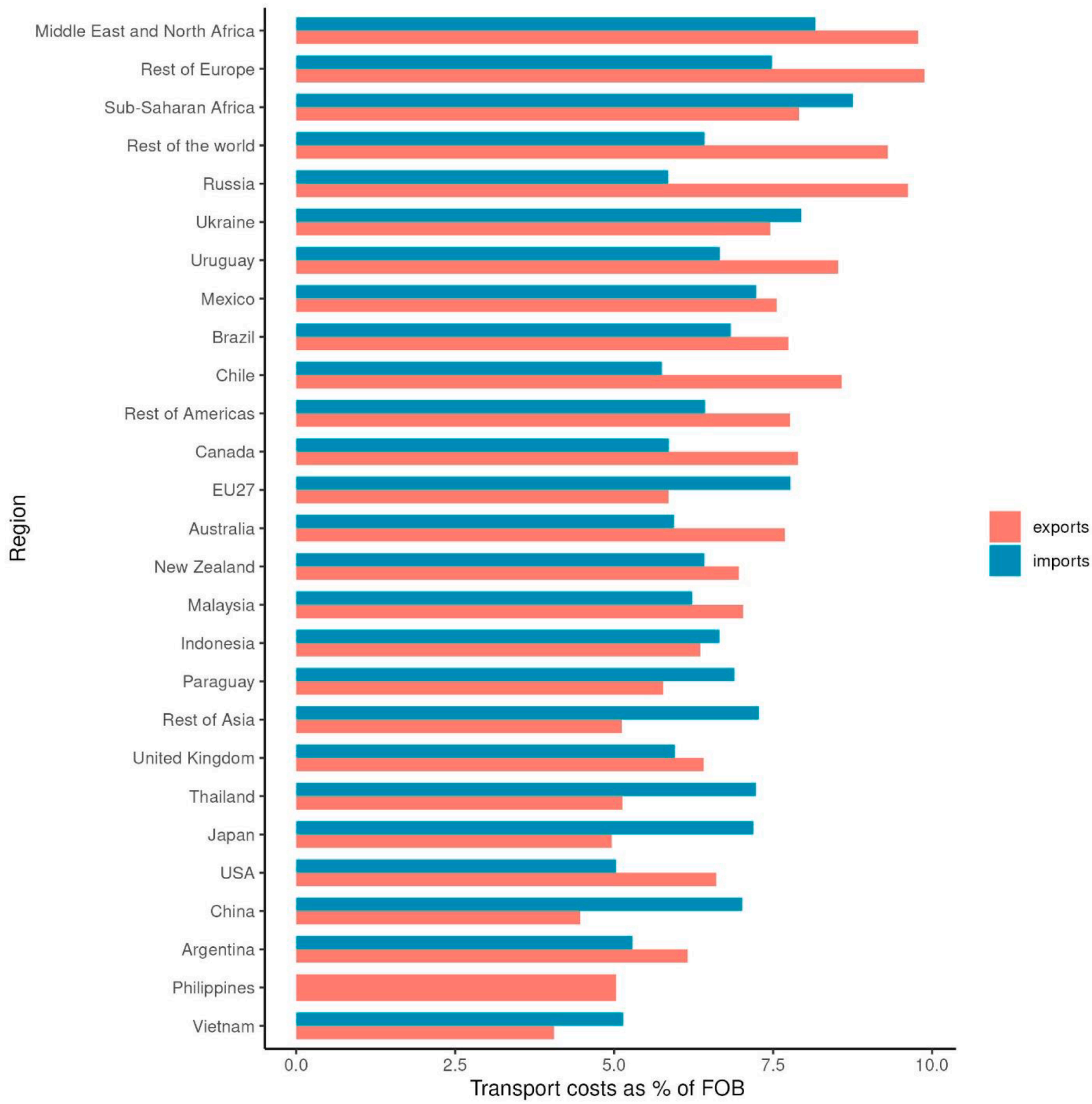
The high variance of the impact of transport costs for each commodity or region implies that an increase in maritime transport costs, either uniform at global level or localised in specific regions or market segments may lead to diverse impacts for international trade.

The other main source used in this work concerns the data on the changes in maritime transport rates using the Freightos Baltic Index (Freightos, 2022). The index tracks daily average market rates from container shippers and represents a benchmark for the evolution of prices across the international maritime container transport market. We extracted data for 13 different regional combinations as regards the change in their respective market index, between 1st January 2021 and 31st December 2021 (Fig. 4), to quantify the actual changes in shipping costs during the period. The indexes reflect the market imbalances that led to a steep increase in container rates, namely the increase in exports from China following the post-COVID-19 recovery of international trade, the congestion in Chinese and US West coast ports and the bottleneck created by the lack of empty containers. The global container market already depended on the demand and supply for containerized goods from China. The rates for containers from China were significantly higher than those with China as destination, and this asymmetry was only accentuated when demand in the global container market increased. With Chinese exports as a driver, the rates from China increased by more than 100 % for all its main export markets. Characteristically, the increase in rates in the opposite direction was much lower (even negative in the case of North Europe to China). Even though trade flows with China were the main driver, there were second order effects that led to prices increasing in unrelated markets, as for example in the Europe to South America market (probably because of scarcity of container ships).

The situation in the bulk transport sector, both dry and liquid, was different. The shipping market is more uniform, and local bottlenecks may be more easily absorbed by the global transport supply. The post-COVID-19 recovery stimulated higher transport demand for goods transported in bulk as well, but the pressure for the transport rates was lower than for containers. As a result, rates for dry bulk transport increased on average by 40 % and for tankers by 10 %.

To simulate the impact of the increases in container shipping rates, we decomposed the transport cost data into factors accounting for container costs. We formulated a function of transport cost per value of product that distinguished between a fixed part that depends on the loading/discharging port and a variable part that depends on transport distance.

Transport cost per value is the ratio between transport costs according to the UNCTAD assumptions (CIF price- FOB price) and FOB




Source: authors' calculations based on UNCTAD and GTAP data.

**Fig. 3.** Weighted average of maritime transport costs to FOB price per MAGNET region Source: authors' calculations based on UNCTAD and GTAP data.

value, and represents the weighted average (by value) of all registered trades (at HS2012 HS6 level) of commodity c (in MAGNET commodity groups)

$$tcv_{ijc} = \frac{TotalCIF_{ijc} - TotalFOB_{ijc}}{TotalFOB_{ijc}} \quad (1)$$

where i is the exporting region, j is the importing region and c the commodity (i, j and c all according to the MAGNET structure) A non-linear relationship between container shipping costs and distances between ports has been widely reported in the literature (Furuichi and Otsuka, 2015; Tran et al., 2017). The cost of maritime transportation is determined by the port characteristics and the business conditions agreed between ports and shipping companies. Port-specific factors include port capacity, infrastructure, and productivity (Coşar and Demir, 2018; Notteboom, 2012). Market conditions, such as the relative demand for space in carriers, the world-wide supply of carriers, prevailing market prices for vessels and bunker fuel costs, can all affect the cost of shipping cargo between two ports (Haralambides, 2002). To account for the port specific characteristics shipping costs, we express the transport cost per unit of value as:

$$tcv_{ijc} = \left(\frac{Fixedcost}{FOB}\right)_{ic} + \left(\frac{Fixedcost}{FOB}\right)_{jc} + \left(\frac{Variablecost}{FOB}\right)_{ijc} \times Transportdistance_{ij} \quad (2)$$

which allows the distinction between fixed cost components for both origin and destination, and a variable cost component that is proportional to the transport distance.

The processed dataset, using MAGNET commodities and sectors, contains 12 808 observations. For each commodity c, we applied a regression model that aimed at estimating the port and distance related components of costs. The regression model treats origin and destination as categorical variables, permitting the estimation of fixed port-related

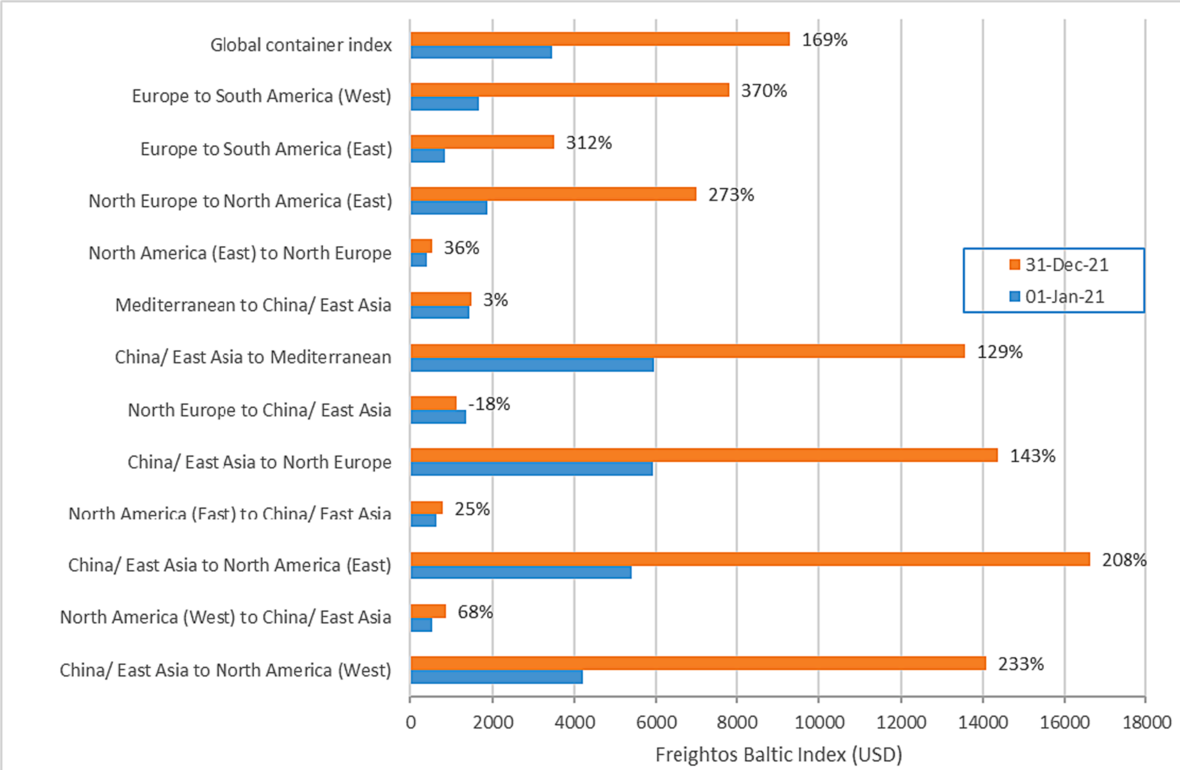



**Fig. 4.** Change in container rate index, year 2021 (Freightos Baltic Index).

costs:

$$tcv_c = f(i, j, Transportdistance) \quad (3)$$

The resulting coefficients of the 39 different commodity models correspond to the fixed and variable components of $tcv_c$ and should have positive values. The results of the commodity level models were all significant, with the majority of adjusted $R^2$ values in the range 0.8–0.99 (the only exceptions being wool (0.636) and processed food (0.770)).

The simulation in MAGNET

$$margin_{ijc} = margin^0_{ijc} \times \frac{fcv_{ijc} + vcv_{ijc} \times \frac{rate_{ijc}}{rate^0_{ijc}}}{tcv_{ijc}} \quad (4)$$

where $margin^0_{ijc}$ is the original margin used in MAGNET and $margin_{ijc}$ is the new one after the shock, $rate^0_{ijc}$ is the average shipping rate in 2020 and $rate_{ijc}$ the average shipping rate in 2021, $fcv_{ijc}$, $vcv_{ijc}$ and $tcv_{ijc}$ are the fixed, variable, and total costs per unit of value, and *i, j, c* are the origin, destination, and commodity, respectively.

## 4. Results

Starting from the 2014 base year, the model is updated to the year 2020 using exogenous shocks of GDP, population, oil price and land productivity growth. The macroeconomic developments exogenously imposed to the model follow the forecasts adopted in the EU Medium-Term Agricultural Outlook (European Commission. Directorate General for Agriculture and Rural Development, 2019). In addition, the model is calibrated around 2020 trade statistics to replicate EU bilateral imports and exports for crucial sectors and trading partners (Ferrari et al., 2021).

The MAGNET model captures the direct impacts from transport costs changes across all regions, providing heterogeneous results per each of them. The model also captures the re-allocation of production factors and redistribution of trade flows accounting of second-round general equilibrium effects.

Unless otherwise stated, reported results in the following section are expressed as percentage deviation from the calibrated baseline for the year 2020.

### 4.1. International trade

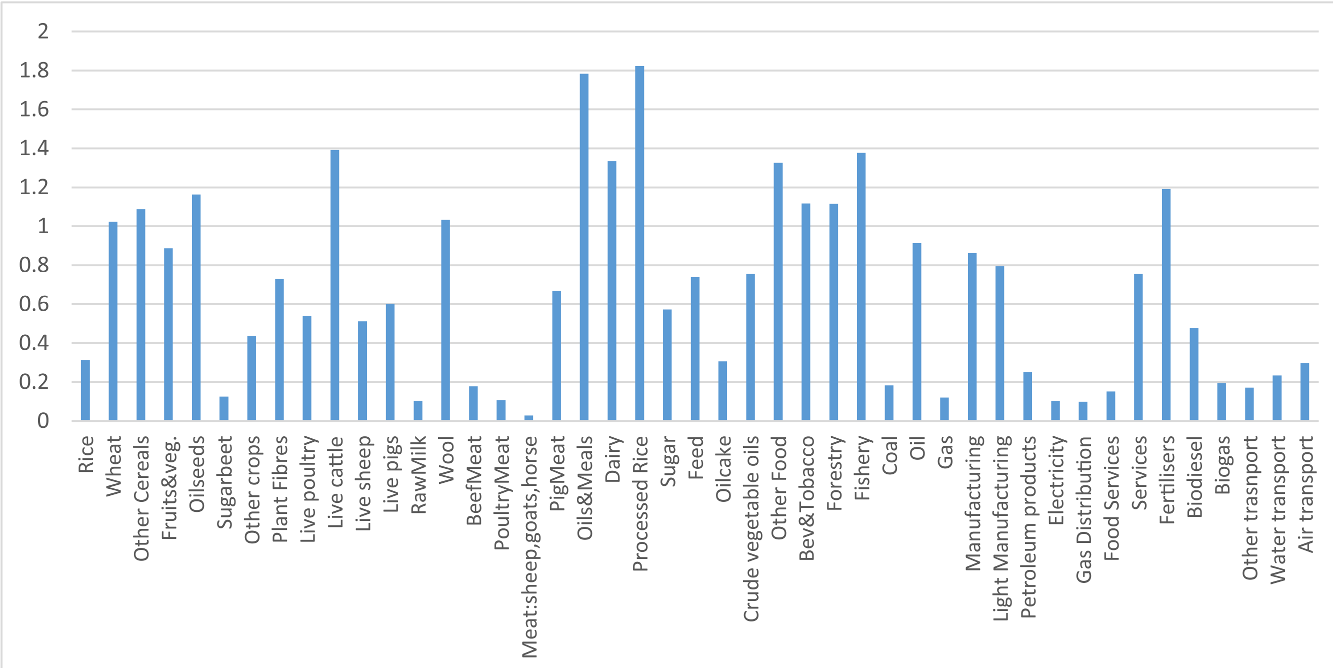
This section presents the impacts of the trade shocks on the global trade main variables such as CIF price, global price, and merchandise volume per commodity.

The implemented trade shocks show a generalised increase of CIF prices. The percentage change of the price index of imports, calculated as a weighted average of CIF prices imports of each commodity in all regions (Fig. 5), shows a linear relationship with the shock applied to the model. CIF prices, which include transportation costs show that products whose transport margins increased the most due to the shock are among those showing the highest CIF prices increase such as wool, dairy, and other food (Fig. 6).

The model calculates the percentage change of CIF price by summing the change of FOB price weighted by the share of FOB price within the CIF price (which depends on the change of domestic production price) and the change of transport fare prices weighted by the share of transport within the CIF price.

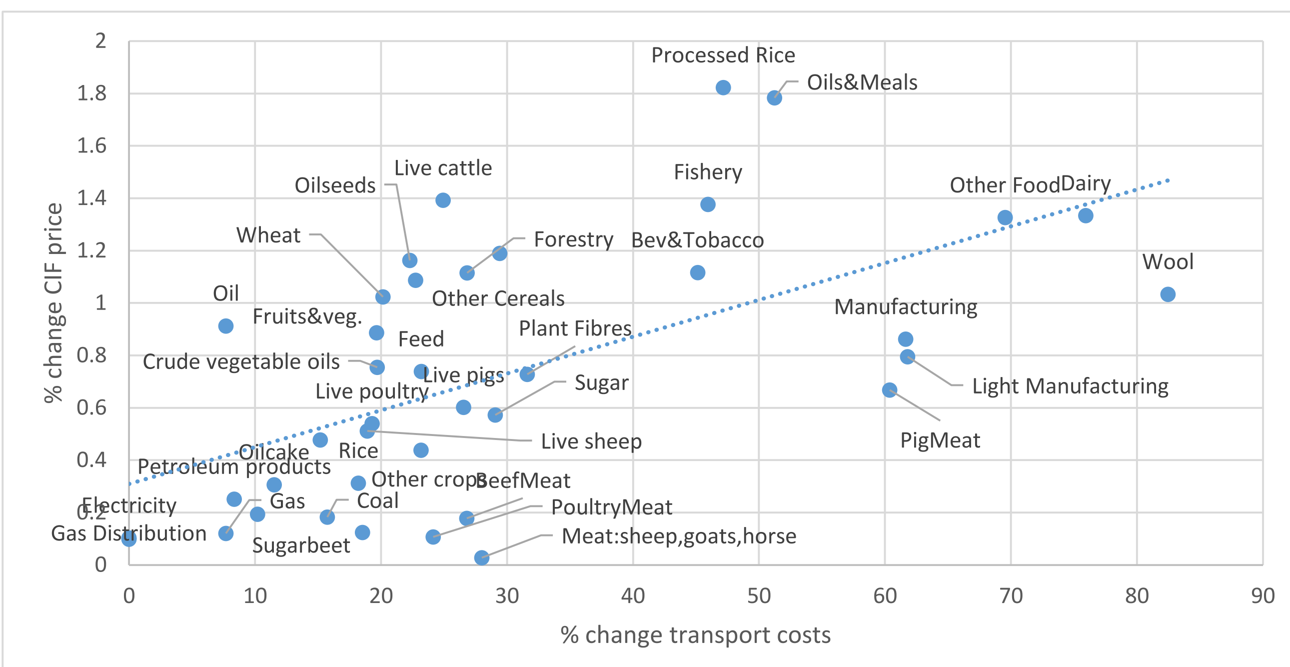
Thus, the key variables causing the increase of import price are the initial share of maritime transport costs within transport costs and the share of transport costs within the CIF prices. This explains the high impact on commodities such as processed rice, and vegetable oils and meals.

The comparison between the change in import price of dairy products and processed rice in the EU helps in understanding the factors behind the different increase of the EU CIF price. First, the two commodities show a different share of maritime transport cost in importing a commodity (65 % for processed rice versus 52 % for dairy products). The cost index for international transport does not only depends on the shock derived from the econometric model but it is weighted by the share of




Source: authors' calculations based on MAGNET results.

**Fig. 5.** Change in CIF price index of imports of commodity (% change from 2020) Source: authors' calculations based on MAGNET results.




Source: authors' calculations based on MAGNET results.

**Fig. 6.** Relationship between % increase in margin and % change of CIF price index. Source: authors' calculations based on MAGNET results.

maritime transport. This means that the weighted average for this index for the EU increase by 7 % for dairy products (as most of the trade is internal to the EU) and 27 % for processed rice, implicitly accounting for the distance the commodity needs to travel to be traded and its characteristics. An additional factor influencing the result is the overall share of the transport cost in the CIF price, whose weighted average for the selected example is around 3 % for dairy products and around 5 % for rice. All these factors lead to an increase of price of imported commodities in the EU by 0.46 % for dairy products and 1.46 % for rice, despite the shipping costs increase more for dairy rather than for processed rice.

On the other hand, the world price index calculated using the FOB prices for each considers the second order effects of the increase in shipping costs which is the increase in production costs indirectly caused by the simulated shocks and the changes in commodity demand driven by changes in prices and income. For this reason, the changes in the FOB price index does not show any linear correlation with applied shocks and while the shocks in maritime transportation costs have mixed impacts on the FOB index prices (Fig. 7), which are steered by the change in the demand of the products. As an example, the effects on wool products FOB price have an opposite sign than on CIF. The demand of imports of wool products due to the increased margins falls (global imports fall by more than 2 %) and due to the specific sector elasticities and market structure, particularly where most of the domestic production is export-oriented, their FOB price falls to reach an equilibrium. More in general, FOB prices in countries that are more export oriented tend to fall, while FOB prices in import-oriented countries grow.

This also explains the differences for example between oil and coal prices. Increased demand of transportation drives the demand of crude oil and petroleum products, even if the shipping cost of oil increases only marginally, while coal demand goes down.

Following the trade cost shock, the volume of world trade would decrease by 0.42 %, while the value of world trade would decrease by 0.23 % (which is equal to around 103 billion USD), compared to the 2020 values estimated by the model. Looking at the volume of trade by commodities, and excluding a few exceptions (poultry and other meat, petroleum products), results show a decrease of both imports and export globally (Fig. 8).

Commodities whose CIF prices increase the most also see the highest reduction of trade volumes, as the case of wool, dairy, and light manufacturing. A peculiar case is represented by the poultry sector, whose increased exports from Brazil, also due to the cross-elasticities between pig meat and poultry meat, are driving the global trade into positive territory.

The CIF price index per country (Fig. 9) reflects the impact of the shocks on analysed countries and regions and is driven by the increase in the margins for manufactured goods, which are the products with the highest margin increase and highly trade products. Countries whose CIF price index grows the most (i.e., Malaysia, Brazil, China, Chile Japan, USA, and Argentina) are either those countries whose import price index for manufacturing grow the most or those countries whose share of manufacturing on imports are the highest.

### 4.2. Macroeconomic impacts

This section analyses the effects of the presented shocks on some of the most relevant macroeconomic indicators such as GDP and terms of trade.

The increase of transportation cost has a marginal negative impact on the gross domestic product (GDP) of all countries covered (Fig. 10). In global terms, the GDP loss is equal to −0.05 %, which is equal to around 45 billion US dollars. Regionally, South-East Asian countries are the most affected ones with China accounting for almost half of the global loss, and together with Vietnam and Malaysia the most affected in percentage terms.

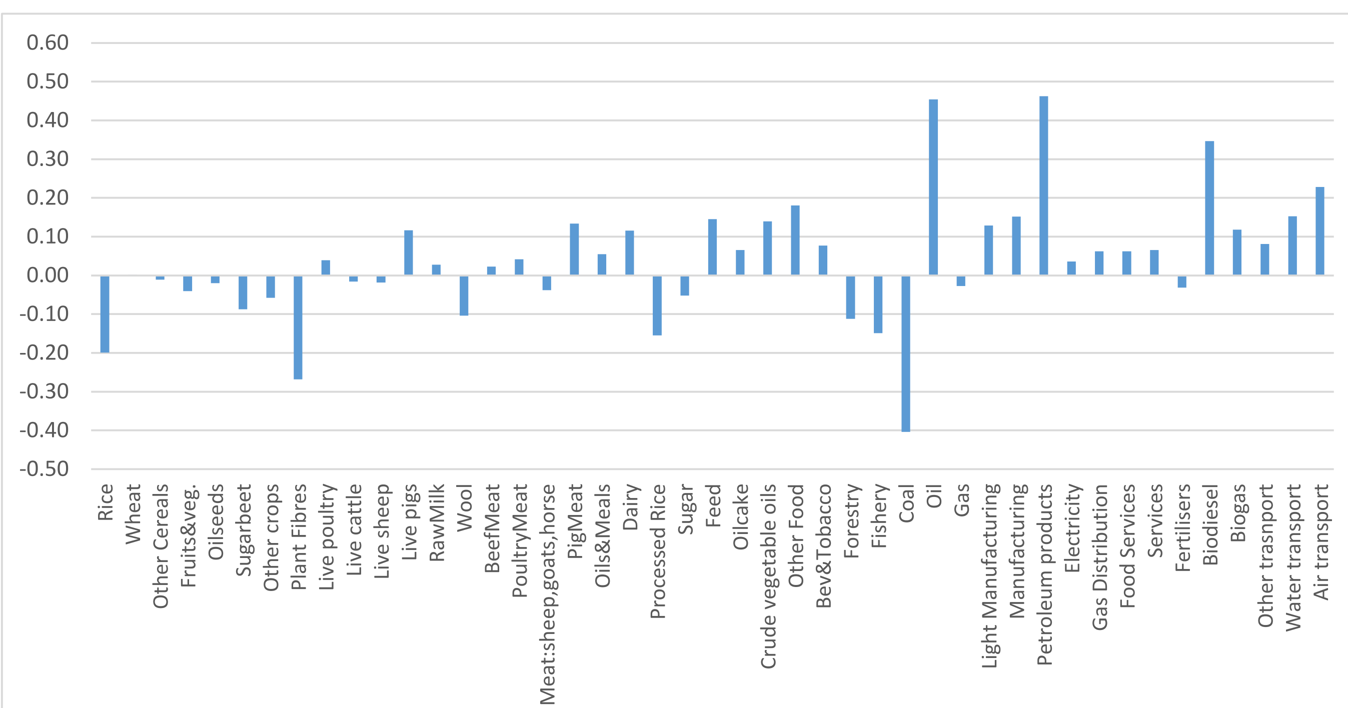
The change of a country's terms of trade, i.e., the ratio between a country's index of exports prices and imports prices (Fig. 11) explains part of the impact on the countries' GDP. The rise of the imports bill is in all cases superior to the rise in the index of price received for exports (which in some cases is already negative) causing a generalised fall in the terms of trade.

In the cases of Vietnam and Malaysia, which show among the highest GDP fall, their production of light manufacturing drops significantly, causing an associated drop of their domestic income and consumption and consequently a reduction of their GDPs.

### 4.3. Domestic price impacts

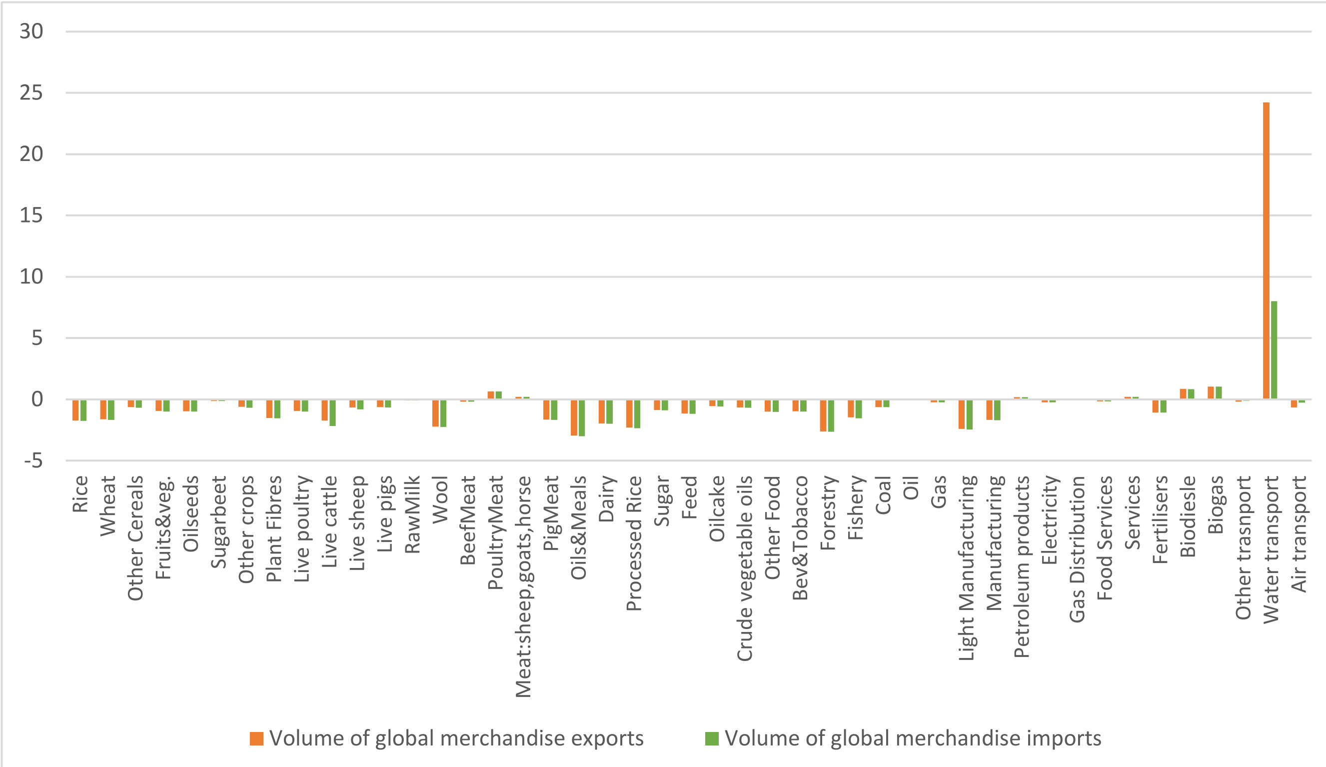
This section focuses on the impact of the rise in transportation costs on the domestic prices in all regions analysed within the modelling framework to check how much the shock might affect the formation of domestic prices in different sectors. In particular, the focus is on agri-food products as maritime transport costs are particularly high for some agricultural products (Korinek and Sourdin, 2010).

One of the main indirect effects of increased shipping costs is the increase in the producer price of commodities and consequently their consumption prices. The price of imported goods (used for intermediate or final consumption) increases, causing an increase of production costs. The increase of costs has a further indirect effect of reducing demand on



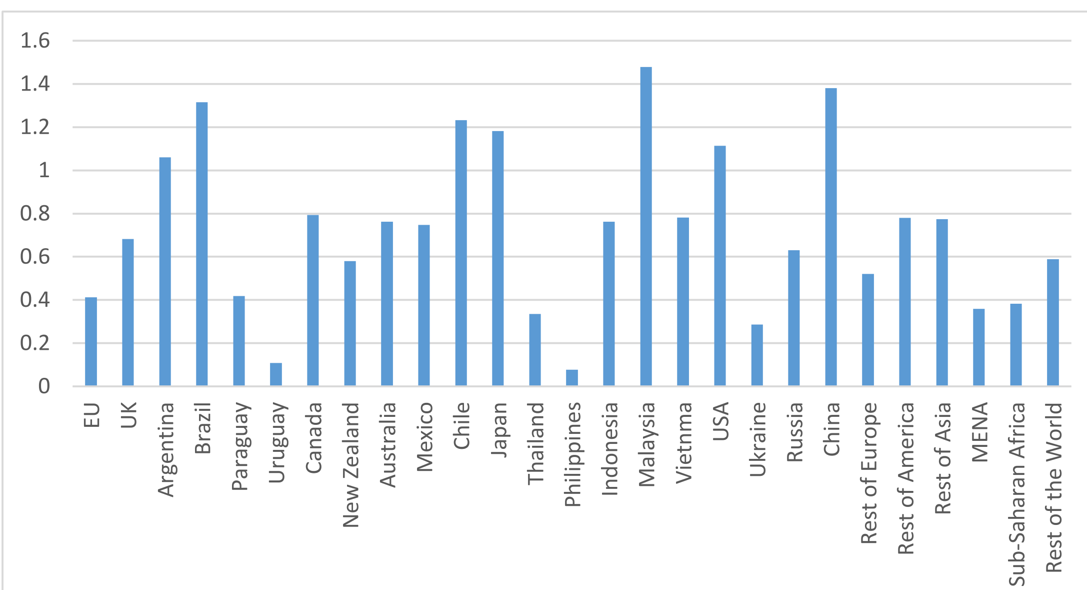
Source: authors' calculations based on MAGNET results.

**Fig. 7.** Impacts of global prices (% change from 2020), selected commodities Source: authors' calculations based on MAGNET results.




*Source: authors' calculations based on MAGNET results.*

**Fig. 8.** Impacts on global trade volume (% change from 2020) Source: authors' calculations based on MAGNET results. Source: authors' calculations based on MAGNET results.

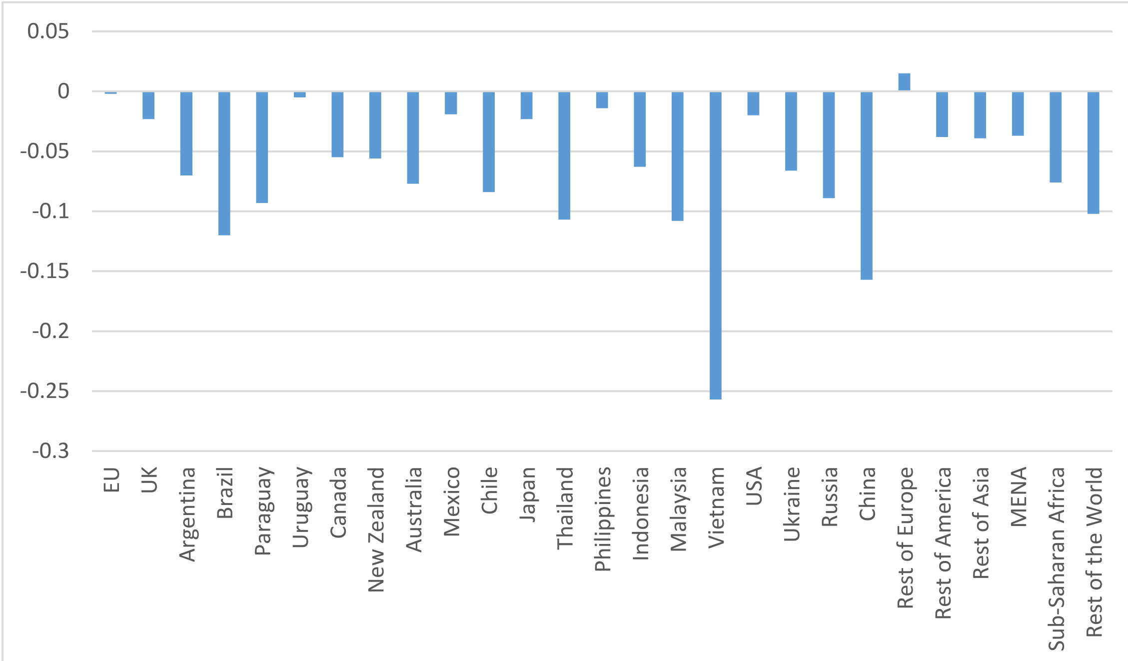



*Source: authors' calculations based on MAGNET results.*

**Fig. 9.** CIF Price index of imports, by region (% change from 2020) authors' calculations based on MAGNET results.

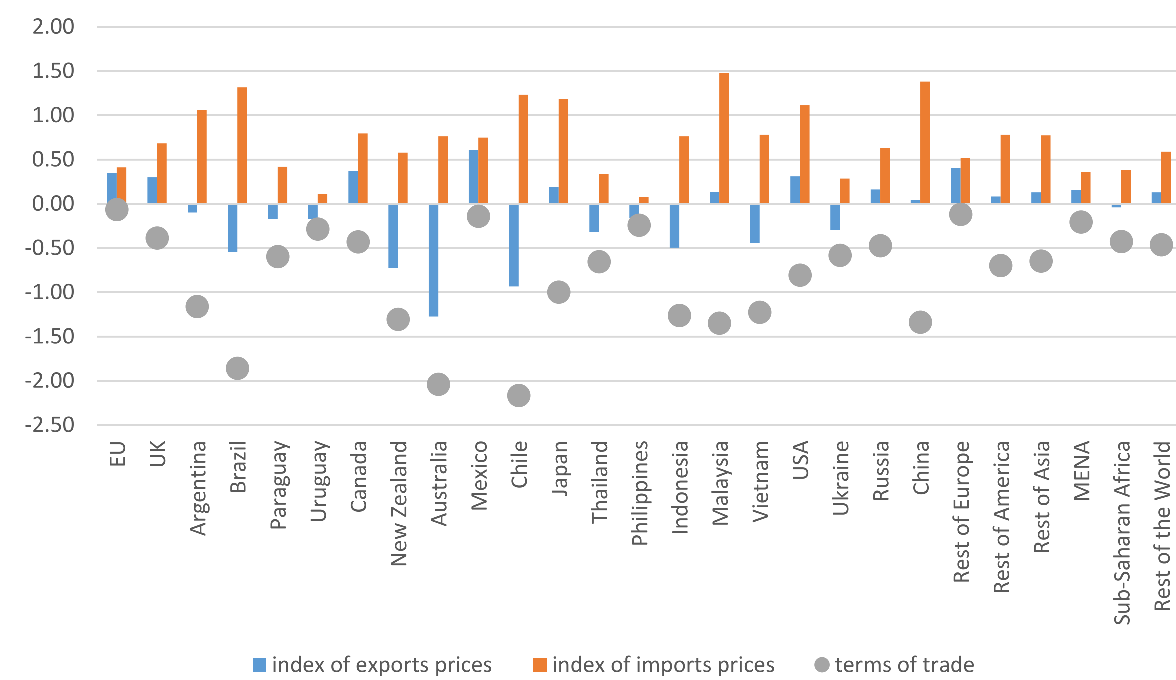
domestic market and consequently a slight price reduction. Once again, the net trade position of the countries and their trade patterns determine if the dominant effect is coming from the external or internal markets.

The percentage change of the price index for private household consumption expenditures, the price index for private consumption for cereals, the price index for private agriculture consumptions, and the price index for private agri-food consumption expenditure (including meat, processed rice, dairy, and other processed food) show how the change in transportation costs affect domestic consumption prices. These indexes show the effects of the shocks on the price change in the selected countries, (Fig. 12). Countries that are large importers of agri-food commodities, (e.g., Japan) see their agri-food related price indices increase. The cereal price index increases by around 1.5 % in Japan while the manufactured food price index by around 0.5 %. In agri-




*Source: authors' calculations based on MAGNET results.*

**Fig. 10.** Impacts on real GDP (% change from 2020) Source: authors' calculations based on MAGNET results.

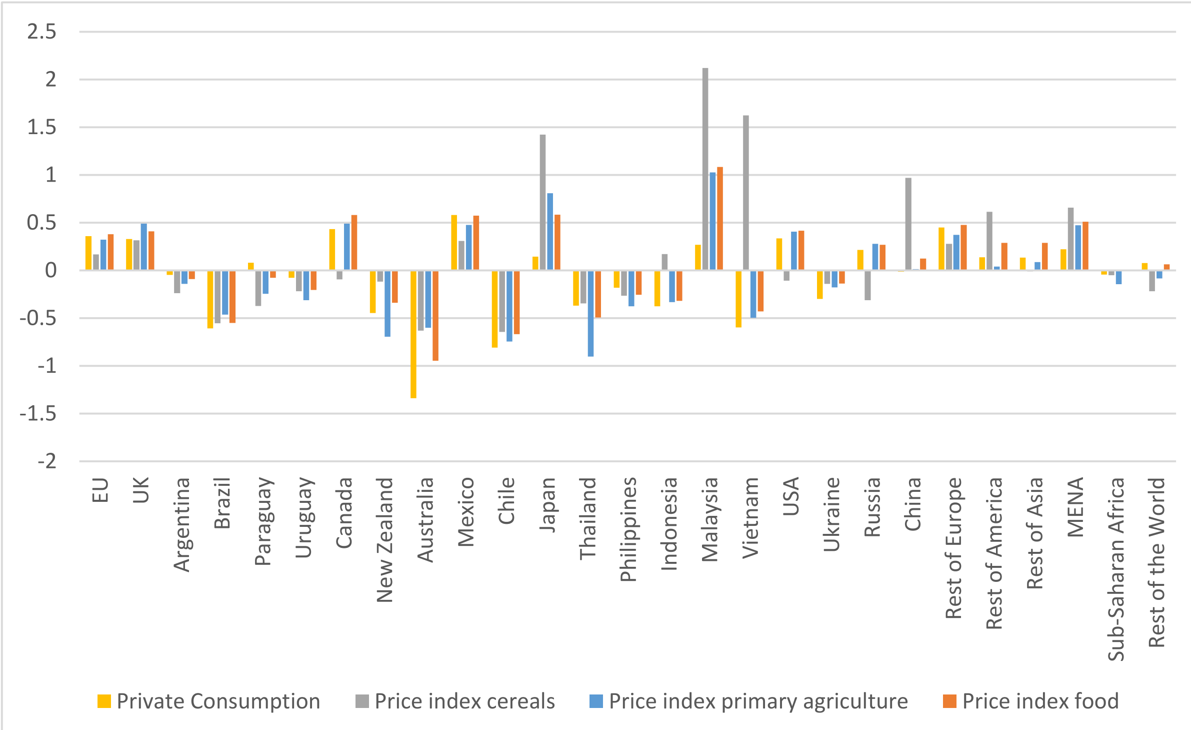



*Source: authors' calculations based on MAGNET results.*

**Fig. 11.** Impacts on Terms of trade, (% change from 2020) Source: authors' calculations based on MAGNET results.

food exporters countries (e.g., Mercosur countries), the agri-food related price indices drop as their exports diminish (also causing a decrease in household's income) and the increased availability of commodities for domestic consumption (together with decreased income) depress domestic prices. The same holds for the overall price index. Net-sellers countries of light and manufactured goods face a reduction in their exports demand, which causes a fall in domestic production and in associated commodities price. This is the case of most South-East Asian countries such as Vietnam, and Thailand.

The MAGNET model, as for all this class of models, returns real and not nominal price changes. In this model, monetary policies are not considered, and the presented changes of prices do not attempt to analyse inflationary shocks but rather how the transportation cost increase is affecting production costs and modify relative prices within the model.




*Source: authors' calculations based on MAGNET results.*

**Fig. 12.** Price index for private consumption expenditure, cereals, primary agriculture, and processed food (% change from 2020) Source: authors' calculations based on MAGNET results.

## 5. Discussion

This paper combines a global transportation database to a global economic model in an interdisciplinary manner to improve modelling capacity and to measure the global impacts of the recent episode of increase of freight transport costs. The approach presented here is applicable to a wide range of issues where the link between transport costs and international trade is of relevance.

The model is responsive to the variance of transport costs within each commodity group and applying specific origin–destination dependent margins (as opposed to a uniform increase of the margin per commodity) improves the reliability of the results. The non-uniform increase in transport costs leads to a shift towards the markets with the lowest resulting CIF price and creates a within-sector substitution effect. For commodities with very elastic demand and for which the transport costs represent a high share of the CIF price, such as perishable agricultural products, an increase in transport costs leads to only combinations with lower FOB prices to be traded, resulting in lower volumes at lower prices.

The indirect effects (increase in production price, change in income and demand) across all commodity groups are also considerable. Even commodities that are not directly affected by costs in transport (no change in the margin) present fluctuations in their prices and volumes, reflecting the changing conditions in their input sectors. This is an indication of relative price distortion both across markets –as would be expected by an increase in transport costs- and within markets since the change in production and consumption patterns would lead to the re-allocation of resources globally. Rising maritime transport costs would discourage transportation flows with high increase of costs (e.g., longer distances of higher share of margins within the overall price) and international trade would be more localized. On the contrary, lower transportation costs (as trade facilitation in general) encourages a wider geographic and sectoral dispersion.

The results confirm the correlation between maritime transport accessibility and economic growth as extensively discussed in the literature (Fratila (Adam) et al., 2021; Lane and Pretes, 2020; Park et al., 2019 to cite the most recent literature findings). In that sense, economies with lower transport costs for international trade have an advantage as regards access to markets and are more resilient to fluctuations in shipping costs. Seen from the opposite extreme, though, developing countries with weaker economic structures are more vulnerable to such distortions, since their productive capacity cannot easily adapt and find new geographic and commodity markets. The results also confirm the impact of the high degree of interdependence of maritime transport markets at international level (Christodoulou et al., 2019). A disruption in the operations of even a limited number of routes can have repercussions on trade in different geographical areas that form part of the global supply chains, directly or indirectly.

The challenges that the fluctuation of maritime costs raise for international trade also provide cause for a reflection on the resilience of global supply chains. The container crisis of 2022 has shown that a global event such as the Covid-19 pandemic might impact the seamlessness of important nodes for international trade, causing spill-over effects to other countries and impacting prices.

The international maritime transport market is the archetypical example of an open, international market that follows the law of supply and demand. Disruptions in operations can lead to price shocks in the short term and the re-allocation of capacity in the medium- to long-term, with the market normally self-regulating without the need of policy interventions. Price shocks may, however, affect international trade patterns and hurt specific sectors or regions disproportionally. Our analysis shows that the risk is higher in markets with limited production or transport options. Smaller economies without sufficient flexibility to modify their production, source of imports or destination of exports can be especially vulnerable. Regions with limited infrastructure have less flexibility in using alternatives for transportation.

## 6. Conclusion

This paper evaluates the impact of the 2021–22 surge in rates for containerized and bulk costs applying a detailed transport database. A multi-region general equilibrium model analyses the sectorial and macroeconomic impacts of the recent surge in shipping costs. The increase in shipping rates had widespread repercussions on international trade, causing the increase in price and reduction in trade flows. The results show how rising maritime transport costs tend to reverse the trend towards globalisation of international trade and favour localization.

From a policy perspective, two options could mitigate the impacts of fluctuations of maritime transport costs. On one hand -at the micro level- higher public and private investment can improve the readiness, productivity and capacity of transport infrastructure for maritime and other modes would increase the options available and limit the extent of the distortions caused by occasional bottlenecks, for example, ports allowing a larger variety of ship calls, or improved rail freight services could reduce port congestion. In addition, operators and authorities can explore organisation and procedural measures to reduce the costs and time associated with handling goods at port level. On the other hand –at the macro level- increasing diversification in production and supply chains would spread the risks inherent in international supply chains, hence absorbing shocks in prices and limiting the macroeconomic impacts. If left on its own, the market can adapt to such risks of disruption but –as our results suggest- the resulting international trade equilibrium may have disproportionate impacts for specific regions and sectors. Facilitating trade through revised international agreements can remove barriers that limit the flexibility of the markets and allow a softer reaction to such disruptions.

The typical methodological caveats associated to any economic modelling approach are also applicable to this study, such as the deterministic behaviour of agents, the assumption of equilibrium market clearing and the optimal allocation of resources in initial situation and given available technologies. However, the modelling of a shock to prices would not reflect the effect on commodity prices observed in real markets, as price elasticities would not consider market speculation and substitution effects by consumers faced with a surge of prices. Despite these caveats and the fact that MAGNET has certain specific limitations, i.e., it is not a network model where transport distance and logistics between countries can be simulated with geographical detail., the model, connected with the employed detailed trade database, is extremely useful to get insights into directions of trade, price changes and macroeconomic reactions resulting from shocks on the maritime transport sector. While the accuracy of the projections may be subject to an important level of uncertainty, the direction of the expected impacts can be considered as reliable and can be validated empirically. The shock in transport prices is simulated as a combination of fixed and variable costs but it does not model the dynamics happened post-Covid, specifically about port congestion and lack of containers. Finally, the commodity aggregation of the GTAP database employed in MAGNET is rather coarse, hiding potential differences in commodity transportation and handling within the same group. Finally, the methodology presented here uses a regression model to associate shipping costs with geographic aspects and links it with a complex economic model. While shipping costs are a crucial factor, and the central issue in the research question, there are numerous other factors that influence the fluctuations in final prices.

Future research could further investigate the effects of shocks on factors such as employment, distribution and food security in more vulnerable countries, and the effects of policies (trade facilitation, trade integration) and investments on key socioeconomic indicators. Future work can also explore suitable indicators on the structure of each economy and correlate how factors such as the size, depth, complexity of each regional economy contributes to its resilience as regards shocks in shipping costs. Considering the power of general equilibrium models and the risks that international trade faces due to geopolitical, economical as well as climatic nature, it is worth expanding this approach of combining trade models with transport data and models to explore additional modelling scenarios. For example, a better breakdown of transport cost drivers within maritime fares, highlighting the share of fuel costs or loading costs within transport costs, or modelling of economies of scale within container handling (e.g., larger ships, or more efficient ports) could allow also to define options to mitigate the impact of maritime costs. The combination of trade models with global maritime traffic tools could also allow for a better rendition of maritime traffic routes and allow a better simulation of the economic impacts of disruptions.

**Disclaimer:** The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect those of the European Commission.

## CRediT authorship contribution statement

**Emanuele Ferrari:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Panayotis Christidis:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Paolo Bolsi:** Conceptualization, Validation, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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