Which routes to inflation?

An analysis of the impact of global shipping cost shocks on import prices and market dynamics.

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Abstract

This paper examines the impact of rising air and maritime transport costs on the prices of imported goods in the European Union during the 2021-2022 inflationary surge. Building a unique dataset on all extra-European imports at the product level, we construct an index of transport shocks based on air and sea freight prices, differentiated by routes and accounting for shock vulnerability. We find that the elasticity at a 1% shock for China on the cost of air and sea transport on cumulative import price changes peaks one year after the shock, around 0.15. Restricting to a sample for which the share of sea and air freight sum to one, after a 1% increase in transport costs, import prices increase on average by 0.24%, 13 months after the shock. The shock lasts for 18 months. Finally, we build a model à la Atkeson, Burstein (2008) to explain the incomplete pass-through of transport cost shocks, attributing it to a reallocation of market shares towards domestic firms, which increase their markups, while foreign firms reduce theirs. Our model predicts that a 10% rise in transport costs would lead to a 7-9% increase in domestic price indexes and a 0.9-1.9% rise in foreign price indexes, resulting in an overall aggregate price index increase of 4%.

Keywords: Inflation, Transport costs, Supply chain disruption

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Of course, all mistakes are my own.

Contents

1 Introduction

After three decades of price stability, inflation in most Western economies has been rising and accelerating since the middle of 2021. In 2022, inflation peaked to 9.0 %, 6.3% and 7.5% in the United Kingdom, the United States and the Eurozone respectively, (Reis, 2022). Inflation gradually receded in 2023. A combination of causes was invoked to explain this surge in inflation, a quick rebound after the Covid-19 pandemic, disruption in the global value chain, the production of microchips hitting its capacity constraint and the energy crisis, in particular resulting from the war in Ukraine.

This paper focuses on the second family of causes identified by Reis (2022). While the price of transport has decreased over the last decades, the quick rebound after the Covid-19 pandemic and the revival of Chinese production result in an insufficient supply of ships and containers to satisfy the demand. Some bottlenecks appeared in ports, in particular in China, causing congestion, and disruption in the global value chain (Bai and al., 2024). Similarly, from the beginning of March, 2020, air freight, based on regular lines and passenger flights was impacted by restrictions imposed during the pandemic and the price of air freight continued to increase from the second half of 2021.

Despite the attention to energy, metal commodity and food price shocks, little works have been done to try to quantify the contribution of an increase in transport costs to the recent inflation surge. Carrière-Swallow and al. (2022) found that a one-standard-deviation increase in global shipping costs increases domestic headline inflation by about 0.15 percentage point. This effect depends on the degree of integration into global value chains, on the share of imports and domestic consumption and on the strength of monetary policy. However, this study, done at the aggregate level, does not distinguish by types of transport and uses the same index for the price of transport for all countries. Moreover, goods are heterogeneously affected by transport shocks depending on their types. For instance, perishable goods are more vulnerable to an air freight shock.

Our first contribution is to quantify the impact of an increase in transport on the price of manufacturing imported goods in the European Union at a disaggregated level, including in our analysis a factor of vulnerability to the shock. We built a unique dataset on all Extra-European manufacturing imports from 2017 to 2023, at the product (CN-8-digit) level with information about shares transported by each mode of transport and containers in value and quantity. Our dataset includes 27 European declarants (The United Kingdom is excluded) and 214 extra European partners. Even if the ratio between the cost of insurance and freight (CIF, the value at the importer border) and the free on board (FOB, value at the exporter border) is the standard indicator for the price of transport, it cannot be usable as such and could only be exploited as proxy of transport costs as long as one looks at variations across exporters (Hummels (2007), Hummel and Lugovskyy (2006), Gaulier and al. (2008)). Ocean freight is structured around routes with fixed departures and arrival times, while tramp shipping consists of an agreement between the charterer and the ship owner. We were able to measure precisely the price of transport of the main routes. We extracted the Drewly price index for the maritime freight for 8 routes for containerized products, The Baltic Exchange Dry Index (BDI) for goods transported in bulk and finally the Traffic Air Cargo (TAC) for air freight. Section 3 presents the methodology we followed to build our dataset.

Having precise estimates for the price of maritime freight from the port of Shanghai, we choose to focus our empirical analysis on China. Being the first trading partner with Europe, Chinese ports were particularly impacted by bottlenecks during the pandemic (Bai and al., 2022). In particular, the zero-Covid policy in Shanghai in the spring of 2022 led to port closure, and large delays in production, and international container trade in manufacturing. Section 4 underlines the key descriptive facts. From the second half of 2021, the total value of Extra-European imports increased by more than the total quantity. The frequency of price adjustments and positive variations increased in 2021 and 2022. At the same time, the price of air and sea freight for departures from Shanghai rose from the end of 2020. The Drewly price index for the Shanghai-Rotterdam route peaked at 14807 on October 7, 2021, while it was only 2325 USD per 40ft container on January 03, 2020. Similarly, the TAC index peaked at 5254 USD per kg on December 09, 2021 while it was only 1552 on January 02, 2020.

Then, we try to estimate the effect of this increase in transport cost on the price of imported goods for the period 2018-2023. Using a weighted estimate of the price of air and maritime transport, depending on quantity and value shares imported by each mode of transport, we use the first and cumulative local projection estimators to quantify the impact of the shock, following Jordà (2005). Section 5 presents the empirical strategy and our main results can be found in section 6. The elasticity at a 1% shock for China on the cost of air and sea transport on cumulative price changes, peaked one year after the shock, around 0.15. Restricting to a sample for which the share of sea and air freight sum to one, after a 1% increase in transport costs, import prices increase on average by 0.24%, 13 months after the shock, compared to the period of the shock. The effect is quite persistent, lasting 18 months. Import prices increased by less than the shock and responded with a lag. This suggests the existence of price rigidities and incomplete pass-through of the shock into prices.

Our last contribution is to simulate a shock on the price of transport, underlying the channel explaining the incomplete pass-through of transport cost shocks. Based on Atkeson-Burstein (2008), our model, presented in section 7, is an extension of De Loecker and al. (2022) for an open economy with two countries. In this model, there is a finite number of firms within each sector. The demand elasticity is a decreasing function of the market shares. The markup is no longer constant, like in Guironi and Melitz (2005) but is an increasing function of the market shares. An increase in transport costs, implies a reallocation of market shares towards the domestic firms, increasing domestic markups at the expense of foreign firms for which markups decrease. Import prices increase by less than the shock, while the price of goods produced domestically also increases. We calibrate the model in section 8 on the European Union, using the level of concentration and the import shares as our key moments. Finally, we simulate a shock on the price of transport in section 9. We find that after a 10% increase in transport costs, the aggregate domestic and foreign price indexes are expected to increase respectively to 7-9% and 0.9-1.9%, resulting in a rise in the aggregate price index of 4%.

2 Literature review

This paper builds on and tries to contribute to three different strands of literature. First it underlines the importance of transport costs, in still impacting aggregate economic variables. Focusing on price variations, our paper tries to contribute to understanding better the causes of the recent inflation surge of

2021-2022. Finally, it builds on the large literature of pass-through and tries to quantify market disruption after a shock on the price of transport.

First this project builds on the existing literature about the importance of shipping costs on trade. One could have though the world was becoming flat. The price of transport costs gradually decreased, in particular with the development of containers. Before, shipping activities were highly labor intensive. It was time-consuming to load and unload freight on ships, trains or trucks. The container facilitated intermodal transports. Using a dataset on dry bulk freights rates over the period 1850-2020, Jacks and Stuermer (2021) found that they followed a downward path with a cumulative decline of 79%. Hummels (2007) with air freight came to the same conclusions. The price of air freight decreased from $3.87 in 1955 to under $0.30 in 2004 (expressed in 2000 U.S. dollars). Despite this downward trend, twenty years ago Anderson and Van Wincoop (2004) showed that trade costs were still high, particularly for poor countries. The ad valorem tax equivalent (a constant percentage of the producer price per unit traded) is about 170%, which can be decomposed into "21% transportation costs, 44% border-related trade barriers and 55% retail and wholesale distribution costs (2.7=1.21*1.44*1.55)" (Anderson and Van Wincoop, (2004), p.692)). Transport costs have still implications on global trade and prices. In early February 2024, The Canal of Suez was affected by disruption and global exports had declined by more than 7%. (Dunn and Leibovici, (2024)). Carrière-Sallow and al. (2022), using the BDI index for sea freight, at the aggregate level, found a significant increase in import prices, Producer Price Index (PPI), headline, and core inflation, as well as inflation expectations. Our paper contributes to this literature, by finding evidence of an impact of an increase in transport cost, on the price of goods imported from China in Europe. To our knowledge our paper is the first to use index for the cost of transport, depending both on air and sea freight and to run an analysis at the product level. We also contribute to the discussion about the form of transport cost by providing descriptive evidence of asymmetry in the price of maritime transport.

Our empirical analysis tries to contribute to understanding the drivers explaining the inflation surge of 2021-2022, by finding evidence of an effect of the price of sea and air transport on the price of imported goods from China at destination to Europe. Lafrogne Joussier and al. (2023) found that, while energy shocks were fully pass-through by firms, the impact on manufacturing inflation was limited, accounting for approximately 10% of total PPI growth. di Giovanni and al. (2022) found that foreign shocks and global supply chain bottlenecks played a greater role in explaining inflation in the Eurozone over the period 2020-2021. Our paper also relies on recent studies about the effects of supply chain disruptions during the COVID-19 pandemic on inflation (Finck and Tillmann (2022) for the euro area and Gordon and Clark (2023) for the US). Bai and al. (2024) documented that supply chain shocks drove inflation in 2021 but, in 2022, traditional supply and demand shock also played a role in explaining inflation in the US. They measured global supply chain disturbance by building a new index based on the Automatic Identification System, which gives instantaneous information about container ships in major ports of the world. Finck and Tillmann (2022) also found that global supply chain shock caused a drop in euro area real economic activity and a strong increase in consumer prices.

Finally, our project tries to contribute to the literature on incomplete pass-through. Atkeson and Burstein (2008) proposed a trade model generating incomplete pass-through in the presence of imperfect competition and trade costs, which was then widely used in theoretical and empirical works (Amiti and al., (2019)). We developed a model close to De Loecker and al. (2022), which proposed a general equilibrium economy with endogenous markups in which two channels explain changes in market power: competition (number of potential competitors) and technology shock. Our paper is also inspired from Edmond and al. (2015), which studied the procompetitive gains from international trade with a model à la Atkeson and Burstein (2008), comparing the extreme cases of autarky and a simulated economy based on Taiwanese data. We extend De Loecker and al. (2022) with a two-country economy, emphasizing the importance of transport cost as a key channel in the reallocation of market power, assuming, as in Edmond and al. (2015) that the two countries are perfectly symmetric in terms of sector and aggregate productivity. We quantify market disruptions at the firm, sector and aggregate level after a transport cost shock and their consequences on consumption, price indexes, market concentration and imports.

3 Data and stylized facts

This paper is based on an original dataset of extra-European trade flows, including vulnerability to transport shocks and several indexes for the price of transport at a monthly frequency over the period 2017-2023.

First, we use the COMEXT dataset from EUROSTAT to recover the import prices, and quantities imported in the European Union for the period 2017-2023. This dataset includes all trade flows for the European Union. We focus our analysis on extra-European import flows, as we are interested in the increase in transport costs, in particular maritime and air freights. To remove the effect of the Brexit, we exclude the United Kingdom from the analysis. Prices are sensitive to aggregation and disaggregation so we choose the lowest level of aggregation, at a declarant x partner x cn8 level. We follow the recommendations of, Bergounhon, Lenoir, Méjean (2018). Because of changes in the cn8 nomenclature and in particular in 2022 when the HS6 system was modified, some declarant x partner x cn8 relationships may be affected. We chose to start our analysis in 2017 to limit the errors due to a change in the HS6 nomenclature in 2017. To test the robustness of our results, it would be relevant to use other levels of aggregation such that the "id_conc", from Behrens and Martin (2015), which identifies the smallest level of aggregation such that, one can assign a common, time-invariant, new product code. We define prices as unit values while ensuring the units are consistent over the time period within a declarant x partner x cn8 relationship. We compute the share transported by one of the main modes of transport, rail, road, air, sea and inland waterway, as well as the share containerized at the HS6 level. We assume that the shares are similar for each cn8 within the HS6 nomenclature. To avoid contamination effects due to the presence of energy goods, we focus our analysis on the manufacturing sector at the 2 digit- level as defined in the ISIC, United Nations systems. We further exclude from this dataset motor vehicles, transported by Ro-Ro cargo, for which the price of transport could be different from the one used for shipping containerized goods (the list of products excluded is provided in the appendix, Tables 12.1 and 12.2). We also remove medicals products identified by the World Bank and the World Trade Organization as necessary during the pandemic (listed in the appendix, Tables 12.3, 12.4, 12.5, 12.6). The sample includes 41,552,616 observations, a total of 8,547 cn8 products.

Then, we extract indicators for the price of sea and air frieght. Direct transport charges data are available at disaggregated level and are considered of good quality. For instance, Hummels and Lugovskyy (2006) used transport costs for New Zealand but they remain limited to a small number of countries or localities. Due to the difficulty of accessing such data, researchers often use the ratio between the cost of insurance and freight (CiF, the value at the importer border) and the free on board (FoB, value at the exporter border) values. As a given trade flow is counted twice, comparing these two values gives an indicator of the price of transport. They can be compared across pairs of countries and are publicly available for a broad range of countries and years at aggregated and disaggregated levels (COMTRADE dataset). However, as mentioned in Gaulier and al. (2008), the CIF/FoB ratio suffers from measurement errors, and differences in registration methods across countries in particular. Moreover, this estimate does not distinguish by mode of transport. Sea and air freight are affected by different shocks. To differentiate the impact of transport costs on the price of imported goods, we use indexes from consulting companies for our estimates of the price of transport for containerized and non-containerized maritime flows and air freight. There are two kinds of sea freight, tramp and liner shipping. Liner shipping is based on regular routes, with fixed departure and port calls. Tramp shipping is an agreement between the ship owner and the charterer for cargo transportation. It is not regular and is based on the demand from the charterer. Even if we cannot capture the price of tramp shipping, we can use information about shipping routes, which are likely to be a good estimate for the price of maritime freight. We extract the Drewly indexes for the containerized maritime freight, which is available for eight routes from January 2017 to January 2024. It captures information about potential perturbation of the supply chain, among other, security charge, canal fees/surcharges, cargo declaration fees, and port congestion surcharges. Several private consulting firms provide indexes for the price of maritime freight. To ensure the shock on the price of transport was not due to specific methodology used by Drewly, we compare this index with other companies (Figure 12 in the appendix). They are very similar. The correlation between the Freightos and the Drewly price indexes was 0.9992 over the period 2017-2024. They are seasonally adjusted and include a currency adjustment factor. In addition to these indexes for the price of containerized goods, we extract the Baltic Dry index (BDI) from the London-based Exchange for solid bulk, goods not packed and loaded directly into a vessel (Figure 13). It is based on more than twenty routes and is a composite of the index for different sizes of vessels. Finally, we extract the Traffic Air Cargo index (TAC), to estimate the cost of air freight, which includes 17 routes and all costs paid to carriers. We were able to extract only the BDI and the TAC indexes at a worldwide level. Further details about the methodology used to calculate these indexes are provided in the appendix . The TAC index is only available from 2018.

Finally, we recover the price of crude oil and the World Food Index from the International Monetary Fund (IMF) and the U.S. Dollars to Euro Spot Exchange Rate from the St. Louis FED.

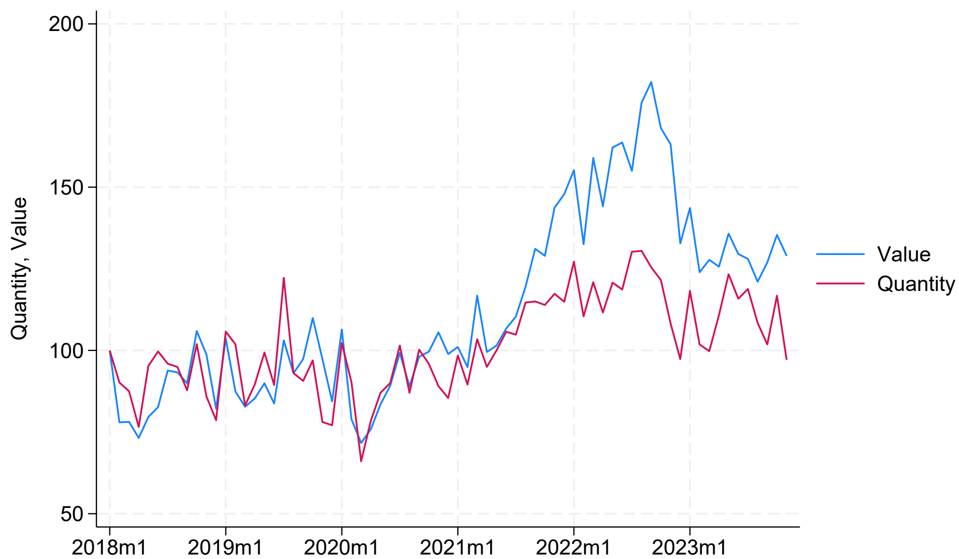
4 Descriptive statistics

In the rest of the analysis, we restrict our sample to imports from China, as China is the principal trading partner with the European Union, representing 19.8% and 29.8% of the quantity and value of manufacturing goods imported in Europe for the period 2017-2023. The dataset includes all imports from China in the manufacturing sectors, a total of 7,894 different goods (cn8) and 5,670,725 observations. We chose this country to reduce the measurement errors in our estimate for the price of transport, using the Shanghai-Rotterdam route as our estimator for the cost of sea freight. Moreover, Chinese ports were particularly impacted by bottlenecks in 2021, causing congestion and increasing delays for delivering.

After the pandemic, because of a combination of factors affecting demand and supply, the monthly imported prices increased while in parallel, the price of maritime and air freight rose. This section recovers four stylized facts about the increase in import and freight prices before and during the inflationary period.

4.0.1 Fact 1: Variations of total quantity and value imported

Figure 1: Quantity and value of imported manufacturing goods from China (100 in January 2018)



Notes: This figure plots the total value and quantity of imported manufacturing goods from China relative to January 2018 level. Medical products (list in the appendix, Tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix) are excluded.

In Figure 1, we plot the total value and quantity imported from China by the European partners, relative to the level of January, 2018. We can observe a drop in both total value and quantity at the beginning of 2020. During this period, Chinese production dropped as well as European demand because of lockdowns. At the end of 2020, with the increase in the demand for Chinese goods, and the reopening of China, the total quantity and value imported increased, recovering their pre-pandemic level. It further increased from 2021. Interestingly, from the middle of 2021, values increased more than the quantities imported. The gap peaked in September 2022 at 56 points and then narrowed from the end of 2022. Similar findings can be found for all Extra-European imports (Figure 14 in the appendix). Figure 2 explores further the monthly price variations and suggests, that indeed, prices were more likely to change and these variations being positive during the high inflationary period.

4.0.2 Fact 2: Monthly import price variations

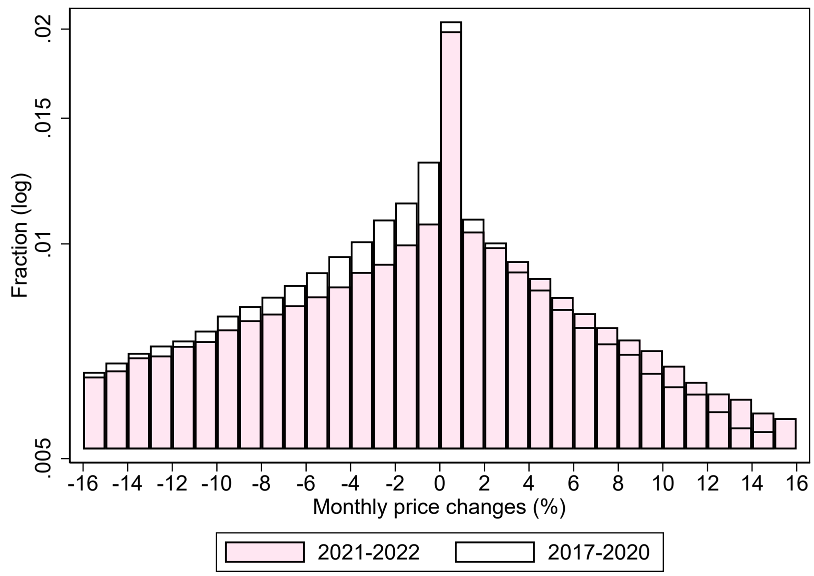


Figure 2: Distribution of monthly price changes

Notes: This figure plots the distribution of monthly price changes for Chinese imports over the 2017-2020 and the inflationary period 2021-2022. Medical products (list in the appendix, Tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix) are excluded. The dataset includes all imports from China in the manufacturing sectors, a total of 7,894 different goods (cn8) and 5,670,725 observations.

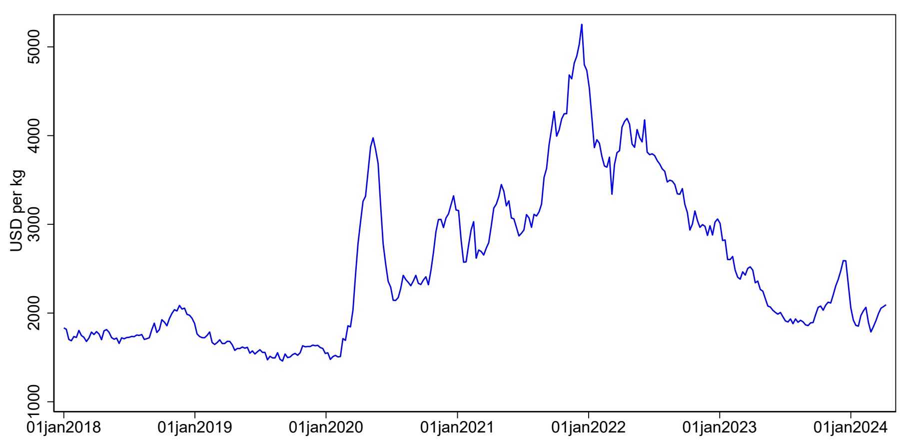
In Figure 2, we present the distribution of monthly price changes over the pre-inflationary period 2017-2020 and during the inflationary period 2021-2022. There is a right shift in the distribution of the monthly price changes, suggesting that the frequency of positive price variations increases after 2021. Moreover, the mass of price changes around 0 is lower after 2021, which means that the prices adjust more frequently after 2021. We found the same empirical evidence as Lafrogne Joussier, Martin and Méjean (2023) for producer prices. Price adjustments are a combination of a change in the frequency of price adjustments and their size. We run similar analyses for all Extra-European imports and get similar evidence in favor of a right shift of monthly price variations(Figure 15 in appendix). Nevertheless, we do not find evidence of a lower mass of price changes around 0 at the aggregate level. In parallel to this inflationary period for the price of imported goods, the price of sea and air freight increased abruptly.

4.0.3 Fact 3: Transport prices

The price of sea freight, measured by the Drewly price index increased from the second half of 2020, before stabilizing at the end of 2022 for all routes. However, this change in the Drewly price index was heterogeneous depending on the route. While the price for shipping goods from China increased sharply from the end of 2020, the rise in this index was significantly lower for routes at the destination to China. This asymmetry in transport prices can be explained by a difference in demand for ships and the limited capacity of containers and cargo. Once in Europe, cargo coming from China must return to Chinese ports, sometimes not at full capacity. Similar asymmetry can be observed for the transatlantic route. This underlines the importance of distinguishing by route while studying the price of air freight. In the appendix, we report the BDI price index for goods in bulk (Figure 13) at a monthly frequency and worldwide level. We can observe similar trends to the one observed for the Drewly price index at a worldwide level (Figure 4). Because of the large heterogeneity across routes, we assume in further analysis that the variations in the BDI are similar to the one observed with the Drewly price index, and keep the Drewly price index Shanghai-Rotterdam as our indicator for the price of sea freight between China and Europe. The Drewly price index for the Shanghai-Rotterdam route peaked at 14807 on October 7, 2021, while it was only 2325 USD per 40ft container on January 03, 2020.

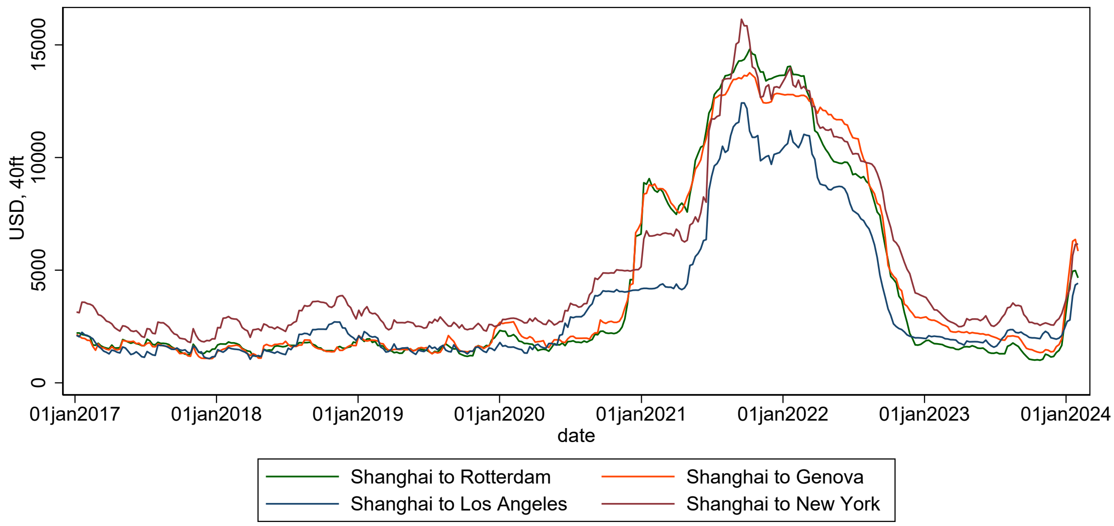
Moreover, the variation in the price of air freight underlines the importance of distinguishing by transport mode. Sea and air freight are affected by different shocks during the period considered. Figure 3 gives the TAC index over the period 2018-2023. One can observe a peak in March 2020. At this period, most of the passenger flights were cancelled because of the pandemic, which affected the air freight. The TAC index peaked at 5254 USD per kg on December 09, 2021 while it was only 1552 on January 02, 2020.

Figure 3: Traffic Air Cargo Price index

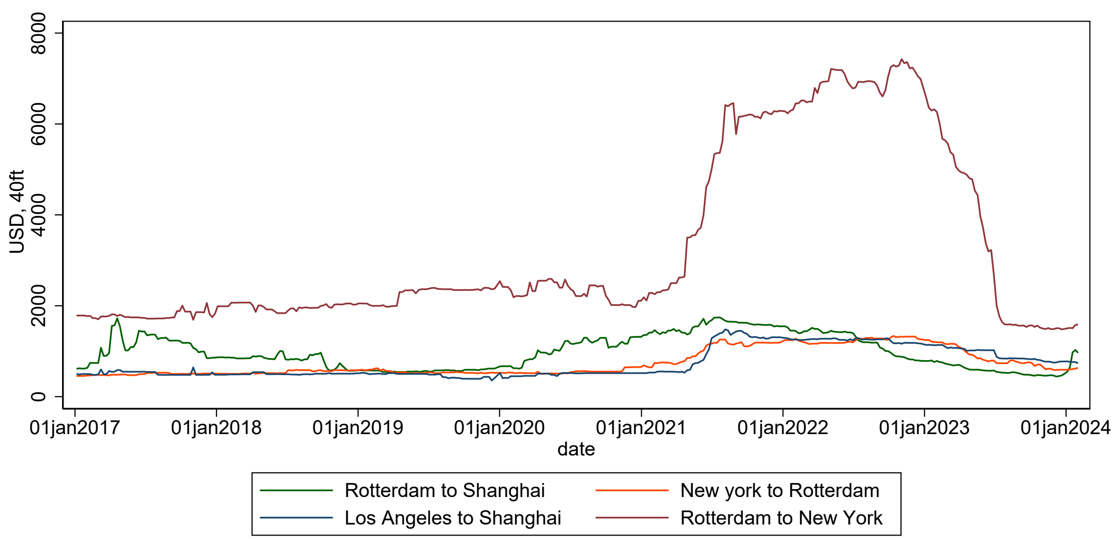


Notes: This figure presents the Traffic Air Cargo price index at a weekly frequency over the period 2018-2024.

Figure 4: Drewly Price indexes



(a) Shipping routes from China



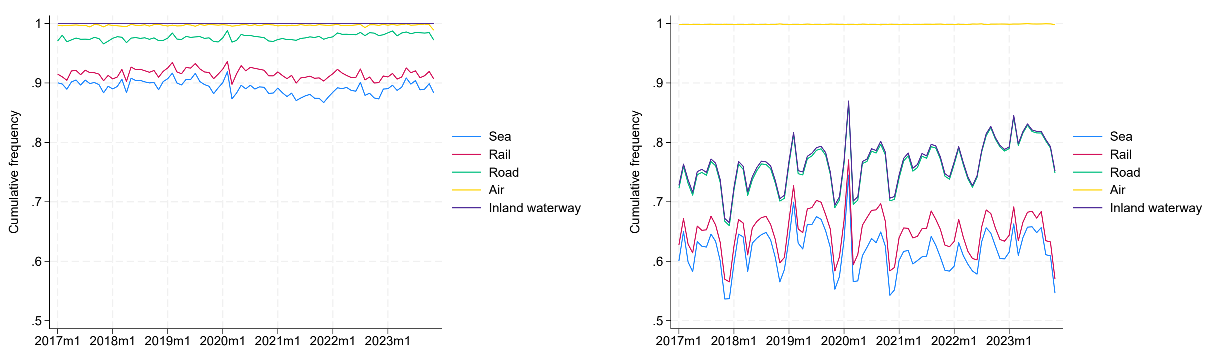
(b) Shipping routes at destination to China and Transatlantic route

Notes: This figure presents the Drewly price indexes by routes from January, 2017 to January, 2024. The Drewly price index is a weekly indicator for the price of a 40ft container.

4.0.4 Fact 4: Distribution of the main modes of transport

One possible concern for our identification of the impact of the shock of transport costs on inflation is possible substitutions. Firms could choose to substitute from one mode of transport to another because of the disturbances concerning the air and sea freights in particular. Apart from seasonal trends, there is no evidence of substitution from one mode of transport to another, at the aggregate level. One possible reason is the high price of air relative to sea freight to ship goods over long distances. As Hummels (2007) underlines, when the value/weight ratio increases, this leads to a larger share transported by air transport. This is in line with what is advised by shipping companies. Freightos, one leading consulting company on shipping costs advises using air freight when the cost of shipping is less than 15-20% of the value of the good. Indeed, the marginal fuel cost of shipping a good into the air is higher than the cost of floating it on water. The counterpart of more expensive air transport is more reliability, flexibility and timeliness, which are key determinants for some kinds of goods such as technological or perishable products. These costs and advantages are more pronounced on larger distances. According to MSC departure times (February 2024), choosing air transport from Barcelona to Valencia may save 2 days, while choosing air transport from Naples to Montreal may save 15 days (MSC departures times, March 2024). Concerning hazardous materials, substitution is sometimes impossible because of strong restrictions for air freight (among others gases, flammable, toxic, magnetic substances, etc.). While, maritime freight represents around 90% of all quantities shipped and air around 2%, in terms of values, more than 20% of all imported goods from China were shipped by air. The share of values transported by the maritime sector drops to 50%. We found similar results by sector. For textiles, interestingly, we can observe the impact of masks which caused a huge increase in the share transported by air in March 2020, both in value and quantities. Removing masks and other medical products used during the pandemic, the substitution is no longer observable. This underlines the importance of removing these products from the analysis. We report the graph in the appendix (Figure 17). We observe similar trends for all Extra-European imports, even if the share of maritime transport is quite lower, as expected as it includes countries closer to the European Union. (Figure 16 in the appendix).

Figure 5: Share of quantities and values transported by the main mode of transport (2017-2023, manufacturing goods)



(a) Quantity

(b) Value

Notes: The dataset includes all imports from China in the manufacturing sectors, a total of 7,894 different goods (cn8) and 5,670,725 observations from January, 2017, to December, 2023. Medical products (list in the appendix, Tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix) are excluded. The manufacturing sectors are defined at the ISIC 2 digits level.

5 Empirical strategy

The descriptive statistics suggest that during the inflationary period, transport costs increased and manufacturing import prices were more likely to increase at the end of 2020 and from 2021. In this section, we try to estimate the effect of a shock in the price of transport on import prices, using local projection method. We start our analysis with an accounting identity. The CIF value by definition includes the marginal cost, the markup and the price of transport. We express the import price $I_{ij,t}$ as the product between the marginal cost of production and the markup charged by the firm. Shipping a good to Europe is costly so the marginal cost is scaled up by an iceberg trade cost. As it is standard in the literature, transport costs are modelled as an iceberg-type cost.

$$I_{ij,t} \equiv \mu_{ij,t}\tau_{ij,t}mc_{ij,t}$$

with $I_{ij,t}$, the price of imported goods, $\mu_{ij,t}$, the markup, $\tau_{ij,t}$, the iceberg trade cost and $mc_{ij,t}$, the marginal cost. i, j and t denotes respectively the European partner, the product and the time period.

Taking differences in log gives the decomposition of price changes according to variations in marginal costs, markups and iceberg transport costs. ($\Delta \ln I_{ij,t} = \ln I_{ij,t} - \ln I_{ij,t-1}$)

$$\Delta \ln I_{ij,t} = \Delta \ln \mu_{ij,t} + \Delta \ln \tau_{ij,t} + \Delta \ln mc_{ij,t} \tag{1}$$

We measure the transport cost shock by using the observed heterogeneity in transport modes per country x product. This helps to approximate their exposure to (common) transport price increases. We define a transport cost index per European country x product relationship which depends on the price of each mode of transport and shares for air α_{ij}^{a}, sea α_{ij}^{s}, road α_{ij}^{ro}, rail α_{ij}^{ra} and inland waterway α_{ij}^{in} transports.

$$P_{ij,t} = \left(P_{ij,t}^{a}\right)^{\alpha_{ij}^{a}} \left(P_{ij,t}^{s}\right)^{\alpha_{ij}^{s}} \left(P_{ij,t}^{ro}\right)^{\alpha_{ij}^{ro}} \left(P_{ij,t}^{ra}\right)^{\alpha_{ij}^{ra}} \left(P_{ij,t}^{in}\right)^{\alpha_{ij}^{in}}$$

with $\alpha_{ij}^{a} + \alpha_{ij}^{s} + \alpha_{ij}^{ro} + \alpha_{ij}^{ra} + \alpha_{ij}^{in} = 1$

Taking logs and the first difference, we get our indicator for the changes in transport prices at time t:

$$\Delta\omega_{ij,t} = \alpha_{ij}^{a}\Delta \ln P_{ij,t}^{a} + \alpha_{ij}^{s}\Delta \ln P_{ij,t}^{s} + \alpha_{ij}^{ro}\Delta \ln P_{ij,t}^{ro} + \alpha_{ij}^{ra}\Delta \ln P_{ij,t}^{ra} + \alpha_{ij}^{in}\Delta \ln P_{ij,t}^{in}$$

To measure the contribution of air and sea freight shocks, we use the mean share of quantity, within a European country x product (cn8) relationship before the pandemic (before 2020). Alternatively, we could have used the mean share of value. We provide the results of this alternative definition in the appendix, as a robustness check. We do not have an indicator of transport costs for rail, road and inland waterway transports. So, we assume in the rest of this analysis, that variations in prices of air and sea freights are orthogonal to price variations for rail, road and inland waterways transport costs. In our regressions, we will control for oil price variations as it is likely that they are correlated with road transport price variations. Rail, road and inland waterway represent respectively less than 10% and 15% in quantity and values of all imports from China to Europe. We only consider air and sea freight price variations to build a weighted estimator of the price of air and maritime freight. In case of $\alpha_{ij}^{a} + \alpha_{ij}^{s} = 1$, the weighted estimator we derive with the price variations of sea and air freight is equal to the change in transport costs.

One other concern about this indicator in the price of transport at t is time inconsistency between the departure and arrival times for sea and air freight. It takes between 30 and 45 days to ship goods by sea from China to Europe, and a charterer usually agrees to a shipping quote with add-ons at the time of booking. We change our definition of the change in transport costs, defining an indicator of the shock of transport cost, at the time the good is delivered. Indeed, we only observe import price variations when a good arrives in Europe. We are interested in the effect of an increase in maritime cost on price variation one month after the container leaves China. As it takes only a few hours to ship goods from China to Europe with air freight, there is no time inconsistency for this mode of transport As such, our indicator for the shock of air and maritime transport costs for a good arriving at t in Europe is defined as the sum between the weighted difference in log of a proxy for the price of air freight at t (TAC index) and the weighted difference in log of a proxy for the price of maritime freight (measured by the Drewly price index Shanghai-Rotterdam) at $t-1$:

$$\Delta\tilde{\omega}_{ij,t} = \alpha_{ij}^{a}\Delta\ln TAC_{ij,t} + \alpha_{ij}^{s}\Delta\ln Drewly_{ij,t-1} \tag{2}$$

Moreover, some shipping companies give the option to fixe the shipping price when the booking is done in advance, in particular for maritime freight. Thus studying the dynamic effects of an increase in transport cost is particularly relevant in our analysis. If booking are done in advance, we expect the increase in the price of transport today having an impact with some lags once the good is shipped. So, we first forcast price changes in simple differences and then, we measure the long-difference with the cumulative local projection estimator.

We use local projection method to measure the effect of an increase in air and sea transport costs on the rise of imported goods prices at different horizons. Local projection method does not constrain the shape of the impulse-response function, is more flexible to make estimations of non-linearities, and is more robust to misspecification than VAR, since the set of coefficients is estimated using a different regression for each horizon (Jordà, 2005). It does not constrain the response of import price variations to increase or decrease monotonically over time. One question of interest would be to estimate the effect of an increase in transport costs on the rise of imported goods in isolation of potential further fluctuations in the intervention (here fluctuations in transport costs). Recent papers, (De Chaisemartin and D'Haultfoeuille, 2022) showed that the local projection method is not adequate to answer this question, because it also includes past values of the intervention. However, as Jordà (2023) shows, the local projection method is still a valid object to identify "the likely effect on the outcome of an initial intervention at time t, recognizing, that the intervention itself generates subsequent interventions" (p.621). Thus, in the following section, we use local projection method to estimate the effect of an increase in transport costs, recognizing that this intervention generates subsequent interventions.

5.1 Forcast in simple differences

We first estimate the simple local projection equation to forcast import price variations in differences.

$$\Delta \ln I_{ij,t+h} = \delta^h + \sum_{l=1}^{H} \gamma_l^h \Delta \ln I_{ij,t-l} + \sum_{l=0}^{H} \beta_l^h \Delta\tilde{\omega}_{ij,t-l} + \sum_{l=0}^{H} \theta_l^h \Delta X_{ij,t-l} + FE_t + FE_{ij} + \varepsilon_{ij,t+h} \qquad (3)$$

with h, the response horizon in month, $\Delta \ln I_{ij,t}$, the month-over-month log price change of an imported goods j by an European country i, δ^h, the constant. $\Delta X_{ij,t-l}$ is a set of controls. The coefficient of interest is β_0^h, which captures the elasticity of a 1% shock to air and maritime transport costs on monthly price changes at different horizons.

We include product (cn8) x country fixed FE_{ij} effects to control for the specificity of each product, which could affect the price of transport (weight, volume, perishable goods, ...). For instance, some goods require special packaging, kinds of containers (refrigerated) or there exists strong constraints about the delay to deliver the good (perishable goods). These characteristics are assumed to be invariant with time. We include time fixed effect to control for global context (for instance Chinese production). Adding time fixed effects FE_t helps also to control for global demand affecting shipping costs. We control for the month over month growth rate of Dollars to Euro exchange rate. As in Carrière-Swallow and al. (2022), we include the month over month growth rate of crude oil and food prices. Including the month-over-month growth rate of crude oil is also likely to be correlated with road transport costs, for which we do not have indicators. The number of lags has been chosen to twelve, as in Carrière-Swallow and al. (2022), to control for additive seasonal effects. We estimate this regression for each horizon using Ordinary Least Squares Estimator. Standard errors are clustered at the European country x product level to adjust for serial correlation, cluster and heteroskedasticity. Clustering by groups is relevant if the number of groups is large enough, otherwise it can create distortions (Cameron and al., 2008, 2011) and it is recommended to use bootstrapped standard errors instead.

We do not have disaggregated data to have an estimate of the marginal cost of the firm. According to equation (1), with our local projection equation, we make the strong implicit assumption that the shock to transport cost is orthogonal to changes in markups and marginal costs, included in the error term. The limits of this assumption are discussed in section 6.3.

5.2 Forecast in cumulative differences

Then, we estimate the elasticity of a 1% increase in air and maritime transport cost at t, given by β_0^h on cumulative price changes. The local projection method estimate, measures in this case the overall percentage change in the outcome since the cost shock. Similarly, we use the Ordinary Least Square estimate, with European country x product, and time fixed effects and the same set of controls as in equation (3). Standard errors are clustered at the European country x product level.

$$\ln I_{ij,t+h} - \ln I_{ij,t-1} = \delta^h + \sum_{l=1}^{H} \gamma_l^h \Delta \ln I_{ij,t-l} + \sum_{l=0}^{H} \beta_l^h \Delta\tilde{\omega}_{ij,t-l} + \sum_{l=0}^{H} \theta_l^h \Delta X_{ij,t-l} + FE_t + FE_{ij} + \varepsilon_{ij,t+h} \tag{4}$$

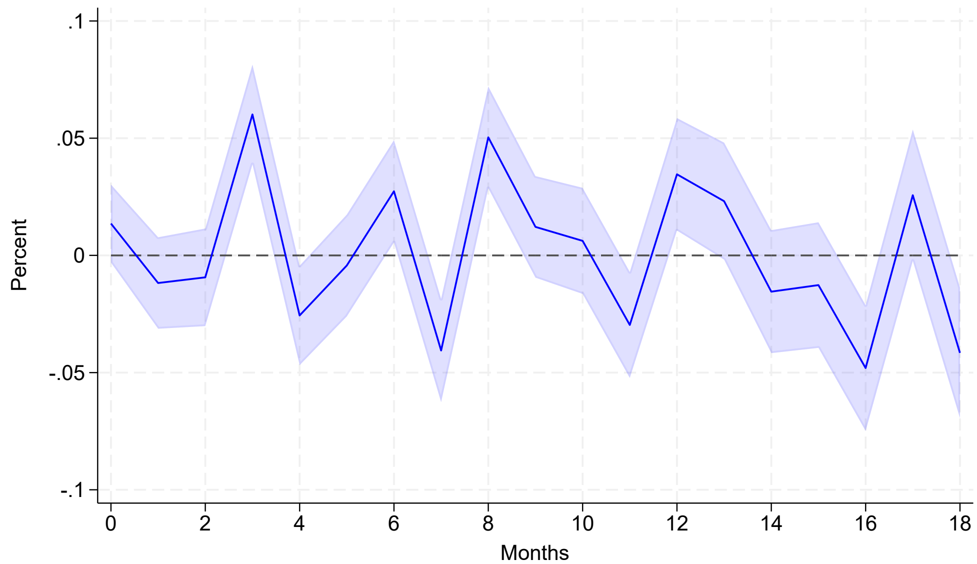
6 Empirical results

Figures 6 and 7, estimate respectively the first and the cumulative local projection forecast, using the 2018-2023 period of observations. We could not use a larger horizon, as the TAC index is only avalaible from 2018. We find a significant, non-negligible and persistent effect of an increase in import prices after a one percent shock on the price of air and maritime freight cost. Full regression tables can be found in the appendix (Table 12.7 and 12.8).

6.1 Forecast in first and cumulative differences

Figure 6 estimates equation (3) for all Chinese imports and reports the local projection coefficients and their 95% confidence interval. We can observe that the increase in our estimate of air and maritime transport cost has an effect with a lag on import price variation. The coefficients for periods 0 to 2 are insignificant. The elasticity of a 1% shock to air and maritime transport costs on monthly price changes, for the third, sixth , eighth months, twelve months, are significantly positive, respectively equal to 0.06, 0.027, 0.05 and 0.03 on average. This analysis suggests import prices do not adjust immediately to a shock in the cost of air and maritime transport. The three peaks we observe may be due to price rigidities, firms adjusting their prices with a lag. Figure 19 reports a similar analysis, weighting by the mean value share instead of the mean quantity share. The two graphs are very similar, even if under weight as mean share value, variations are slightly amplified. Peaks at two, six and eighth months are also significant. We observe significant negative peaks at five and seven months, suggesting that prices tend to decrease after a high increase in the former period. These opposite effects smooth the cumulative variations of prices. Finally, we can observe a significant peak one month after the shock, with weights as mean value shares. The definition with value puts more weight of air freight, which could explain this significant peak. Air freight is sometimes used to overcome disruption in the supply chains under short delays. Price may be more flexible than with maritime freight. We intend to deepen this question in future research. Finally, our specification explains 29,2% of the variance for the horizon 0 and it falls to 1.2% for the first and later horizons. This suggests that most of the variance is captured by time-fixed effects. While the first difference local projection gives indications about the dynamics of price changes, we cannot infer the cumulative effects of a transport cost shock on inflation, with such a regression.

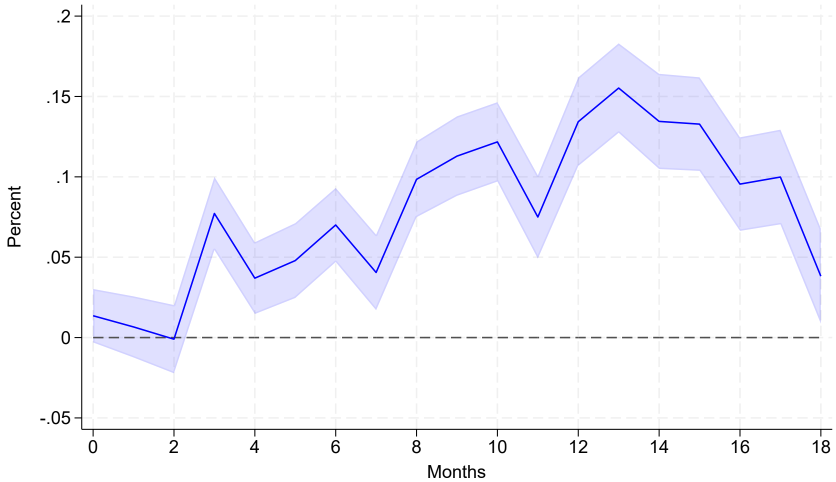
Figure 6: First difference local projection estimates



Notes: This figures presents the first-difference local projection coefficients and their 95% confidence interval. If the sum of air and sea coefficients sum to 1, after a 1% shock in air and maritime transport cost at $t = 0$, import prices are likely to increase by 0.06% between the second and the third month after the shock. The full regression table is given in appendix (Table 12.8). Standard errors are clustered at the country x product (cn8) level. This specification includes time and country x product (cn8) fixed effects.

In order to get a smoother estimate of the long-term effects of transport cost shock, we report in Figure 7 the long-difference local projection estimate, corresponding to equation (4). The full regression table can be found in the appendix (Table 12.7). These estimates measure the approximate percentage change in the outcome, from the period $t - 1$ before the shock to h periods in the future. The effect of an increase in the price of transport is highly significant three months after the shock, suggesting that import prices increase after an increase in transport costs. Prices increase with a lag in response to an increase in transport costs. Our coefficients are insignificant for the first three months and then are highly significant and positive. Even if the effects are smoother compared to the first-difference graph, we can observe three peaks at three, six, ten and thirteen months, in the cumulative-difference graph. If sea and air weights sum to one, after thirteen months, import prices are predicted to increase by 0.155% compared to the baseline period after a 1% shock. After this peak, import price increases revert 18 months after the shock. The effect is quite persistent, lasting for eighteen months. Similar findings can be found under the alternative definition of weights as mean share values (Figure 18 in the appendix). The only difference concerns the first three periods. The cumulative effects of the shock are amplified, peaking at 0.19% thirteen months after the shock, if sea and air weights sum to one. Our coefficients are now statistically significant. This can also be due to a higher weight put on air freight. These results suggest an incomplete pass-through of costs into prices. Import prices increase by less than the size of the shock. Our specification explains between 29.2% and 39.4% of the variance over the 18 horizons.

Figure 7: Long difference local projection estimates



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. If the sum of air and sea coefficients sum to 1, after a 1% increase in air and maritime transport cost at $t = 0$, import prices are likely to increase by 0.12% 10 months, after the shock compared to the period $t - 1$ before the shock. The full regression table is given in appendix (Table 12.7). Standard errors are clustered at the country x product (cn8) level. This specification includes time and country x product (cn8) fixed effects.

6.2 Robustness checks

To check our first assumption about the orthogonality of the different modes of transport, we run a similar analysis for the first (Figure 21) and the cumulative local projection estimates (Figure 20) with a restricted sample. We only keep the observations for which the sum of the share in quantity for sea and air transport is higher than 0.95. As such, our coefficient for the price of air and maritime freight can be interpreted as the response to a shock in transport costs, as the sum of weights is close to the one. Concerning first difference, coefficients are larger in magnitude and we still observe significant peaks at 3, 8-9 and 12 months respectively reaching 0.08%, 0.05-0.08% and 0.05%. In terms of cumulative differences, the coefficients are larger in magnitude. After 9 months, prices increase on average by 0.25% after a 1% shock in transport costs and after 13 months by 0.24%. The effects also revert after 18 months. Confidence intervals are larger, as the sample size is smaller.

From 2020, many shocks affect the economy. So, we choose to report the results under the restricted sample of observations before 2020 (Figure 22). Because of the short period of observations (2018-2019), we were able to report only the forecast for a horizon of 8 months. We find significant coefficients for horizons 1, 2, 3, 4. However, due to the low number of observations, the confidence intervals are extremely large, so interpreting the size of the coefficients is not relevant. We can still infer that the trend we observe in the short term is not due to the disrupted context of the pandemic because it was already present before 2020. We run a similar exercise for the period 2020-2023, affected by the shock (Figure 24 and 23). For the first difference, we observe three significant positive peaks at 3, 9 and 12 months, respectively reaching 0.06, 0.04 and 0.16. In terms of cumulative difference, we observe a short term effects, (the effects for the first and the second month are significant), peaking at 3 months (0.11), reverting at 10 months and a long-term effect, with a peak at 12 and 13 months, reaching 0.09. Because of the large confidence interval from 14 months, no conclusions can be made from that horizon. As such, the long-term impact on air and maritime transport is less smooth than over the period 2018-2023 This can be explained by the existence of long-term contracts, at 12 months on the price of transport. It may be possible that during the inflation surge, because of higher uncertainty about congestion and transport prices, firms chose to book more in advance sea and air freight at a fixed price, explaining the peak at 12-13 months. Moreover, the coefficients at 0, 1 and 2 months are now significant, and the size of the coefficient at 3 months is larger, which can be due to another effect of uncertainty. Because of uncertain demand and production during the pandemic, firms could also choose to book less in advance their prices, explaining larger short-term effects of the price of transport. These two hypotheses must be tested in further research.

We use an alternative specification with time x industry (2-digit, ISIC) fixed effects instead of time fixed effects to control for sector-specific shocks. Because of computational constraints, we randomly select 10% of the country x product relationships in the original sample. Despite a larger confidence interval because of a restricted sample, the amplitude and the sign of the first difference and the cumulative difference are similar. Only the first and the cumulative local projection coefficients for the first month are now significantly positive.

6.3 Limitations and extensions

These empirical evidences suggest that a shock on the price of transport tends to increase import prices and the effect is quite persistent, lasting for 18 months. It also suggests an incomplete pass-through of transport costs into import prices. The elasticity at a 1% shock on the cost of air and sea transport on cumulative price variations, is around 0.15, 13 months after the shocks. Restricting to the sample for with the sum of shares of air and sea transport is closed to 1, after a 1% increase in transport costs, import prices increase on average by 0.24%, 13 months after the shock. However, these results raise questions for further research. First, as our exercise after the shock suggests, there would exist some price rigidities. This could be explained by the presence of contracts at 12 months. It would be interesting for further research to study the probability of price adjustment after a shock in the price of transport. Indeed, we made the hypothesis that what we observed is due to price rigidities but it could also be due to some very specific shocks in the data, affecting certain sectors only. If the peak we observe is due to price rigidities, we could also explore further if these price rigidities are due to contracts between the ship owner and the charterer or, like in the intermediary good market, contracts between a supplier and a buyer.

We could also exploit our full sample and our different estimates per route, to study more in-depth the vulnerability of countries to transport cost shock depending on the level of economic integration, the presence of transport infrastructure and geographical location. We could study if there is a reallocation of trade towards routes less affected by the rise in transport costs. For instance, we could compare China and the United States export flows at destination to Europe, as they were differently affected by the shock.

Finally, our empirical strategy relies on the assumption that changes in transport costs are orthogonal to variations in markups and marginal costs, including in the error terms. This rules out strategic interactions between competitors. However, it is possible that the markup adjusts when there is an increase in the price of transport, or in response to competitor's price changes. For instance, it is possible that if the price of transport increases more in China than in the US, Chinese producers lose competitiveness. They would lose market shares and maybe their markup will decrease. American exporters may benefit from this situation and may gain market shares and increase their markups. As such, an increase in own costs may have an impact on competitors' prices. In further research, we would like to deepen this question by exploiting firms' level data and running an analysis based on Amiti and al. (2019). We could decompose price changes into the response to own cost shocks and changes in competitor prices. In the next section, we propose a model à la Atkeson Burstein (2008), generating incomplete pass-through because of an endogenous markup, which now depends on the market shares.

7 Model

The increase in the price of transport does not transmit one to one into the price of an imported good. In this section, we propose a model based on Atkeson Burstein (2008), with imperfect competition and trade costs. Thus model helps to understand why foreign firms does not increase one to one their prices, resulting from an increase in their transport costs. This model is an extension of De Loecker and al. (2022) in an open economy with two countries $i \in \{1, 2\}$ which produce and trade a continuum of goods on international goods markets. The first section presents the theoretical framework, then we quantify the model, based on the European context. First, we consider the benchmark model, a static environment with an inelastic labor supply to isolate the role of transport costs and the market dynamics, explaining the incomplete pass-through. Then we study the dynamics of the static equilibrium resulting from a short term shock in the price of transport.

Time is discrete. There are two classes of agents, firms and households. All prices are expressed in the same currency.

Preferences in country i are given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^i, l_t^i) \tag{5}$$

where c_t^i and l_t^i denote respectively consumption and labor of the representative household in the country i at time t. In the benchmark model, the labor supply is assumed to be inelastic, normalized to one. The utility function is strictly increasing and strictly concave in consumption.

7.1 Demand for the final goods

As in Atkeson, Burstein (2008), final consumption, denoted c^i is a double constant elasticity of substitution (CES) aggregator of consumption from within and across a continuum of sectors j, with $j \in [0, 1]$. For the sake of clarity, time subscripts are omitted.

At the aggregate level:

$$c_{it} = \left[\int_0^1 {c_{jt}^i}^{1-\frac{1}{\eta}} \, dj \right]^{\frac{\eta}{\eta-1}} \tag{6}$$

where $\eta > 1$ denotes the elasticity of substitution across sectors.

At the good level:

$$c_{jt}^i = \left[\sum_{k=1}^{2K} {c_{jkt}^i}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{7}$$

$\rho > \eta > 1$ denotes the elasticity of substitution between goods within sectors. Goods k are more substitutable within sectors than across sectors. Each good k is distinct. As in Atkeson, Burstein (2008), goods are imperfect substitutes $\rho < \infty$. There are $2K$ different varieties of goods which can either be produced domestically or abroad in each sector.

The household chooses the optimal quantity of goods to consume c_{jkt}^i such that he maximizes his utility. He can buy each period, assets traded on the international market. His income is given by his revenue from labor and the return on assets. The labor supply is inelastic, $l_t^i = 1$ His budget constraint is given by:

$$\int_0^1 \sum_{k=1}^{2K} P_{jkt}^i c_{jkt}^i dj + X_t^i \leq W_t^i l_t^i + X_{t-1}^i R_{t-1} \tag{8}$$

Solving the household's minimization problem gives the inverse demand functions and the theoretical price indexes at both levels of aggregation (mathematical details can be found in the appendix)

At the aggregate level:

The inverse demand function

$$\frac{P_{jt}^i}{P_t^i} = \left(\frac{c_{jt}^i}{c_t^i} \right)^{-\frac{1}{\eta}} \tag{9}$$

The theoretical aggregate price index:

$$P_t^i = \left[\int_0^1 {P_{jt}^i}^{1-\eta} dj \right]^{\frac{1}{1-\eta}} \tag{10}$$

As the sector consumption becomes perfectly substitutable, $\eta \to \infty$, a small change in the relative price index of a sector j compared to the aggregate price index results respectively in an infinite or a zero demand for this sector if the price decrease or increase by a small amount ε. *At the sector level*:

The inverse demand function:

$$\frac{P^i_{jkt}}{P^i_{jt}} = \left(\frac{c^i_{jkt}}{c^i_{jt}}\right)^{\frac{-1}{\rho}} \tag{11}$$

The theoretical sector price index:

$$P^i_{jt} = \left[\sum_{k=1}^{2K} {P^i_{jkt}}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{12}$$

As the goods become perfectly substitutable, $\rho \to \infty$, a small change in the relative price index of a good k compared to the sector price index results respectively in an infinite or a zero demand for this good if the price decreases or increases by a small amount ε.

Finally, at the equilibrium, the terms of trade are respected:

$$\frac{c_{it}}{c_{-it}} = \frac{P_{-it}}{P_{it}}$$

7.2 Intermediate production

Each firm, within each sector, produces a distinct type of good k with constant returns to scale production function: $y^i_{jkt} = z^i_{jk} l^i_{jkt}$. In this model, countries are perfectly symmetric in terms of aggregate and sector productivity: $Z^i = Z^{-i} = Z$ and $z^i_j = z^{-i}_j = z_j$ but idiosyncratic productivity is drawn from a log-normal distribution with parameter θ: $z \sim \log \mathcal{N}(0, \theta)$. Idiosyncratic productivity is constant over time. As the two countries are perfectly symmetric in terms of productivity, preferences and labor supply, the wage levels equalize in both countries: $W_{it} = W_{-it} = W_t$. Productivity does not depend on time, to isolate the role of transport costs. Labor is the only input in production and there is no capital. Firms do not encounter fixed costs of exporting. Thanks to this simplification from the original model of Atkeson, Burstein (2008), there is no need to model firms entry and exit decisions in the foreign market after a shock. We assume that the number of firms K in each country is exogenous. Atkeson, Burstein (2008), showed that the assumption of zero fixed costs does not change the quantitative implications of the models in terms of market concentration, measured by the median Herfindahl-Hirschmann index.

The good producer plays a Cournot game. In this benchmark model, each firm chooses quantities to produce to serve the domestic and the foreign markets. In the latter case, it has to pay an additional iceberg-type trade cost $\tau_t \geq 1$, which scales up its marginal cost of producing. Exporters in the two countries face symmetric iceberg trade costs. The trade costs evolve stochastically, following an autoregressive process of order 1:

$$\log \tau_{t+1} = \rho_\tau \log \tau_t + \epsilon_t$$

with $\epsilon_t \sim \mathcal{N}(0, \sigma^2_\tau)$. The parameter $0 < \rho_\tau \leq 1$ determines the persistence of a shock.

Now we solve for the firm's equilibrium, dropping time subscripts for the sake of clarity. We solve for the static Nash equilibrium of the firms. The equations we derived in this section hold for every periods.

The measure of sectoral and aggregate productivities are defined, similarly as in Edmond and al. (2015) as the weighted average of domestic and foreign firms' idiosyncratic productivities serving the domestic market i:

$$z_j = \left(\sum_{l=1}^{K} {z^i_{jl}}^{\rho-1} + \tau^{1-\rho} \sum_{l=1}^{K} {z^{*i}_{jl}}^{\rho-1} \right)^{\frac{1}{\rho-1}} \tag{13}$$

$$Z = \left(\int_0^1 z_j^{\eta-1} \right)^{\frac{1}{\eta-1}} \tag{14}$$

where ${z^{*-i}_{jl}}$, denotes the productivity of foreign firms exporting in the domestic market. The cost of transport acts like a shifter in the idiosyncratic productivity of the firm producing for the foreign market. The marginal costs for the domestic firms producing for the domestic and the foreign market are given respectively by $\frac{W}{z_{jk}}$ and $\tau \frac{W}{z_{jk}}$.

The goods market clearing conditions impose that, at all levels of aggregation, the quantities produced by the domestic and foreign firms for the domestic market equate to the quantity consumed in the domestic market $y^i_j = c^i_j$, $Y^i = c^i$, $q^i_{jk} = c^i_{jk}$, $q^{*i}_{jk} = c^{*i}_{jk}$ for all countries, sectors and firms. A good producer wants to maximise its profit from its production for the domestic and foreign markets separately. Quantity produced and price indexes of a good sold in the domestic (foreign) market and produced by a foreign (domestic) firm are denoted by an asterisk.

Solving for the domestic market

In particular, a firm in the domestic market chooses its production for the domestic market i, q^i_{jk} by solving the maximization program (mathematical details in the appendix):

$$\max_{q^i_{jk}} P^i_{jk} q^i_{jk} - q^i_{jk} \frac{W}{z^i_{jk}} \tag{15}$$

subject to the inverse demand function given by combining (5) and (7):

$$\left(\frac{P^i_{jk}}{P^i} \right) = \left(\frac{q^i_{jk}}{y^i_j} \right)^{\frac{-1}{\rho}} \left(\frac{y^i_j}{Y^i} \right)^{\frac{-1}{\eta}} \tag{16}$$

Firms recognize that the sectoral production y^i_j and price level P^i_j change when they solve the maximization problem. They take into account the strategic interaction with the other firms in sector j. The quantities from the other firms q^i_{jl} operating in the sector and serving country i, with $l \neq k$, the final consumption price P^i, the wage level W and aggregate quantity Y^i are taken as given.

Solving for the foreign market

Similarly, the domestic firm k chooses the optimal quantity to export q^{*-i}_{jk} to the foreign country $-i$. The problem is the same, only the marginal cost of producing is scaled up by the iceberg trade cost. Similarly, firms recognize that the sectoral production y_j^{-i} and price level P_j^{-i} change when they solve the maximization problem. They take into account the strategic interaction with the other firms in sector j. The quantities from the other firms q_{jl}^{-i} operating in the sector and serving country $-i$, with $l \neq k$, the final consumption price P^{-i}, the wage level W and aggregate quantity Y^i are taken as given.

$$\max_{q_{jk}^{*-i}} P_{jk}^{*-i} q_{jk}^{*-i} - q_{jk}^{*-i} \tau \frac{W}{z_{jk}} \tag{17}$$

subject to the inverse demand function given by combining (5) and (7):

$$\left(\frac{P_{jk}^{*-i}}{P^{-i}} \right) = \left(\frac{q_{jk}^{*-i}}{y_j^{-i}} \right)^{\frac{-1}{\rho}} \left(\frac{y_j^{-i}}{Y^{-i}} \right)^{\frac{-1}{\eta}} \tag{18}$$

The unique Cournot Nash equilibrium, gives firm k two prices, the first to serve the domestic market and the other to serve the foreign market. Both are a markup over marginal cost (mathematical details are in the appendix). Market shares of the firms in their domestic and foreign markets are calculated as the share of their revenues in the corresponding market.

For the domestic market

$$P_{jk}^i = \frac{\epsilon(s_{jk}^i)}{\epsilon(s_{jk}^i) - 1} . \frac{W}{z_{jk}} \tag{19}$$

with the market share of the firm in market i, in sector j

$$s_{jk}^i = \frac{P_{jk}^i q_{jk}^i}{\sum_{l=1}^K P_{jl}^i q_{jl}^i + \sum_{l=1}^K P_{jl}^{*i} q_{jl}^{*i}} = \left(\frac{P_{jk}^i}{P_j^i} \right)^{1-\rho} \tag{20}$$

Using the expression for the inverse demand, the prices indexes and the equilibrium prices, the quantity produced is given by:

$$q_{jk}^i = \left(\frac{P_{jk}^i}{P_j^i} \right)^{-\rho} \left(\frac{P_j^i}{P^i} \right)^{-\eta} Y^i \tag{21}$$

For the foreign market

$$P_{jk}^{*-i} = \frac{\epsilon(s_{jk}^{*-i})}{\epsilon(s_{jk}^{*-i}) - 1} . \tau \frac{W}{z_{jk}} \tag{22}$$

with the market share of the firm in market $-i$, in sector j

$$s_{jk}^{*-i} = \frac{P_{jk}^{*-i} q_{jk}^{*-i}}{\sum_{l=1}^K P_{jl}^{-i} q_{jl}^{-i} + \sum_{l=1}^K P_{jl}^{*-i} q_{jl}^{*-i}} = \left(\frac{P_{jk}^{*-i}}{P_j^{-i}} \right)^{1-\rho} \tag{23}$$

Using the expression for the inverse demand, the prices indexes and the equilibrium prices, the quantity produced is given by:

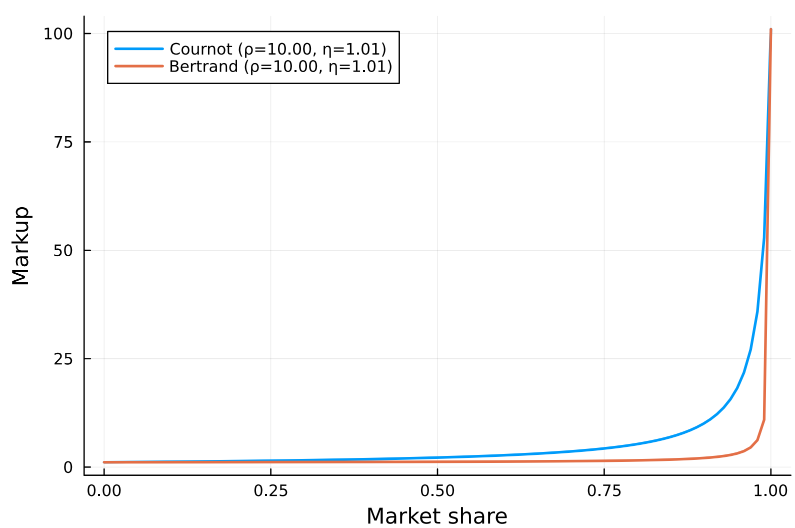
$$q_{jk}^{*-i} = \left(\frac{P_{jk}^{*-i}}{P_j^{-i}}\right)^{-\rho} \left(\frac{P_j^{-i}}{P^{-i}}\right)^{-\eta} Y^{-i} \tag{24}$$

$\epsilon(s_{jk}^i) > 1$ and $\epsilon(s_{jk}^{*-i}) > 1$ are the demand elasticities a domestic firm k located in country i faces to serve the domestic and the foreign market in sector j. $s_{jk}^i \in [0,1]$ and $s_{jk}^{*-i} \in [0,1]$ denote the market share a domestic firm has respectively in the domestic and the foreign market. Under Cournot competition, this elasticity is given by:

$$\epsilon(s) = \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right)^{-1} \tag{25}$$

7.3 A model generating incomplete pass-through

Figure 8: Markups as a function of the market share, under Cournot and Bertrand competition



Notes: This figure shows displays the markups, as a function of the market shares under Cournot and Bertrand competition. At the limit, for both specifications, when $s = 0$, $\mu(s) = \frac{\rho}{\rho-1} \approx 1.111$ and when $s = 1$, $\mu(s) = \frac{\eta}{\eta-1} \approx 100.99$

Contrary to the model presented by Guironi and Melitz (2005), the markup of each firm is no longer constant, as the demand elasticity is a weighted average of the good and sectoral elasticities: $\mu(s) = \frac{\epsilon(s)}{\epsilon(s)-1}$. At the limit, when the elasticity of substitution between goods $\rho \to \infty$, the distinction between goods disappears. The model becomes Ricardian, as only the elasticity between sectors matters. The assumption that $\rho > \eta$ ensures that each firm in a sector charges a distinct price for its product.

The markup is a strictly increasing and strictly convex function of the market share (proof in the appendix), under the assumption that $\rho > \eta > 1$. At the limit case, when a firm's market share within a sector and a country tends to zero, the market power of the firm is not high enough to let it perceives a high markup. Its markup is only determined by the high demand elasticity between goods ρ, $\mu(s) = \frac{\rho}{\rho-1}$. On the contrary, when the market share approaches one (the monopoly case), the markup of the firm is maximizes and determined only by the sectoral demand elasticity: $\mu(s) = \frac{\eta}{\eta-1}$. When $\eta = \rho$, the markup reduces to the model of monopolistic competition, where the markup over marginal cost is constant and given by: $\frac{\rho}{\rho-1}$. This corresponds to the Guironi and Melitz (2005) model. In our model however, the dispersion of markup depends both on the difference between ρ and η and the dispersion of market shares.

The assumption that $\rho > \eta$ and the finite number of firms within each sector allows firms to not fully pass through an increase in their marginal cost into their prices. When a group of firms experience an increase in their marginal costs, their market share and thus their markup will decrease, increasing the price less than the increase in their marginal cost. When the iceberg trade cost increases, it scales up the marginal cost of foreign firms. They lose in competitiveness, their market share decreases, which decreases their markups. On the contrary, domestic firms benefit from this increase in the iceberg trade cost. Their market shares increase, which increase their markups. When the transport cost $\tau \to \infty$, the economy converges towards the autarky case. The market shares of foreign firms in the domestic market become infinitesimal and at the limit, only domestic firms serve the domestic market. This is what we observe in our quantitative exercise in section 7.

7.4 Extensions with Bertrand competition

The implications under the assumption of Bertrand competition are the same as for Cournot. The equilibrium for Bertrand is similar that for Cournot, only the expression for the elasticity of substitution changes (derivations in the appendix):

$$\epsilon(s) = \rho(1 - s) + \eta s$$

With $\rho > \eta > 1$, the markup is still an increasing function of the market share s. It is equal to $\frac{\rho}{\rho-1}$ and $\frac{\eta}{\eta-1}$ respectively if $s = 0$ and $s = 1$. Under the assumption of zero fixed cost of exporting and price competition, as ρ gets large, it gets close to the standard Bertrand model. It is still a strictly increasing and convex function of the market share (see the mathematical appendix for further details). Under Bertrand competition, the markup, for the same parameters is lower (Figure 8). However, Bertrand competition tends to reward more cost-efficient firms than under Cournot competition. This results in more asymmetric market shares (Amir and Jin, (2001)).

These dynamics at the firms level have implacations at the sector and aggregate level.

7.5 Aggregation

Symmetry implies that all aggregate and sectoral variables are equal in both countries. In this section, we define a sectoral μ_j^i and an aggregate markup μ^i. We take the example of the domestic market i. The equilibrium conditions, resulting from equation 19 are given by:

$$P_{jk}^i = \mu_{jk}^i \frac{W}{z_{jk}} \tag{26}$$

$$P_j^i = \mu_j^i \frac{W}{z_j^i} \tag{27}$$

$$P^i = \mu^i \frac{W}{Z} \tag{28}$$

Similarly, for a domestic firm serving the foreign market:

$$P_{jk}^{*-i} = \mu_{jk}^{*-i} \frac{W}{z_{jk}} \tag{29}$$

Extended De Loecker and al. (2022) to our open economy, it can be shown that the markups at the sectoral and aggregate level are determined by relative productivities (see mathematical appendix for further details):

$$\mu_j^i = \left(\sum_{k=1}^{K} \left(\frac{z_{jk}}{z_j} \right)^{\rho-1} \left(\frac{1}{\mu_{jk}^i} \right)^{\rho-1} + \tau^{1-\rho} \sum_{k=1}^{K} \left(\frac{z_{jk}^*}{z_j} \right)^{\rho-1} \left(\frac{1}{\mu_{jk}^{*i}} \right)^{\rho-1} \right)^{\frac{1}{1-\rho}} \tag{30}$$

Similarly, the economy-level aggregate is defined as:

$$\mu^i = \left(\int_0^1 \left(\frac{z_j}{Z} \right)^{\eta-1} \left(\frac{1}{\mu_j^i} \right)^{\eta-1} dj \right)^{\frac{1}{1-\eta}} \tag{31}$$

Finally, we calculate the import shares for a country i are given by the ratio between the expenditure for goods produced abroad for the domestic market $\sum_{k=1}^{K} p_{jk}^{*i}.q_{jk}^{*i}$ and total expenditure:

$$\iota^i = \frac{\int_0^1 \left(\sum_{k=1}^{K} p_{jk}^{*i}.q_{jk}^{*i} \right) dj}{P^i Y^i} = 1 - \frac{\int_0^1 \left(\sum_{k=1}^{K} p_{jk}^{i}.q_{jk}^{i} \right) dj}{P^i Y^i} \tag{32}$$

The total expenditure is given by: $P^i Y^i = \int_0^1 \left(\sum_{k=1}^{K} p_{jk}^{*i}.q_{jk}^{*i} + \sum_{k=1}^{K} p_{jk}^{i}.q_{jk}^{i} \right) dj$

In addition to the markups at the sector and aggregate level, it is useful, for our quantitative exercise to define a sales weighted average of markups, extending De Loecker and al. (2022) to our open economy (see mathematical appendix for further details), denoted $\bar{\mu}$. A change in the sales-weighted markups capture compositional changes across and within firms. Indeed, firms can increase their markup, keeping their sales constant or sales can increase as a result of an increase in the markup.

$$\bar{\mu^i} = \int_0^i \sum_{k=1}^{K} \left(\frac{p_{jk}^i q_{jk}^i}{P^i Y^i} \mu_{jk}^i \right) + \sum_{k=1}^{K} \left(\frac{p_{jk}^{*i} q_{jk}^{*i}}{P^i Y^i} \mu_{jk}^{*i} \right) dj$$

This measure can be reexpressed, using the definition of the import share:

$$\bar{\mu^i} = i^i(\mu_{for}) + (1 - i^i)(\mu_{dom})$$

With μ_{for} and μ_{for} respectively the sales-weighted average foreign and domestic markups (derivation in the appendix).

$$\mu^i_{for} = \int_0^i \sum_{k=1}^K \frac{p^{*i}_{jk} q^{*i}_{jk} \mu^{*i}_{jk}}{\int_0^i \sum_{k=1}^K p^{*i}_{jk} q^{*i}_{jk} dj} dj$$

$$\mu^i_{dom} = \int_0^i \sum_{k=1}^K \frac{p^i_{jk} q^i_{jk} \mu^i_{jk}}{\int_0^i \sum_{k=1}^K p^i_{jk} q^i_{jk} dj} dj$$

Measuring concentration

Market power, driven by an unequal repartition of market shares can be measured using the Herfindahl-Hirschman Index. It is an average of market shares of all firms operating in the market, weighted by market shares.

$$HHI^i_j = \sum_{k=0}^K {s^i_{jk}}^2 + \sum_{k=0}^K {s^{*i}_{jk}}^2 \tag{33}$$

It is included between $\frac{1}{2K}$ and 1. If the HHI is equal $\frac{1}{2K}$, the market is competitive, all firms have the same market share. On the contrary, in the monopoly case in which one firm has a market share equal to one, the HHI will be equal to 1. The agencies usually calculate this indicator by using percentages instead of ratio for the market shares. The HHI^i_j calculated above is thus scaled by a factor 10,000. According to the U.S. Department of Justice, the agencies usually consider that markets with a Herfindahl index below 1,000 to be "unconcentrated, between 1,000 and 1,800 to be moderated concentrated, above 1,800 to be highly concentrated". The level of concentration within sector is expected to be higher when there is more heterogeneity in terms of idiosyncratic productivity within a sector. More competitive firms can thus exert more market power. The same logic applies to sectoral markup, which we expect to move in the same direction as the sectoral HHI. This is what we observe in our quantitative exercise.

We compute the aggregate HHI using the method presented in the CompNet Productivity Report 2023 from the European Union. [1]. Following any partition of firms (for instance sectors), the HHI can be written as a weighted mean of the sectoral HHIs over the J sectors, where weights are the squared shared on total revenue for each sector. We compute the HHI for the domestic firm including the revenue from serving the domestic and the foreign market. The aggregate HHI for firms located in country i is thus given by:

$$HHI^i = \int_0^i \left(HHI^i_j . \left(\left(\frac{P^i_j}{P_i} \right)^{1-\eta} \right)^2 \right) dj \tag{34}$$

[1]CompNet (2023), "Firm Productivity Report", p.74 URL: https://www.comp-net.org/fileadmin/_compnet/user_upload/CompNet_Productivity_Report_-_July_2023.pdf

where HHI_j^i is the HHI at the sector level.

7.6 Labor market

Labor is assumed to be immobile across countries but mobile within sectors. Households supply inelastically one unit of labor. The labor clearing condition must satisfy:

$$\int_0^1 l_j^i dj = 1$$

with l_j, the labor demand at the sectoral level:

$$l_j = \sum_{k=1}^{K} l_{jk}^i + \sum_{k=1}^{K} l_{jk}^{*-i}$$

with l_{jk}^i and l_{jk}^{*-i}, the labor demand of a domestic firm for producing respectively q_{jk}^i and q_{jk}^{*-i} goods for domestic and foreign markets.

8 Calibration

Our model generates incomplete pass-through because of a reallocation of market shares towards the most productive firms (domestic). We now quantify the prediction of our model, using the European context for our calibration. In this qualitative exercise, we simulate the model assuming that the labor supply is inelastic and normalized to one in both countries. As in Edmond and al. (2015), Both countries are symmetric in terms of aggregate and sectoral productivity and $W = 1$ is set to be the numeraire. As part of further research, we intend to solve for a fixed point in which labor supply is elastic, as in De Loecker and al. (2022). Our model has five parameters: K, η, ρ, τ and θ. We use, as in Atkeson Burstein (2008), a constant number of domestic firms in each sector $K = 20$. In our exercise, we simulate the model for 1000 sectors for a total of 40,000 firms. We choose η and ρ as in Atkeson, Burstein (2008). η is closed to one to keep sectoral expenditure shares roughly constant. The aggregate HHI is thus expected to be close to the mean HHI. Anderson, van Wincoop (2004) concluded that the elasticity of demand for imports at the sectoral level is in the range of 5 to 10. We choose the upper bound of this interval to make the import demand at the sectoral level quite elastic. These values are coherent with the literature. Edmond, Midrigan and Xu (2015) estimated within and across sector elasticities of substitution of respectively 10.5 and 1.24.

We choose the remaining parameters to match two key moments of the European market. First, θ controls the distribution of idiosyncratic productivities within sectors, which determines the levels of concentration.

Following Bighelli and al., the European domestic HHI was around 2100-2150 in 2016. This European concentration index incorporates intra-European trade flows but does not capture the impact of external trade flows to Europe. The authors wanted to use the HHI as a "shape of the firm-sales distribution, which reflects, among others, differences in production technologies across firms." (p.463) This measure is relevant for our calibration, as we assumed that our two countries are perfectly symmetric in terms of aggregate and sectoral productivity. With our calibration, we find an aggregate domestic HHI of 2123.38. We used the same method to estimate the domestic HHI as in Edmond and al. (2015). They defined the weights to calculate the sectoral domestic HHI as the ratio between the market shares for serving the domestic market divided by the sum of the market shares of domestic firms. Our estimate for the productivity parameter is $\theta = 0.32$. In comparison, it was 0.39 in Atkeson Burstein, who chose it to get a median sector moderately concentrated (HHI of 1500). While we used this measure to calibrate our model, we want to measure the impact of transport costs on concentration, so, what we call in the next section "Aggregate sectoral HHI" is a function of all firms (domestic and foreign) active in the market, as defined in equation (34).

Moreover, we chose the level of transport costs τ to match the imports of goods and services as a share of the GDP in the European Union. Before the Covid-19 crisis, according to the World Bank national and OECD accounts data, it was around 44-45% for the European Union (44%, 45.3% and 45.9% respectively in 2017, 2018 and 2019)[2]. The import share we found with our specification is 45.22%. The gross trade cost we found is equal to 1.04. In comparison, Edmond, Midrigan and Xu (2015) set their own trade cost to 1.129.

Parameter	Description	Value
ρ	Within-sector-elasticity of substitution	10
η	Across-sector-elasticity of substitution	1.01
θ	Log-normal parameter, idiosyncratic productivity	0.32
K	Number of firms in each sector in each country	20
τ	Gross trade cost	1.04

Table 8.1: Benchmark parameters

9 Quantification of the transport cost shock

9.1 Comparative statics

In this section, we use our benchmark model to study the importance of trade costs on firms' markup and competitiveness by comparing it to the extreme case of an autarky economy which opens to trade. As the iceberg trade costs increase, the number of firms exporting a positive amount of goods decreases. This exercise underlines the effects of lower trade and transport costs. With openness to trade, market shares are reallocated towards domestic firms. We also report the results for Bertrand competition. We use for both specifications, Bertrand and Cournot, the same underlying parameters and draws in productivity. The differences in the prediction of these two kinds of model, cannot be attributable to differences in productivity and parameters. We simulate the economy for 1000 sectors, 40,000 firms in total. Labor supply is fixed to one and $W = 1$. The algorithm is from the author (more details are provided in the appendix) The full

[2]World Bank, "World Trade Indicators", URL: https://wits.worldbank.org/CountryProfile/en/Country/WLD/Year/2018

tables about our indexes of concentration at the firm, sector and aggregate level can be found in the appendix (Tables 12.18, 12.19, 12.20 and 12.21).

At the firm level, in autarky, the distribution of market shares and markups is shifted to the right. Market concentration increases, resulting in higher markups and market shares for domestic firms, at the expense of foreign firms for which markups reach the lower bound of 1.111 in case of zero market shares. At the sector level, this translates into a shift to the right of the distribution of sector markups and HHI, suggesting that concentration increases at the sector level. Firms have more market shares and can use their market power to charge higher markups. The market becomes more concentrated and markups charged by domestic firms increase. Similar observations can be done at the aggregate level. Interestingly, the skewness for our measure of the dispersion of sectoral productivity (standard errors) at the sector level is always lower than the skewness for the sector markup for all specifications, suggesting that the difference in productivity across firms is amplified in terms of markups. Bertrand competition leads to similar conclusions. Quantities produced under Bertrand competition are expected to be higher while prices and markups tend to be lower. Bertrand competition tends to reward more cost-efficient firms than under Cournot competition. This results in more asymmetric market shares (Amir and Jin, (2001). Indeed, at the firm level, the distribution of market shares and markups is more asymmetric (higher skewness) under Bertrand competition, in autarky and in the benchmark model. For all specifications (autarky or not) and all measures of markups, HHI and market shares, the skewness is always higher under Bertrand competition, at the firm level.

As such, a reduction in trade costs and openness to trade, leads to lower markups, leading to lower prices, and more competition due to the presence of foreign firms. This is in line with what is found in Edmond and al. (2015), for the Taiwanese context. Under extensive misallocation and if dominant producers are exposed to greater competitive pressure, there are procompetitive gains from international trade.

9.2 Response to a short term shock

In this section, we investigate how aggregate variables change over time from steady-state to steady-state when the iceberg trade cost increases after a short-term shock. We simulate the model for a 10% shock in the iceberg trade cost. The persistence of the shocks is set to be quite persistent, $\rho_\tau = 0.95$. For computational purposes, we simulate the economy for 100 sectors. According to the law of large numbers, results are close to the one observed with 1000 sectors, with the benchmark value of $\tau = 1.04$. We plot the deviations from the benchmark calibrated model ($\tau = 1.04$). Results are given in Figure 9, which presents the sequence of steady states for 100 periods.

These implications fit what we observed in our empirical parts, even if the magnitudes are more important in this quantitative exercise. After a shock in trade costs, in our case due to an increase in transport costs, the price of foreign goods is predicted to increase by less of the increase of the transport shock.

9.2.1 Benchmark model: Cournot competition

In response to a 10% in the iceberg trade cost, foreign prices are predicted to increase by 7% only, when the shock occurs. This incomplete pass-through is explained in our model by a reallocation of market shares towards the most productive firms. The foreign firms, lose in competitiveness at the benefit of the domestic firms, not affected by the shock.

In response to a 10% shock in the iceberg trade cost, the aggregate productivity falls by 3%. This shock changes the relative competitiveness towards domestic firms by scaling up their marginal cost. The foreign firms bear the extra cost of exporting, reducing their market shares and thus their sales-weighted markup dropped by 1.6%, when the shock occurs. As a result, the prices charged by foreign firms increase by less than the size of the shock. The concentration within sectors increases, as the domestic firms benefit from this increase in trade costs. The aggregate HHI increases by around 4%, while the import share drops by 11%, when the shock occurs. The sales-weighted domestic markup raises by around 1.4% and this increase overcomes the drop in markups for foreign firms, resulting in an increase in the aggregate sales-weighted markup by 0.5%, when the shock occurs. Aggregate profit, driven by an increase in market power for domestic firms increases by more than the size of the shock. Indeed, while consumption drops by more than 0.8% the aggregate price increases by 4%, when the shock occurs. This increase in concentration results in a welfare loss for the consumer, whose consumption decreases, while domestic firms gain from this decrease in market competition.

9.2.2 Robustness check: Bertrand competition

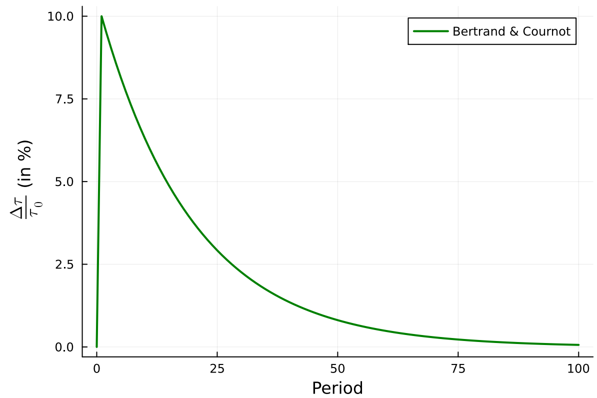
As a robustness check, we run the same simulation for Bertrand competition, using the same benchmark parameters. Similarly, we simulate the economy for 100 sectors, 4,000 firms and an iceberg trade cost in the benchmark steady state: $\tau = 1.04$. The shocks in the gross iceberg trade cost is 10% and is quite persistent, $\rho_\tau = 0.95$. We use the same draw in productivity as in the previous subsection. The dynamics we described while using Cournot competition are robust to a change in specification towards Bertrand competition. As observed in our empirical exercise, there is an incomplete pass-through of transport costs in foreign prices. Foreign prices are expected to raise by 9% in response to a 10% increase in transport costs, when the shock occurs. The pass-through is higher under Bertrand, as the adjustment in markups are predicted to be lower than in the Cournot case.

Even if, under Bertrand competition, market shares are more reactive to a change in trade costs however the changes in domestic and foreign markups are lower. Similarly as in the Cournot case, the shock reallocates market shares toward the domestic firms, which gain in competitiveness. The HHI increases by more than the Cournot case (more than 10% against 4% when the shock occurs). This was expected as the Herfindahl index is higher in Bertrand competition as we have seen in the static exercise. More competitive firms are more rewarded competition and this leads to more asymmetric market shares than under Cournot (Amir, Jin, (2001)). The adjustments of foreign and domestic markups, are lower in the Bertrand case. The ratio of the domestic and the foreign sales-weighted markups stays lower in the Bertrand case. The increase in the sales-weighted domestic markup, is around 0.8% , while the decrease in the sales-weighted foreign markup is around 0.7% when the shock occurs. Interestingly, the increase in the sales-weighted aggregate markup is comparable to Cournot case (around 0.5% when the shock occurs).

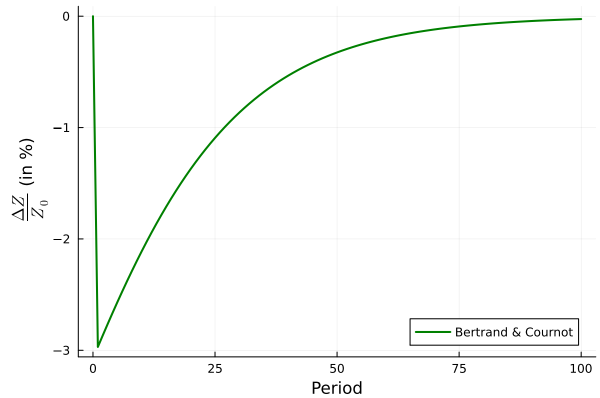
The implication under Bertrand competition in terms of aggregate consumption, prices and sales-weighted aggregate markups are similar to the Cournot case. Under Bertrand competition, changes in the aggregate prices, reflected by changes in the aggregate markup are comparable to the Cournot case, even if it is slightly lower, around 4% decrease when the shock occurs. Changes in aggregate consumption are however slightly higher, a drop of 1.2% against a bit more than 0.8% in the Cournot case, when the shock occurs. The change in import share and profit are amplified compared to the Cournot case.

Our model is robust to a change in the model of competition and fits what we observed in the data. The prices of imports increase by less than the size of the shock, because of a reallocation of market shares towards the domestic firms.

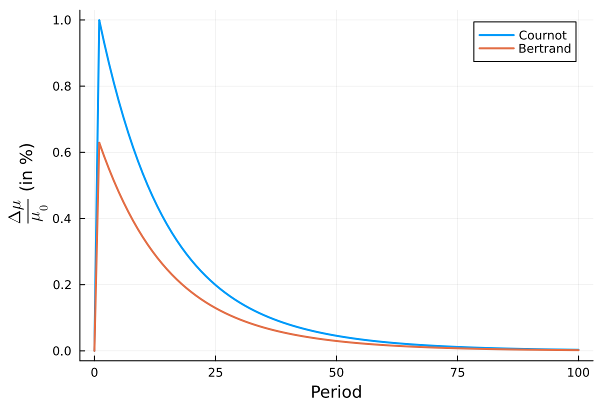
Figure 9: Impulse responses to a 10% iceberg trade cost shock (Bertrand and Cournot competitions)



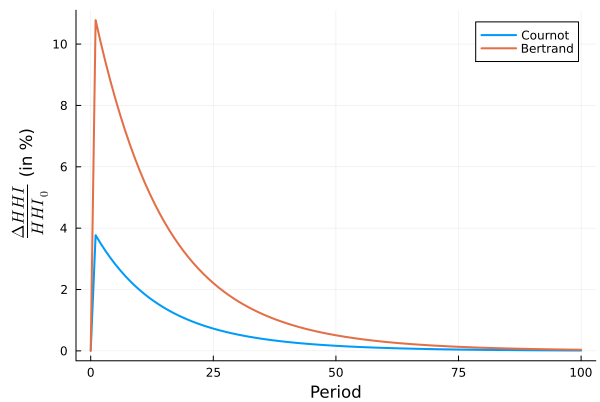
(a) Iceberg trade cost



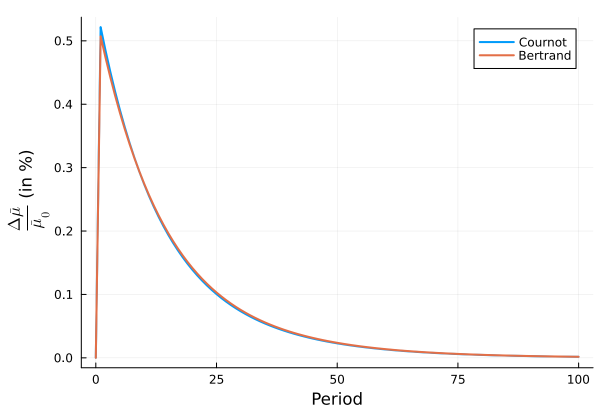
(b) Aggregate productivity



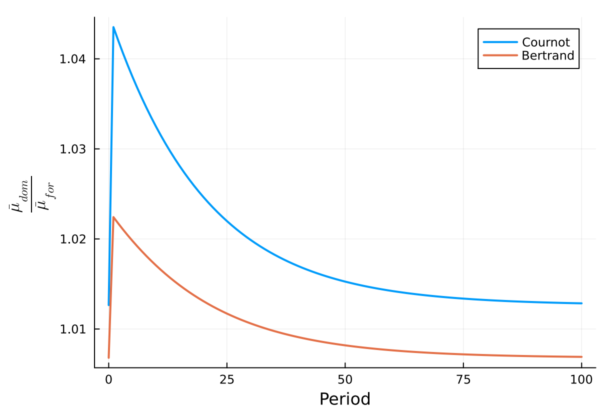
(c) Aggregate markup



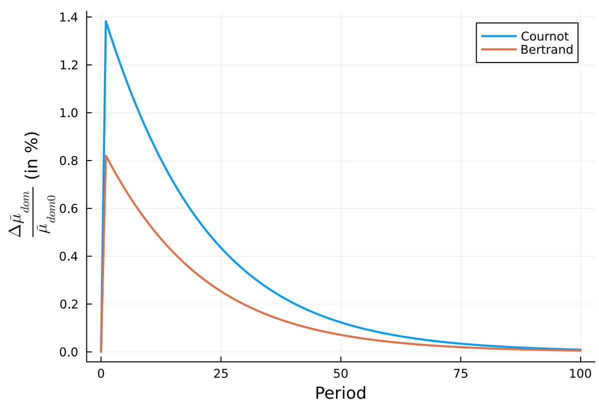
(d) Aggregate HHI



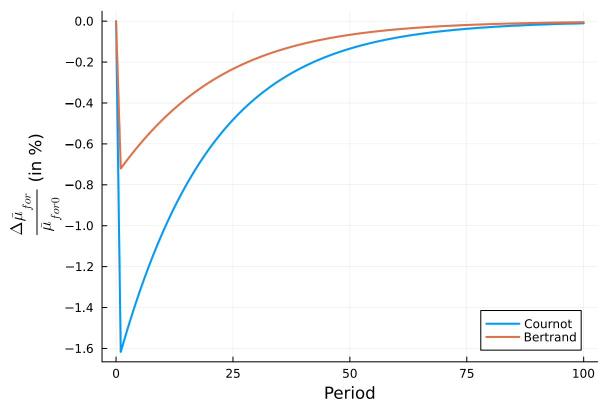
(e) Sales weighted aggregate markup



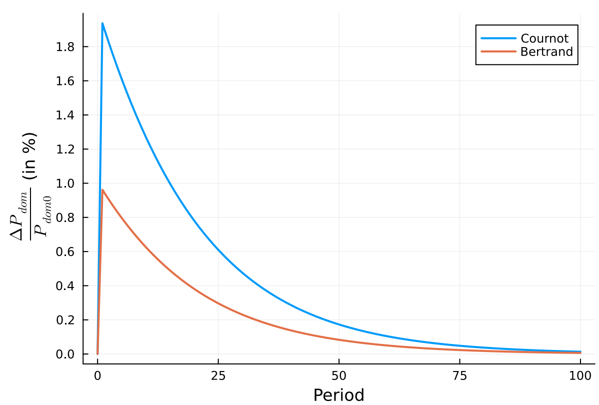
(f) Ratio domestic/foreign markups



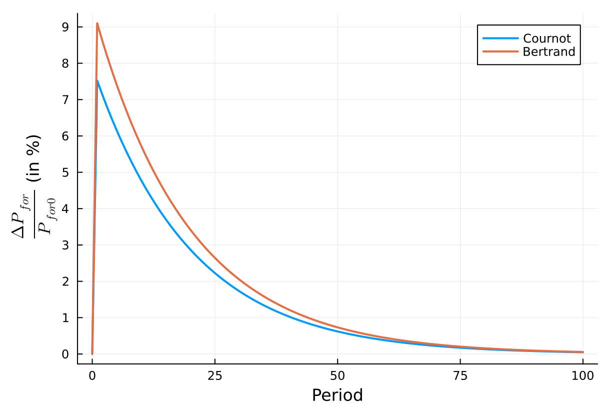
(g) Sales weighted domestic markup



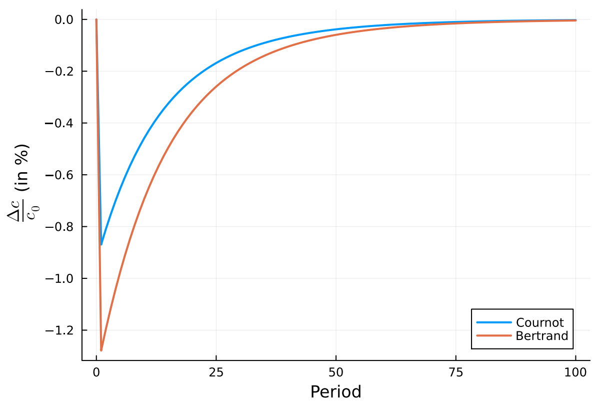
(h) Sales weighted foreign markup



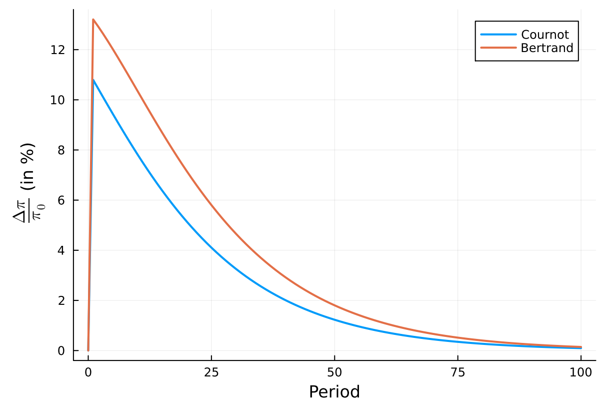
(i) Domestic price index



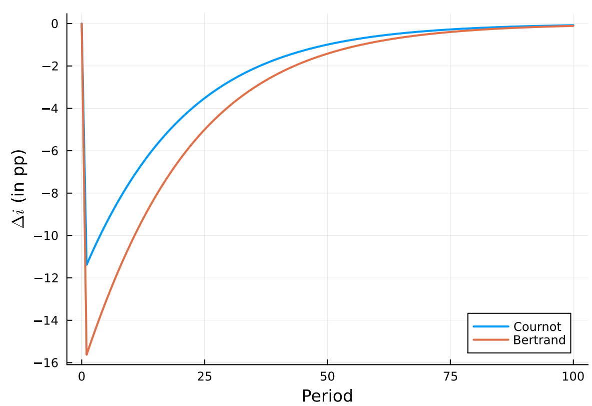
(j) Foreign price index



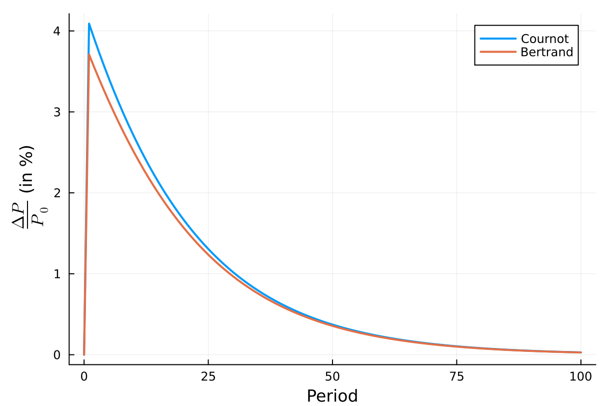
(l) Aggregate consumption



(m) Aggregate profit



(n) Import share



(o) Aggregate price index

Notes: These figures show the impulse response to a 10% shock to the iceberg trade cost. The persistence is set to 0.95. The economy is simulated for 100 sectors, so a total of 4,000 firms, with the same draw in productivity for both specifications. Under the assumption of Bertrand competition, the aggregate consumption is predicted to fall by more than 1.2% after a 10% increase in the iceberg trade costs.

9.3 Limitations and extensions

If our model, fits well the empirical evidence of an incomplete pass-through of transport costs, we assumed that prices can adjust freely. As such, the market reacts directly at the time of the shock in our simulations. However, our empirical analysis suggests that import prices adjust with a lag and there could exist price rigidities. These rigidities can be due to seller x buyer relationships in markets for intermediary goods or to different costs of transports. First, buyers and suppliers of intermediate goods could commit to certain quantities and prices with a contract. As such, a foreign firm affected by a shock in transport could not freely adjust its prices and similarly for a domestic firm. Price rigidities could amplify markups adjustments, resulting in further increases in prices. To check this hypothesis, we intend to extend our model, with sticky prices à la Calvo, such that domestic and foreign firms can adjust their prices with a probability λ and commit to prices and quantities at that price. In case of price rigidities due to contracts between the ship owner and the charterer, if the firm commits to a certain price for a certain number of periods, this would explain why the shock can be long-lasting. We could extend the model by assuming that foreign firms are not all affected by a shock in transport prices at the same moment. This may attenuate the impact of the shock on price increases but result in a more persistent impact of the shock.

Moreover, in our model, we assumed that labor supply was inelastic. It gives no predictions on the change in labor supply and level of wages. One possible extension is to relax this assumption by solving for the optimal level of labour supply as in De Locker and al. (2022). As such, we could furthermore explore how labor supply and level of wages change in case of transport cost shock.

We assumed that the shock to transport cost is a short-term shock, like in the post-pandemic context. Even if the Covid-19 shocks was temporary, some shocks on the price of transport may be permanent. For instance, Panama experiences a critical drought and imposed restrictions on the number of vessels allowed to cross the Canal. Before the water problems, as many as 38 ships a day moved through the Canal. In July 2023 the authorities cut the average to 32 vessels and to 24 in January 2024. About 5% of global maritime trade uses the Atlantic-Pacific shortcut, and 40% of US container traffic. As such, with global warming, this lack of water may become permanent, forcing ships to detour around the Cape of Good Hope. We could extend the model by including capital accumulation and elastic labor supply in the benchmark model and study the transition to two steady states before and after the permanent shock in transport costs.

Finally, we assumed that iceberg trade costs are symmetric, however, this is not empirically true (Figure 4). One can relax this assumption by simulating a one side shock on the cost of transport, in order to study the relative impacts on the two countries in terms of price levels, markup adjustments and consumption levels.

10 Conclusion

Using on an original dataset and a new index of the price of transport, this paper finds new evidence that transport cost still matters. The elasticity at a 1% shock for China on the cost of air and sea transport on cumulative price changes is around 0.15. Restricting to a sample for which the share of sea and air freight sum to one, after a 1% increase in transport costs, import prices increase on average by 0.24%, 13 months after the shock, compared to the period of the shock. The effect is quite persistent, lasting for 18 months.

In our model, this incomplete pass-through results of a reallocation of the market shares towards the domestic firms, more competitive. Markups of foreign firms increase by less than the size of the shock. Our model predicts, after a 10% trade cost shock, an increase in the domestic price index of 4%, because of an increase in domestic and foreign price indexes respectively of 0.9-1.9% and 7-9%.

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12 Appendix

12.1 Dataset

The Comext databaset

Table 12.1: Motor vehicles nomenclature (HS 2017)

HS4	**Description**
8601	Rail locomotives powered from an external source of electricity or by electric accumulators.
8602	Other rail locomotives; locomotive tenders.
8603	Self-propelled railway or tramway coaches, vans and trucks, other than those of heading 86.04.
8604	ailway or tramway maintenance or service vehicles, whether or not self-propelled (for example, workshops, cranes, ballast tampers, trackliners, testing coaches and track inspection vehicles).
8605	Railway or tramway passenger coaches, not self-propelled; luggage vans, post office coaches and other special purpose railway or tramway coaches, not self-propelled (excluding those of heading 86.04).
8606	Railway or tramway goods vans and wagons, not self-propelled.
8701	ractors (other than tractors of heading 87.09).
8702	Motor vehicles for the transport of ten or more persons, including the driver.
8703	Motor cars and other motor vehicles principally designed for the transport of persons (other than those of heading 87.02), including station wagons and racing cars.
8704	Motor vehicles for the transport of goods.
8705	Special purpose motor vehicles, other than those principally designed for the transport of persons or goods (for example, breakdown lorries, crane lorries, fire fighting vehicles, concretemixer lorries, road sweeper lorries, spraying lorries, mobile workshops, mobile radiological units).
8709	Works trucks, self-propelled, not fitted with lifting or handling equipment, of the type used in factories, warehouses, dock areas or airports for short distance transport of goods; tractors of the type used on railway station platforms; parts of the foregoing vehicles.
8710	Tanks and other armoured fighting vehicles, motorised, whether or not fitted with weapons, and parts of such vehicles.
8711	Motorcycles (including mopeds) and cycles fitted with an auxiliary motor, with or without side-cars; side-cars.
8716	Trailers and semi-trailers; other vehicles, not mechanically propelled; parts thereof.

Notes: This table lists the codes excluded from the analysis (motor vehicles)

Table 12.2: Motor vehicles nomenclature (HS 2022)

HS4	**Description**
8601	Rail locomotives powered from an external source of electricity or by electric accumulators.
8602	Other rail locomotives; locomotive tenders.
8603	Self-propelled railway or tramway coaches, vans and trucks, other than those of heading 86.04.
8604	Railway or tramway maintenance or service vehicles, whether or not self-propelled (for example, workshops, cranes, ballast tampers, trackliners, testing coaches and track inspection vehicles).
8605	Railway or tramway passenger coaches, not self-propelled; luggage vans, post office coaches and other special purpose railway or tramway coaches, not self-propelled (excluding those of heading 86.04).
8606	Railway or tramway goods vans and wagons, not self-propelled.
8701	Tractors (other than tractors of heading 87.09).
8702	Motor vehicles for the transport of ten or more persons, including the driver.
8703	Motor cars and other motor vehicles principally designed for the transport of persons (other than those of heading 87.02), including station wagons and racing cars.
8704	Motor vehicles for the transport of goods.
8705	Special purpose motor vehicles, other than those principally designed for the transport of persons or goods (for example, breakdown lorries, crane lorries, fire fighting vehicles, concretemixer lorries, road sweeper lorries, spraying lorries, mobile workshops, mobile radiological units).
8709	Works trucks, self-propelled, not fitted with lifting or handling equipment, the type used in factories, warehouses, dock areas or airports for short distance transport of goods; tractors of the type used on railway station platforms; parts of the foregoing vehicles.
8710	Tanks and other armoured fighting vehicles, motorised, whether or not fitted with weapons, and parts of such vehicles.
8711	Motorcycles (including mopeds) and cycles fitted with an auxiliary motor, with or without side-cars; side-cars.
8716	Trailers and semi-trailers; other vehicles, not mechanically propelled; parts thereof.

Notes: This table lists the codes excluded from the analysis (motor vehicles)

Table 12.3: Covid-19, product list (HS 2017)

HS 6	**Description (short)**
220710	Undenatured ethyl alcohol, of actual alcoholic strength of = 80%
284700	Hydrogen peroxide, whether or not solidified with urea
300120	Extracts of glands or other organs or of their secretions, for organo-therapeutic uses
300190	Dried glands and other organs for organo-therapeutic uses; heparin and its salts, ...
300212	Antisera and other blood fractions
300213 300214 300215 300219	Immunological products
300220	Vaccines for human medicine
300290	Human blood; animal blood; toxins, cultures of micro-organisms and similar products
300310 300320 300331 300339 300341 300342 300343 300349 300360 300390 300410 300420 300431 300432 300439 300441 300442 300443 300449 300450 300460 300490	Medicaments
300510	Dressings, adhesive: and other articles having an adhesive layer, packed for retail sale for medical, surgical, dental or veterinary purposes
300590	Wadding, gauze, bandages and the like put up for retail sale for medical, surgical, dental or veterinary purposes
300610	Sterile surgical catgut, similar sterile suture materials,...

Notes: This table lists the medical products excluded from the analysis.

Table 12.4: Covid-19, product list (HS 2017)

HS 6	Description (short)
300620	Reagents for determining blood groups or blood factors
300630	Opacifying preparations for x-ray examinations; diagnostic reagents for administration to patients
300650	First-aid boxes and kits
300670	Gel preparations designed to be used in human or veterinary medicine ...
340111 340130	Hand soap
340212	Cationic organic surface-active agents
340213	Non-ionic organic surface-active agents
340220	Other cleaning products
350400	Peptones and their derivatives; other protein substances and their derivatives, n.e.s.; ...
350790	Enzymes and prepared enzymes, n.e.s.
370110	Photographic plates and film in the flat, sensitised, unexposed, for X-ray
370210	Photographic film in rolls, unexposed, for X-ray
380894	Disinfectants, put up in forms or packings for retail sale
382100	Prepared culture media for the development or maintenance of micro-organisms
382200	Diagnostic or laboratory reagents on a backing, prepared diagnostic or laboratory reagents and certified reference materials
382499	Hand sanitizer
390421	Chlorine
391610 391620 391690	Raw Materials to produce masks
392329	Sharps container boxes
392390	Bio-hazard bag
392620	Articles of apparel and clothing accessories produced by the stitching or sticking together of plastic sheeting
392690	Face masks
401490	Hygienic or pharmaceutical articles
401511	Surgical gloves, of vulcanised rubber
401519 401590	Gloves, mittens and mitts, of vulcanised rubber

Notes: This figure lists the medical products excluded from the analysis.

Table 12.5: Covid-19, product list (HS 2017)

HS 6	**Description (short)**
481810	Hand drying tissue
530310	Raw Materials to produce masks
530390	
560410	
560600	
600240	
600290	
560311	Textile raw material for masks and coveralls
560312	
560313	
560314	
560391	
560392	
560393	
560394	
590700	Disposable chemical protective overalls
611300	Protective garments
611420	
611430	
611490	
611610	
621030	
621040	
621050	
621132	
621133	
621139	
621142	
621143	
621149	
621600	
621010	Protective clothing
621020	Gloves
621790	Medical Masks
630790	Face masks
650500	Disposable medical headwear
650610	Other medical headwear
701710	Laboratory, hygienic or pharmaceutical glassware, of fused quartz or other fused silica

Notes: This table lists the medical products excluded from the analysis.

Table 12.6: Covid-19, product list (HS 2017)

HS 6	**Description (short)**
701720	Laboratory, hygienic or pharmaceutical glassware having a linear coefficient of expansion = 5 x 10 -6 per Kelvin within a temperature range of 0°C to 300°C
701790	Laboratory, hygienic or pharmaceutical glassware n.e.s
721790 732690 760410 760429 761699	Raw Materials to produce masks
841391	Flow-splitter, for oxygen supply
841920	Medical, surgical or laboratory sterilizers
842129	Fit test kit
842139	Oxygen concentrators
842199	Full face mask filters anti-aerosol FFP3
847989	Humidifier, non-heated
900490	Protective spectacles and visors
901050	Apparatus and equipment ....; negatoscopes X
901110	Stereoscopic optical microscopes X
901180	Optical microscopes X
901811	Electro-cardiographs X
901812	Ultrasonic scanning apparatus X
901813	Magnetic resonance imaging apparatus X
901814	Scintigraphic apparatus
901819	Other electro-diagnostic apparatus X
901820	Ultraviolet or infra-red ray apparatus used in medical, surgical, dental or veterinary sciences X
901831	Syringes, with or without needles, used in medical, surgical, dental or veterinary sciences
901832	Tubular metal needles and needles for sutures, used in medical, surgical, dental or veterinary sciences
901839	Needles, catheters, cannulae and the like, used in medical, surgical, dental or veterinary sciences
901890	Instruments and appliances used in medical, surgical or veterinary sciences, n.e.s. X

Notes: This table lists the medical products excluded from the analysis.

Indicators for the price of transport

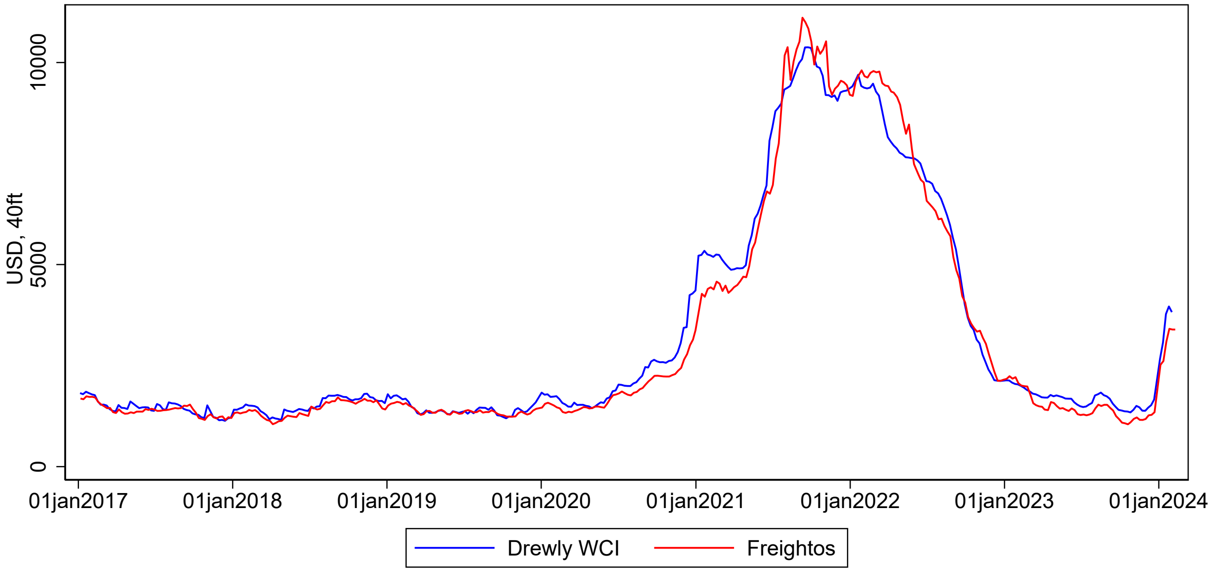
The data for the cost of transport are usually private. In order to obtain these datasets, we used web-scrapping techniques using Python. Among those we selected, we chose the Drewly World Container Index for maritime containerized traffic, the Baltic Price Index for bulk maritime traffic and the Traffic Air Cargo Index for air freight.

Drewly World Container Index

This index reports the container freight rates for the major maritime roads. It is a weekly indicator for the price of a 40ft container. A 40ft container is one of the most widely used in the shipping industry. It is multimodal and can be transported by sea, rail, inland waterway or road. It is collected for the following routes: Shanghai-Rotterdam, Rotterdam-Shanghai, Shanghai-Genoa, Shanghai-Los-Angeles, Los-Angeles-Shanghai, Shanghai-New York, New York-Rotterdam, Rotterdam-New-York. The World Container Index is a composite of these routes, weighted for the quantities and volumes transported. It includes possible surcharges, that affected the shipping industry and the different routes: "bunker adjustment factor (emergency adjustment if any), currency adjustment factor, peak season surcharge, equipment management fee/surcharge, port additional/port dues, emergency risk surcharge, port security charge, carrier security charge, submission of cargo declaration fee /US automated manifest fee, Suez Canal transit fee/surcharge, Panama Canal surcharge, Gulf of Aden surcharge, Port congestion surcharge"[3]. Other indicators for the price of containerized freight exist. Some only concern the freight index at the departure of Chinese ports such as the Shanghai Containerized Freight based on 12 routes from Chinese ports. The dynamics for Atlantic and Asia-Europe freight being different, these indicators would be inadequate to capture them. Drewly is not the only consulting firm providing a containerized index for several routes. Among others, the other leading indexes are that the Freightos Container Index based on 12 routes and the Xeneta Shipping index available for different types of containers. I chose the Drewly price index, as the data for the eight routes were extractable. However, the methodology of these indicators is similar and they are strongly correlated. Figure 12 displays the Drewly World Container Index and the Freightos World Container index, for 40ft containers. The correlation (0.992 over the period 2017-2024) is almost perfect between the two indicators, suggesting that the choice of the Drewly price index may not lead to misleading results.

[3] Drewly, 'World Container Index: Correlations and methodology' (2022). URL: https://www.drewry.co.uk/logistics-executive-briefing/logistics-executive-briefing-articles/world-container-index-correlations-and-methodology#:~:text=METHODOLOGY%3A%20Drewry%20World%20Container%20Index&text=The%20Index%20consists%20of%208,in%20USD%20per%2040ft%20Container.

Figure 12: World container indexes

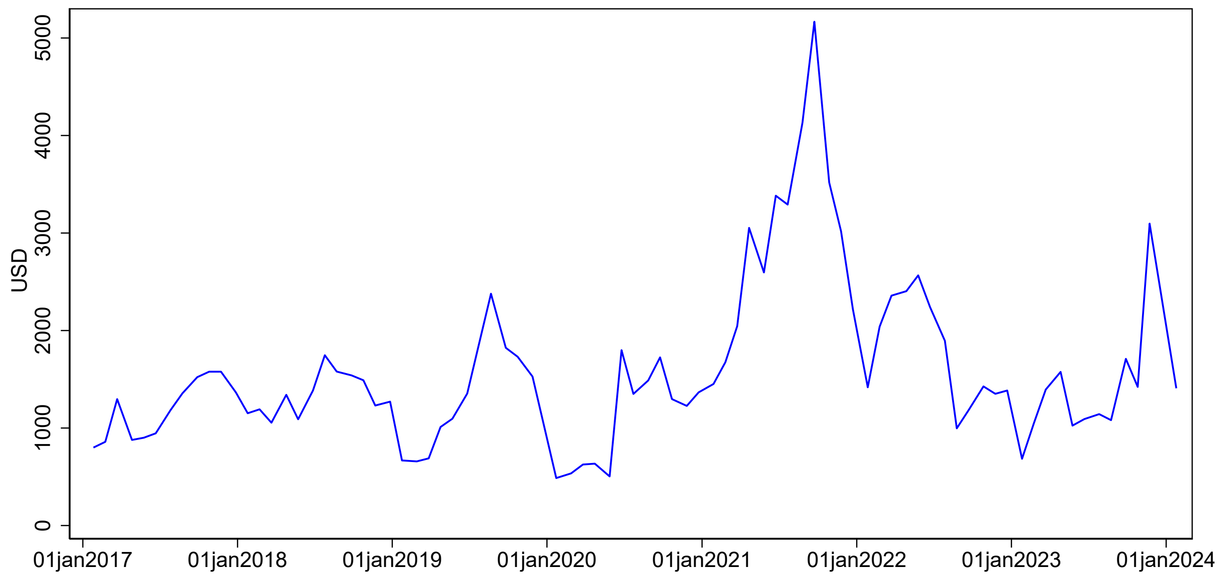


Notes: This figure presents the Drewly World Container Index and the Freightos Baltic Index at a weekly frequence over the period 2017-2024.

Baltic dry price index (BDI)

In addition to these indexes for containerized shipping, some products are transported in bulk. It can be either in solid bulk such as the agricultural products, minerals and ores and industrial solids, or in liquid bulk such as petroleum products, chemicals and edibles. It refers to the transportation of goods in large quantity, usually not packed and loaded directly into a vessel. The reference indicator for the price of transport for bulk materials is the Baltic Dry Index from the London-based Baltic Exchange for solid bulk. It covers 100% of the bulk dry cargo in transit on the world's oceans. It does not incorporate information about containerized goods or liquid fuel. It is a composite of the dry bulk timecharter average: the Baltic Capesize Index (40%), the Baltic Panamax Index (30%) and the Baltic Supramax Index (30%). These indicators concern different sizes of vessels. Panamax and NewPanamax are terms for the size limits through the Panama Canal (deadweight of 65,000–80,000 tonnes). Capesize vessels have been restricted from passing through major sizes due to their size, forcing them to transit via the Cape of Good Hope or the Cape Horn (130,000 – 210,000 deadweight tonnage). Supramax are suitable for ports with limited infrastructure with their typical 52,000-60,000 tonnes deadweight. In total more than 20 routes are used to build the BDI. The BDI was not freely available for different routes. As we concentrated our analysis on the price of manufacturing goods by differentiating the routes, we assumed that the container indexes reflect the dynamics of the goods shipped in bulk. While this index exists at a weekly frequency, we could only extract the BDI at a monthly level. The dynamics in the world BDI are close to the ones we observe in the container price index (correlation of 0.7203 over the period 2017-2024).

Figure 13: Baltic dry price Index (BDI)



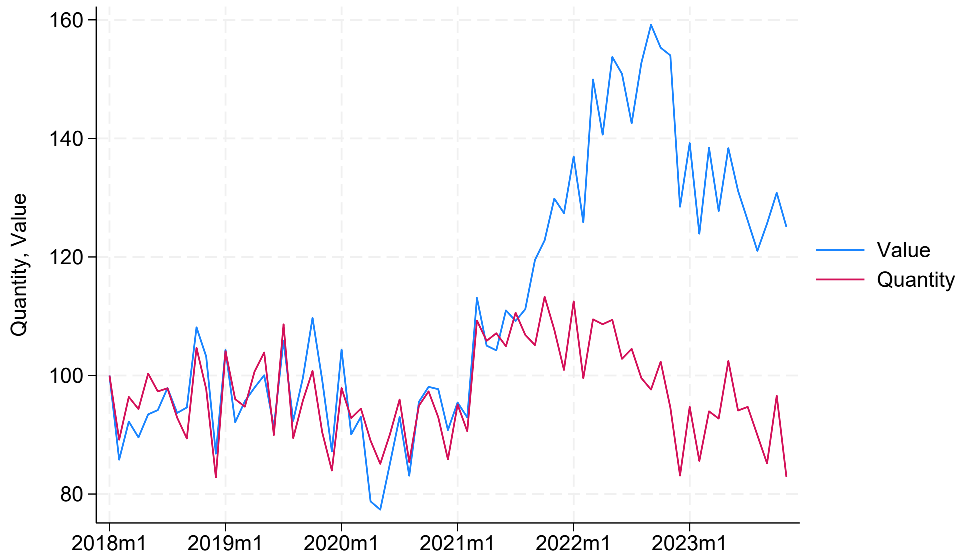
Notes: This figure shows the Baltic dry price index at a monthly frequence over the period 2017-2024.

Traffic Air Cargo Price index (TAC)

Finally, we use the Traffic Air Cargo index, the leading air cargo indicator, to estimate the cost of air freight. This index is done in collaboration with the Baltic Exchange. It is calculated as the ratio between all cost paid to carriers and the actual weight and is expressed in dollars per kilograms. It includes 17 routes. We were able to extract the data only for the world index from 2018 and not for all routes. We can observe that the dynamic are different than those for maritime freight. Indeed, part of the air freight is done with passenger flights, whose traffic was reduced dramatically during the pandemic, explaining part of the increase in the index.

12.2 Descriptive figures for all Extra-European manufacturing imports

Figure 14: Quantity and value of all extra-European imported manufacturing goods (100 in January 2018)



Notes: This figure plots the total value and quantity of all Extra-European imported manufacturing goods in the European Union relative to January 2018 level. Medical products (list in the appendix, Tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix) are excluded.

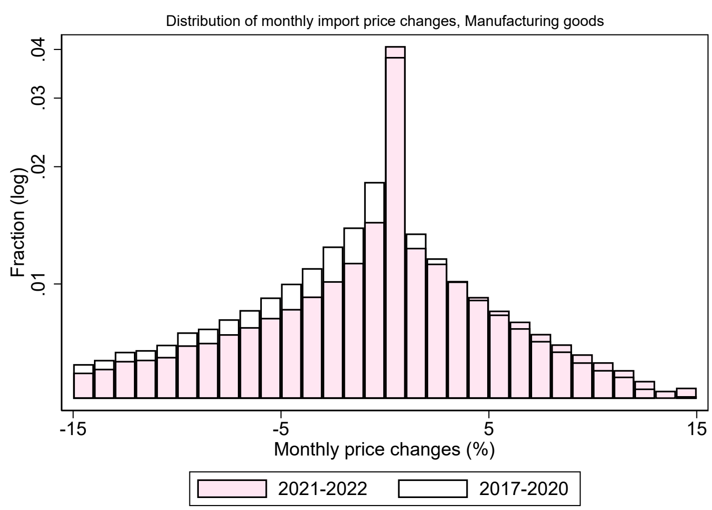
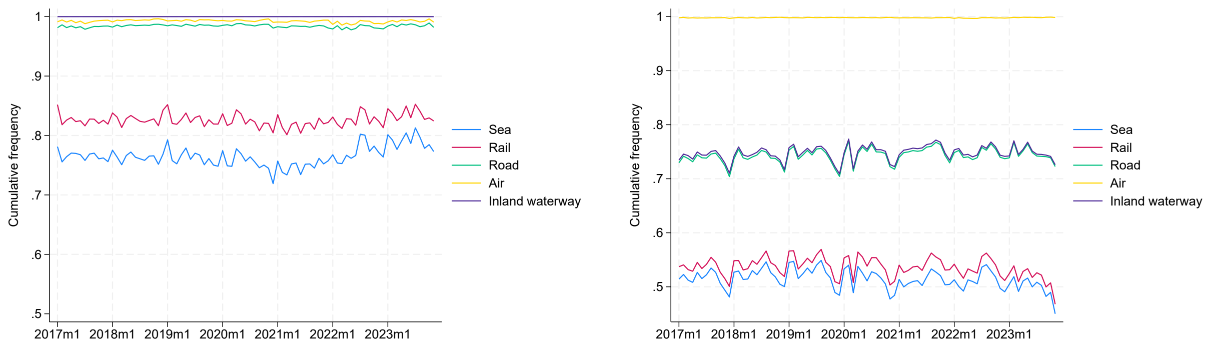


Figure 15: Distribution of monthly price changes

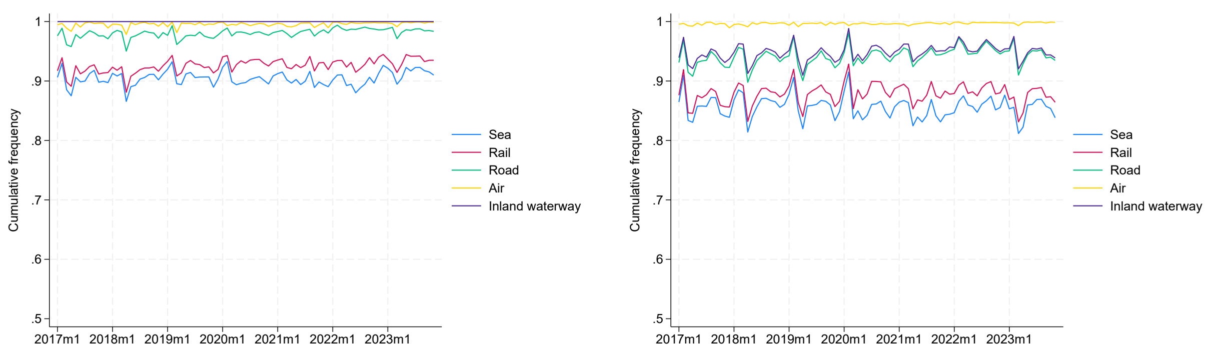
Notes: This figure plots the distribution of monthly price changes for all Extra-European imports over the 2017-2020 and the inflationary period 2021-2022. Medical products (list in the appendix, tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix), are excluded. The sample includes 41,552,616 observations, a total of 8,547 cn8 products.

Figure 16: Share of quantities and values transported by the main mode of transport (2017-2023, manufacturing goods)

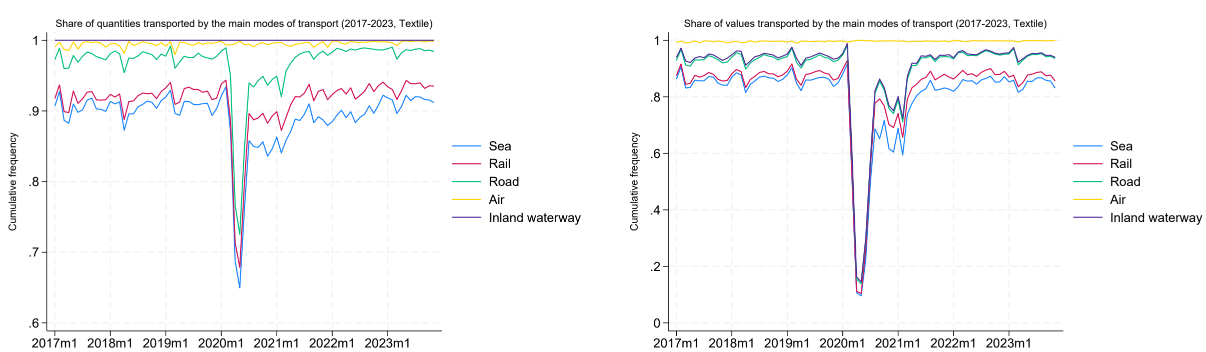


Notes: The dataset includes all extra-European imports in the manufacturing sectors, a total of 8,547 different goods (cn8) and 41,552,616 observations from January, 2017, to December, 2023. Medical products (list in the appendix, Tables 12.3, 12.4, 12.5 and 12.6) and motor vehicles (Tables 12.1 and 12.2 in the appendix) are excluded. The manufacturing sectors are defined at the ISIC 2-digit level.

Figure 17: Share of quantities and values transported by the main mode of transport (2017-2023, textile goods, ISIC 13)



(a) Quantity (no Covid-19 products) (b) Value (no Covid-19 products)



(c) Quantity, including Covid-19 products (d) Value, including Covid-19 products

Notes: The dataset includes all imports from in the textile sector from January, 2017, to December, 2023. The manufacturing sectors are defined at the ISIC 2 digit level.

12.3 Local projection estimates

Table 12.7: Cumulative-difference local projection method

	0	1	2	3	4	5
Transport	0.01358	0.00662	-0.00100	0.07722***	0.03696***	0.04790***
	(0.00850)	(0.00970)	(0.01084)	(0.01161)	(0.01140)	(0.01189)
Exchange	-0.27916	-0.04580	1.6285***	-2.2997***	-3.6268***	-4.0409***
rate	(0.20611)	(0.16854)	(0.36603)	(0.45179)	(0.48041)	(0.44418)
Oil	0.34400**	0.49315***	-0.97536***	0.21561***	0.52391***	0.62387***
	(0.16032)	(0.12741)	(0.24145)	(0.08315)	(0.09988)	(0.12127)
Food	-0.19652**	-0.53398***	0.51659***	-0.90240***	-0.54675***	-0.63629
	(0.08506)	(0.09354)	(0.15744)	(0.17412)	(0.19280)	(0.42079)
Obs	1132352	1086844	1065689	1043468	1021422	999601
R^2	0.292	0.339	0.367	0.384	0.389	0.390

	6	7	8	9	10	11	12
Transport	0.07005***	0.04049***	0.09844***	0.11289***	0.12174***	0.07500***	0.13431***
	(0.01177)	(0.01199)	(0.01203)	(0.01263)	(0.01261)	(0.01321)	(0.01407)
Exchange	-1.10449***	-2.70468***	-5.2124***	-2.9903***	-5.2548***	-1.04311***	-0.89788**
rate	(0.32682)	(0.35843)	(0.41244)	(0.52402)	(0.80344)	(0.27329)	(0.36063)
Oil	-0.06927	0.12995***	0.02012	-0.38164***	0.24122***	-0.07777***	-0.19674***
	(0.05763)	(0.04270)	(0.03749)	(0.04015)	(0.03817)	(0.01635)	(0.01608)
Food	1.0588***	0.97568***	1.4499***	1.42699***	1.0256***	1.94654***	0.71152***
	(0.11323)	(0.18490)	(0.14966)	(0.19331)	(0.30253)	(0.32146)	(0.23592)
Obs	978018	956490	935051	913847	892654	871343	849524
R^2	0.394	0.391	0.384	0.369	0.346	0.327	0.341

	13	14	15	16	17	18
Transport	0.15525***	0.13449***	0.13280***	0.09548***	0.09989***	0.03819**
	(0.01420)	(0.01511)	(0.01486)	(0.01486)	(0.01503)	(0.01512)
Exchange	7.54126***	-2.29421***	3.93706***	1.82795***	-1.46627**	-2.6316***
rate	(0.90199)	(0.58450)	(0.70504)	(0.565012)	(0.61193)	(0.57516)
Oil	0.30210***	-.056111**	-0.18413***	-0.03297	-0.12700***	-0.07711**
	(0.04625)	(0.02332)	(0.05578)	(0.03322)	(.031867)	(0.03332)
Food	-2.07535***	1.65524***	-1.35746***	-0.73264***	0.554668***	-0.58399***
	(0.35248)	(0.219079)	(0.313780)	(0.15216)	(0.12726)	(0.13854)
Obs	827941	806652	785426	764187	743023	721823
R^2	0.362	0.387	0.403	0.410	0.413	0.416

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. Coefficients for oil, food and exchange rate are without lags (occurring at time $t = 0$). We add country x product (cn8) and time-fixed effects. All control variables are log first differences at the time of the shock, $t = 0$.

Table 12.8: First-difference local projection method

	0	1	2	3	4	5
Transport	0.01358	-0.01178	-0.00935	0.06013***	-0.02563**	-0.00432
	(0.00850)	(0.00995)	(0.01063)	(0.01086)	(0.01082)	(0.01109)
Exchange	-0.27916	0.19179	0.85165**	-0.27515	-2.36315***	-2.0693***
rate	(0.20611)	(0.18105)	(0.37275)	(0.34611)	(0.51259)	(0.54891)
Oil	0.34400**	0.33173**	-0.77380***	-0.25593***	0.39025***	0.58630***
	(0.16032)	(0.15068)	(0.19987)	(0.08427)	(0.12439)	(0.14446)
Food	-0.19652**	-0.39505***	0.67494***	0.09863	-0.77125***	-1.70644***
	(0.08506)	(0.08123)	(0.16282)	(0.13199)	(0.27242)	(0.43395)
Obs	1132352	1086844	1043991	1022728	1000681	978855
R^2	0.292	0.012	0.009	0.008	0.008	0.008

	6	7	8	9	10	11	12
Transport	0.02736**	-0.04057***	0.05036***	0.01217	0.00620	-0.02968***	0.03459***
	(0.01113)	(0.01125)	(0.01108)	(0.01105)	(0.01154)	(0.01153)	(0.01224)
Exchange	1.4351***	0.49013	-0.17849	3.8142***	1.44755*	0.90241**	0.70063
rate	(0.33061)	(0.40361)	(0.44639)	(0.58543)	(0.84429)	(0.38164)	(0.48514)
Oil	-0.26022***	0.15180***	0.10561**	-0.02841	0.12478**	-0.12903***	-0.20454***
	(0.07141)	(0.05894)	(0.05375)	(0.03851)	(0.05366)	(0.02455)	(0.02078)
Food	-0.08083	-0.70281***	-0.40823***	-0.77724***	-1.533***	2.15376***	0.45671
	(0.11374)	(0.17679)	(0.13913)	(0.15200)	(0.25201)	(0.47291)	(0.36861)
Obs	957335	935948	914621	893511	872672	851906	830573
R^2	0.008	0.008	0.008	0.009	0.009	0.008	0.007

	13	14	15	16	17	18
Transport	0.02314*	-0.01546	-0.01266	-0.04806***	0.02568*	-0.04158***
	(0.01273)	(0.01338)	(0.01367)	(0.01369)	(0.01430)	(0.01422)
Exchange	4.7969***	-3.51792***	4.10564***	-0.17231	-3.54523***	-2.37274***
rate	(1.27042)	(0.66020)	(0.91778)	(0.76736)	(0.81857)	(0.43426)
Oil	0.24071***	0.09826***	-0.02998	0.03416	-0.13268***	0.01654
	(0.06243)	(0.03057)	(0.03993)	(0.04475)	(0.04401)	(0.02454)
Food	-2.3888***	0.62104***	-1.93878***	-0.59322***	0.83731***	-1.34917***
	(0.52395)	(0.18174)	(0.36629)	(0.18890)	(0.13177)	(0.21359)
Obs	809111	788179	767535	746888	726228	705557
R^2	0.007	0.007	0.007	0.007	0.007	0.006

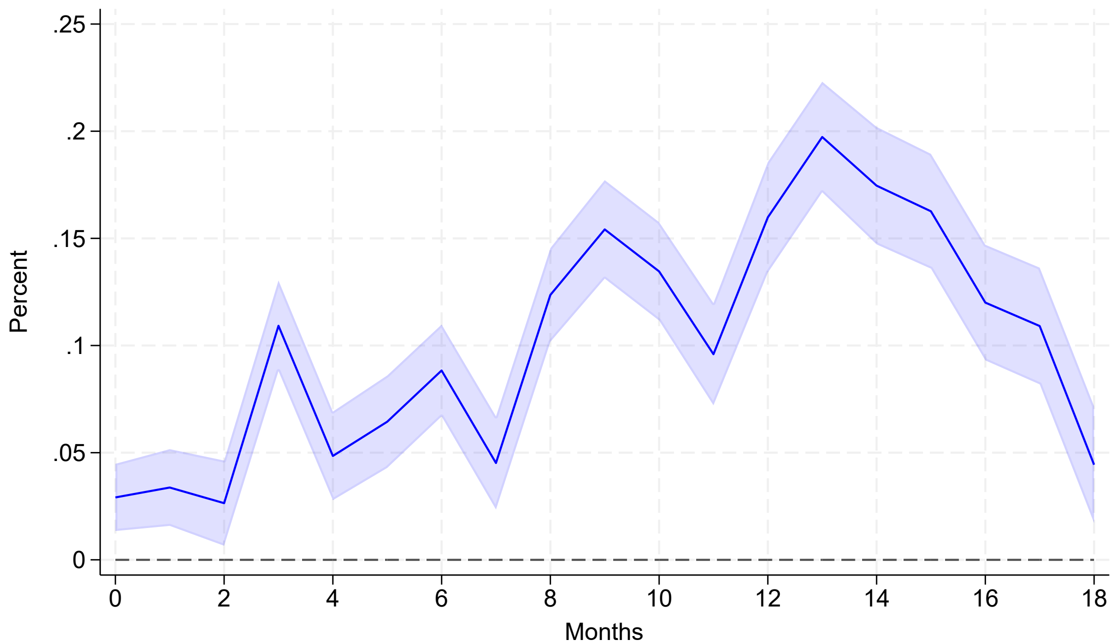
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. Coefficients for oil, food and exchange rate are without lags (occurring at time $t = 0$). We add country x product (cn8) and time-fixed effects. All control variables are log first differences at the time of the shock, $t = 0$.

12.4 Local projection estimates: Robustness checks

12.4.1 Alternative definition for weights (value)

Figure 18: Long difference local projection estimates, alternative definition for weights (value)



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. Weights are defined with value shares. If air and sea weights sum to 1, after a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.15% 9 months, after the shock compared to the period $t - 1$ before the shock. The full regression table is given in appendix (Table 12.9). Standard errors are clustered at the country x product (cn8) level. This specification includes time and country x product (cn8) fixed effects. Weights are defined as value shares.

Table 12.9: Cumulative-difference local projection method, alternative definition for weights (value)

	0	1	2	3	4	5
Transport	0.02912***	0.03374***	0.02644***	0.10922***	0.04848***	0.06446***
	(0.00800)	(0.00913)	(0.01015)	(0.01079)	(0.01055)	(0.01101)
Obs	1132352	1086844	1065689	1043468	1021422	999601
R^2	0.292	0.339	0.367	0.384	0.389	0.390

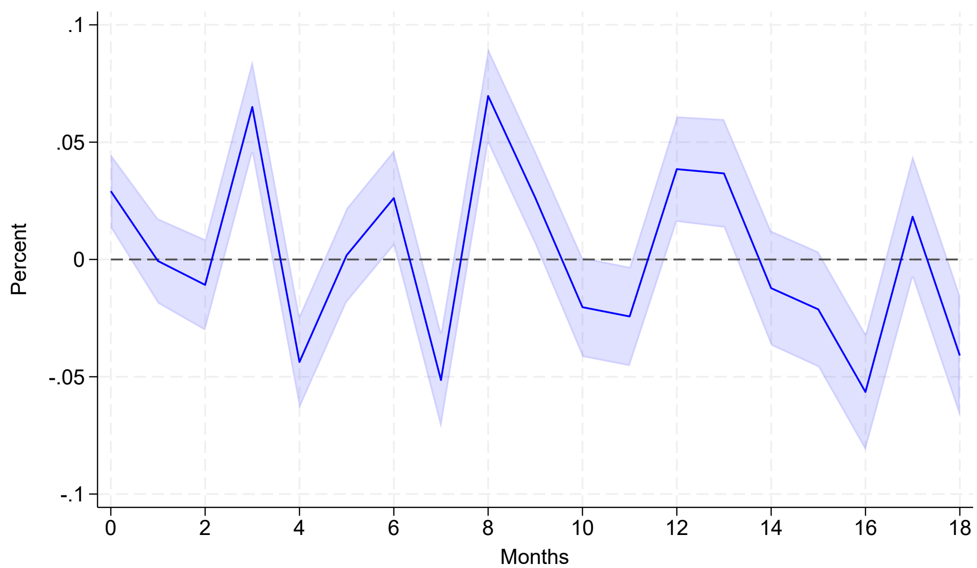
	6	7	8	9	10	11	12
Transport	0.08834***	0.04519***	0.12359***	0.15419***	0.13460***	0.09594***	0.15981***
	(0.01095)	(0.01109)	(0.01117)	(0.01172)	(0.01171)	(0.01217)	(0.01316)
Obs	978018	956490	935051	913847	892654	871343	849524
R^2	0.394	0.391	0.384	0.369	0.347	0.327	0.341

	13	14	15	16	17	18
Transport	0.19730***	0.17460***	0.16264***	0.12004***	0.10910***	0.04438***
	(0.01316)	(0.01399)	(0.01367)	(0.01377)	(0.01389)	(0.01392)
Obs	827941	806652	785426	764187	743023	721823
R^2	0.362	0.387	0.404	0.410	0.413	0.416

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. Weights are defined as value shares.

Figure 19: First difference local projection estimates, alternative definition for weights (value)



Notes: This figures presents the fist-difference local projection coefficients and their 95% confidence interval. Weights are defined with value shares. If air and sea weights sum to 1, after a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.07% between the second and the third month, after the shock compared to the period $t-1$ before the shock. The full regression table is given in appendix (Table 12.10). Standard errors are clustered at the country x product (cn8) level. This specification includes time and country x product (cn8) fixed effects. Weights are defined as value shares.

Table 12.10: First-difference local projection method, alternative definition for weights (value)

	0	1	2	3	4	5
Transport	0.02912***	-0.00065	-0.01084	0.06501***	-0.04372***	0.00178
	(0.00800)	(0.00925)	(0.00992)	(0.01012)	(0.01010)	(0.01026)
Obs	1132352	1086844	1043991	1022728	1000681	978855
R^2	0.292	0.013	0.009	0.009	0.008	0.008

	6	7	8	9	10	11	12
Transport	0.02616**	-0.05141***	0.06971***	0.02627***	-0.02034*	-0.02429**	0.03849***
	(0.01035)	(0.01043)	(0.01032)	(0.01022)	(0.01081)	(0.01079)	(0.01147)
Obs	957335	935948	914621	893511	872672	851906	830573
R^2	0.008	0.008	0.008	0.009	0.009	0.008	0.007

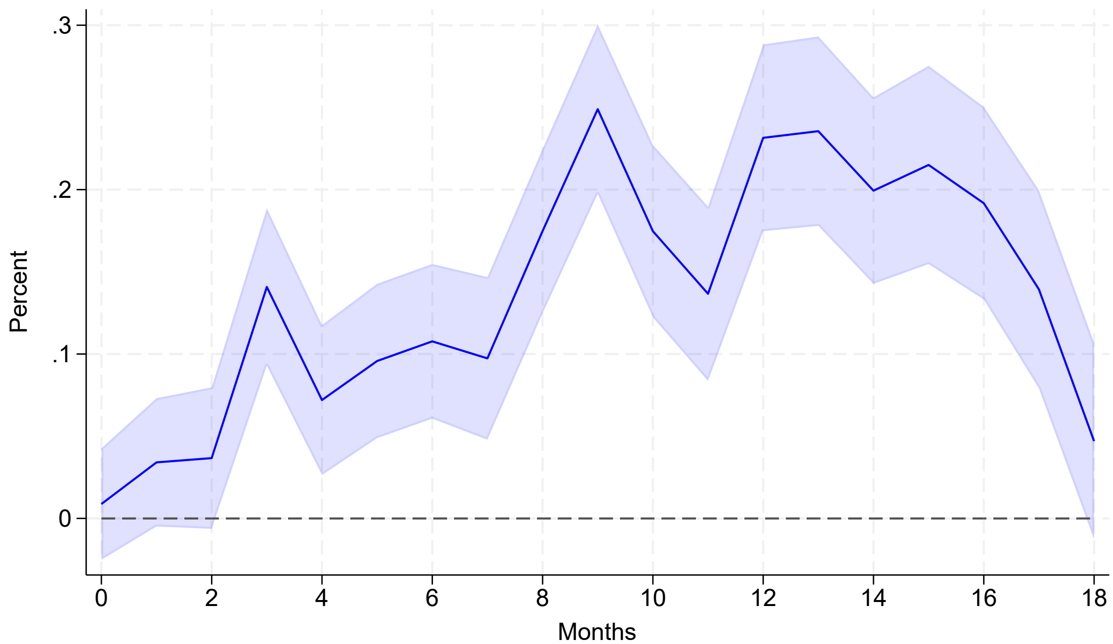
	13	14	15	16	17	18
Transport	0.03669***	-0.01222	-0.02126*	-0.05649***	0.01823	-0.04094***
	(0.01179)	(0.01247)	(0.01257)	(0.01267)	(0.01328)	(0.0132)
Obs	809111	788179	767535	746888	726228	705557
R^2	0.007	0.007	0.007	0.007	0.007	0.007

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. Weights are defined as value shares.

12.4.2 Restricted sample, ($\alpha_{ij}^a + \alpha_{ij}^s > 0.95$)

Figure 20: Long difference local projection estimates, restricted sample ($\alpha_{ij}^a + \alpha_{ij}^s > 0.95$)



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. The sample is restricted to country x product relationships for which the sum of share (quantity definition) transported by air and sea is higher than 0.95 and sum approximately to one. After a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.17% 10 months, after the shock compared to the period $t - 1$ before the shock. The full regression table is given in appendix (Table 12.11). Standard errors are clustered at the country x product (cn8) level. This specification include time and country x product (cn8) fixed effects.

Table 12.11: Cumulative-difference local projection method, restricted sample ($\alpha_{ij}^a + \alpha_{ij}^s > 0.95$)

	0	1	2	3	4	5
Transport	0.00877	0.03412*	0.03670*	0.14082***	0.07202***	0.09578***
	(0.01730)	(0.01991)	(0.02196)	(0.02442)	(0.02327)	(0.02395)
Obs	583092	560439	549531	538148	526837	515619
R^2	0.297	0.337	0.363	0.380	0.384	0.386

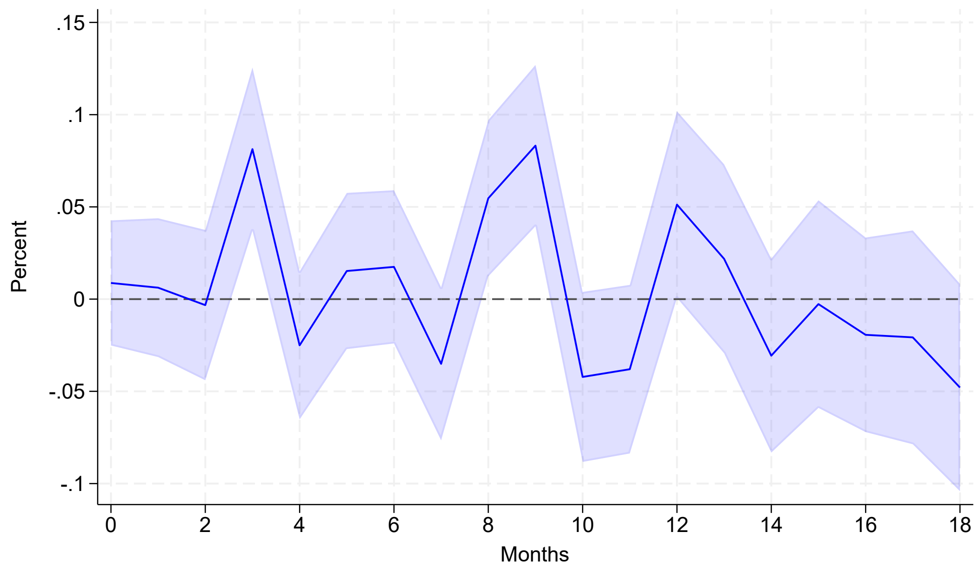
	6	7	8	9	10	11	12
Transport	0.10772***	0.09736***	0.17478***	0.24893***	0.17476***	0.13665***	0.23149***
	(0.02400)	(0.02523)	(0.02552)	(0.02629)	(0.02677)	(0.02704)	(0.02896)
Obs	504518	493459	482493	471652	460779	449801	438607
R^2	0.390	0.386	0.381	0.371	0.354	0.337	0.351

	13	14	15	16	17	18
Transport	0.23555***	0.19936***	0.21502***	0.19177***	0.13935***	0.04703
	(0.02941)	(0.02893)	(0.03078)	(0.02990)	(0.03076)	(0.03050)
Obs	427586	416646	405671	394710	383806	372923
R^2	0.368	0.390	0.406	0.411	0.415	0.417

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. The sample is restricted to country x product relationships for which the sum of share (quantity definition) transported by air and sea is higher than 0.95.

Figure 21: First-difference local projection estimates, restricted sample ($\alpha^a_{ij} + \alpha^s_{ij} > 0.95$)



Notes: This figures presents the first-difference local projection coefficients and their 95% confidence interval. The sample is restricted to country x product relationships for which the sum of share (quantity definition) transported by air and sea is higher than 0.95, and sum approximately to one. After a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.081% between the second and the third month, after the shock compared to the period $t-1$ before the shock. The full regression table is given in appendix (Table 12.12). Standard errors are clustered at the country x product (cn8) level. This specification include time and country x product (cn8) fixed effects.

Table 12.12: First-difference local projection method, restricted sample ($\alpha^a_{ij} + \alpha^s_{ij} > 0.95$)

	0	1	2	3	4	5
Transport	0.00877	0.00621	-0.00325	0.08132***	-0.02507	0.01525
	(0.01730)	(0.01920)	(0.02079)	(0.02258)	(0.02048)	(0.02160)
Obs	583092	560439	539052	528097	516784	505544
R^2	0.297	0.011	0.008	0.008	0.007	0.007

	6	7	8	9	10	11	12
Transport	0.01750	-0.03509*	0.05468**	0.08322***	-0.04218*	-0.03799	0.05125**
	(0.02118)	(0.02116)	(0.02163)	(0.02230)	(0.02351)	0.02332)	(0.02582)
Obs	494464	483456	472516	461714	451026	440308	429318
R^2	0.007	0.007	0.008	0.008	0.008	0.008	0.007

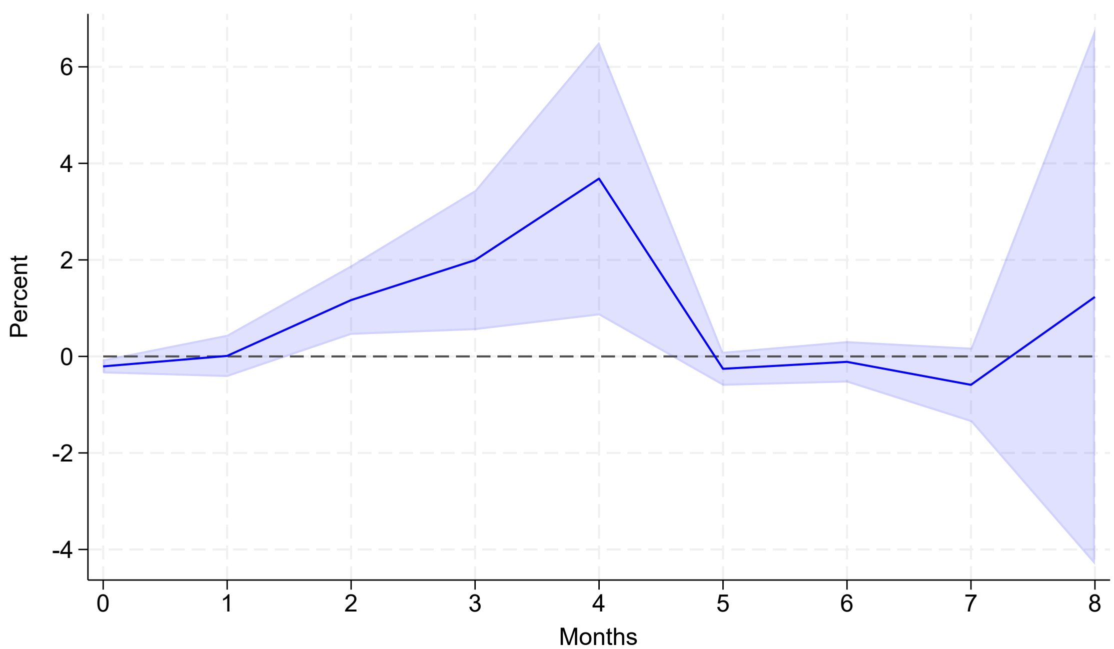
	13	14	15	16	17	18
Transport	0.02184	-0.03064	-0.00269	-0.01936	-0.02073	-0.04793*
	(0.02614)	(0.02682)	(0.02872)	(0.02691)	(0.02957)	(0.02868)
Obs	418339	407624	396955	386255	375575	364922
R^2	0.007	0.007	0.007	0.006	0.006	0.006

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. The sample is restricted to country x product relationships for which the sum of share (quantity definition) transported by air and sea is higher than 0.95.

12.4.3 Local projection estimates before 2020

Figure 22: Long difference local projection estimates, restricted sample (before 2020)



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. The sample is restricted to observations before 2020. The full regression table is given in appendix (Table 11.13). Standard errors are clustered at the country x product (cn8) level. This specification include time and country x product (cn8) fixed effects.

Table 12.13: Cumulative-difference local projection method, restricted sample after 2020

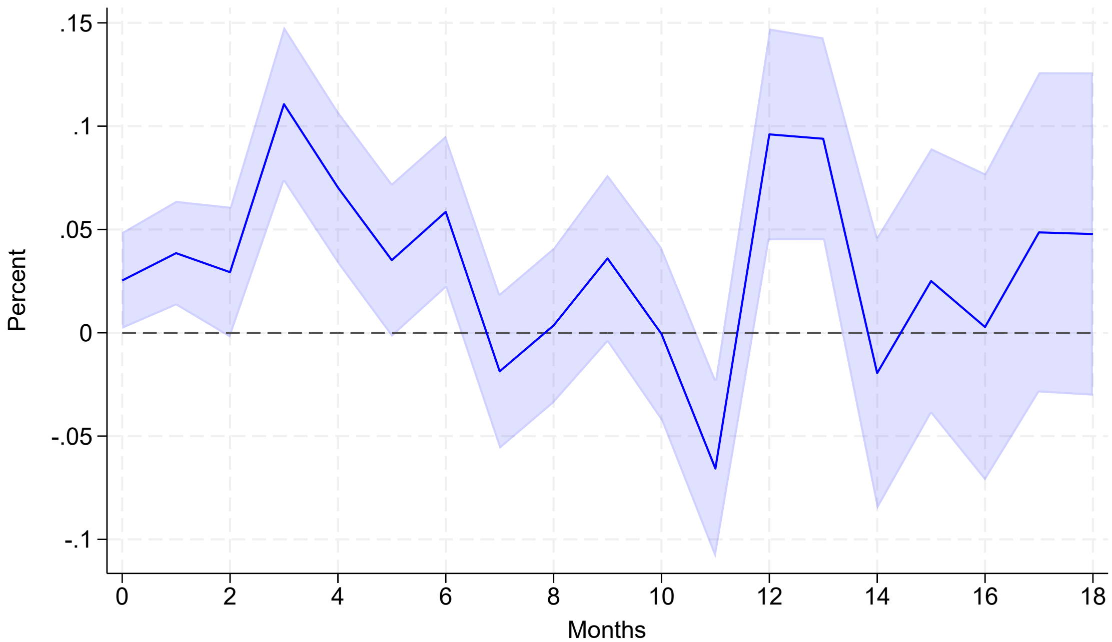
	0	1	2	3	4
Transport	-0.20655*	0.01096**	1.16735***	1.99592***	3.68450***
	(0.07340)	(0.22322)	(0.36740)	(0.73983)	(1.44576)
Obs	194301	171192	152016	132639	113372
R^2	0.401	0.470	0.503	0.514	0.487

	5	6	7	8
Transport	-0.25626	-0.11215	-0.58860	1.23244
	(0.17949)	(0.21856)	(0.39288)	(2.83198)
Obs	94083	74986	56204	37446
R^2	0.456	0.478	0.472	0.481

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. The sample is restricted to observations before 2020.

12.4.4 Local projection estimates after 2020

Figure 23: Long difference local projection estimates, restricted sample (after 2020)



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. The sample is restricted to observations after 2020. If air and sea weights sum to 1, after a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.09% 13 months, after the shock compared to the period $t - 1$ before the shock. The full regression table is given in the appendix (Table 11.14). Standard errors are clustered at the country x product (cn8) level. This specification include time and country x product (cn8) fixed effects.

Table 12.14: Cumulative-difference local projection method, restricted sample after 2020

	0	1	2	3	4	5
Transport	0.02531**	0.03855***	0.02933*	0.11068***	0.07035***	0.03515*
	(0.01194)	(0.01291)	(0.01616)	(0.01919)	(0.01885)	(0.01896)
Obs	693359	657756	636399	614482	592658	571047
R^2	0.306	0.348	0.374	0.393	0.402	0.408

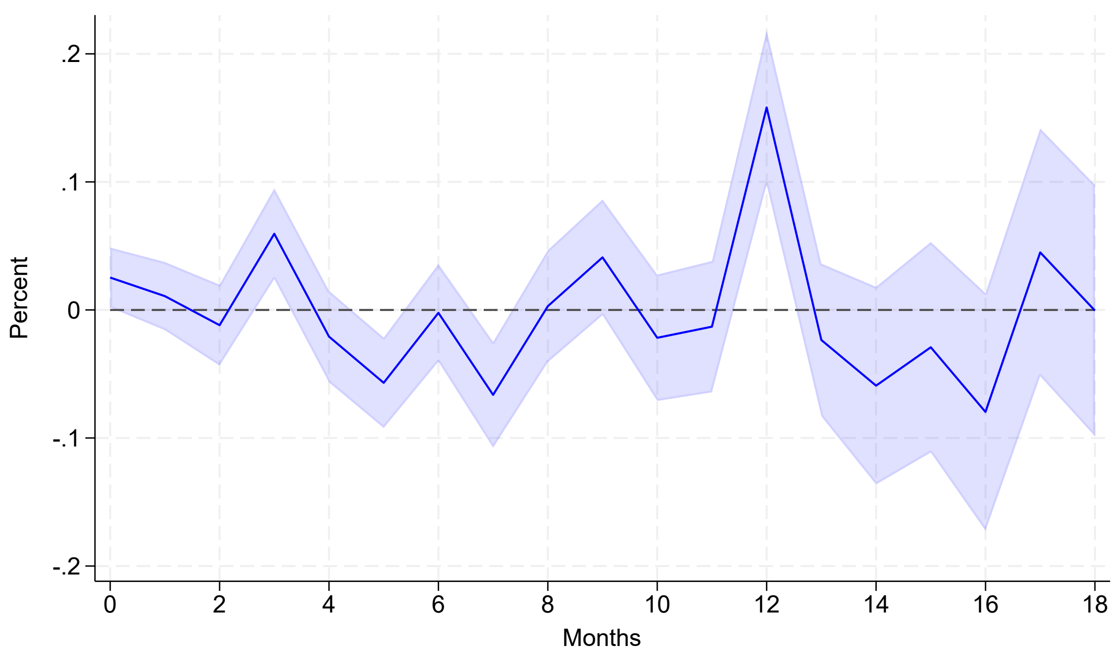
	6	7	8	9	10	11	12
Transport	0.05854***	-0.01866	0.00353	0.03601*	-0.00054	-0.06573***	0.09604***
	(0.01881)	(0.01918)	(0.01918)	(0.02071)	(0.02146)	(0.02214)	(0.02614)
Obs	549664	528345	507104	485960	464731	443334	422644
R^2	0.415	0.415	0.407	0.395	0.382	0.378	0.401

	13	14	15	16	17	18
Transport	0.09391***	-0.01950	0.02507	0.00280	0.04860	0.04779
	(0.02503)	(0.03368)	(0.03281)	(0.03793)	(0.03954)	(0.03991)
Obs	401925	381316	360881	340442	320101	299838
R^2	0.422	0.441	0.451	0.451	0.450	0.450

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. The sample is restricted to observations after 2020.

Figure 24: First difference local projection estimates, restricted sample (after 2020)



Notes: This figures presents the first-difference local projection coefficients and their 95% confidence interval. The sample is restricted to observations after 2020. If air and sea weights sum to 1, after a 1% cost in maritime and air transport cost at $t = 0$, import prices are likely to increase by 0.06% between the second and the third month, after the shock. The full regression table is given in appendix (Table 12.15). Standard errors are clustered at the country x product (cn8) level. This specification include time and country x product (cn8) fixed effects.

Table 12.15: First-difference local projection method, restricted sample after 2020

	0	1	2	3	4	5
Transport	0.02531**	0.01080	-0.01190	0.05952***	-0.02081	-0.05689***
	(0.01194)	(0.01359)	(0.01613)	(0.01806)	(0.01825)	(0.01803)
Obs	693359	657756	623968	602746	581116	559639
R^2	0.306	0.011	0.008	0.007	0.007	0.007

	6	7	8	9	10	11	12
Transport	-0.00225	-0.06630***	0.00295	0.04106*	-0.02173	-0.01305	0.15817***
	(0.01946)	(0.02108)	(0.02235)	(0.02307)	(0.02518)	(0.02617)	(0.03073)
Obs	538443	517393	496405	475507	454656	433725	413380
R^2	0.007	0.007	0.006	0.007	0.007	0.006	0.006

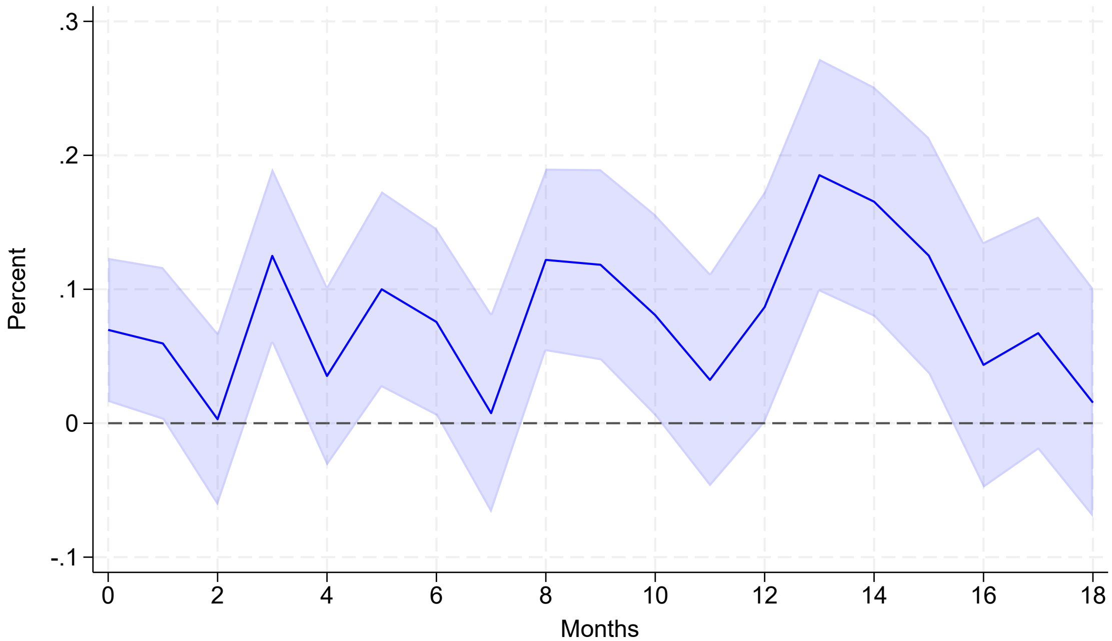
	13	14	15	16	17	18
Transport	-0.02346	-0.05912	-0.02913	-0.07963*	0.04497	-0.00044
	(0.03044)	(0.03940)	(0.04195)	(0.04735)	(0.04936)	(0.05011)
Obs	392962	372639	352569	332608	312685	292873
R^2	0.006	0.007	0.006	0.006	0.006	0.006

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and time-fixed effects. The sample is restricted to observations after 2020.

12.4.5 Industry x time fixed effects

Figure 25: Long difference local projection estimates, industry x time fixed effects



Notes: This figures presents the cumulative-difference local projection coefficients and their 95% confidence interval. If air and sea weights sum to 1, after a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.09% 12 months, after the shock compared to the period $t - 1$ before the shock. The full regression table is given in appendix (Table 12.16). Standard errors are clustered at the country x product (cn8) level. This specification include industry (ISIC 2 digits) x time and country x product (cn8) fixed effects.

Table 12.16: Cumulative-difference local projection method, restricted sample before the inflationary period

	0	1	2	3	4	5
Transport	0.06970**	0.05957**	0.00297	0.12495***	0.03525	0.10002***
	(0.02742)	(0.02904)	(0.03291)	(0.03344)	(0.03420)	(0.03733)
Obs	114371	109791	107645	105381	103134	100924
R^2	0.311	0.358	0.375	0.391	0.394	0.394

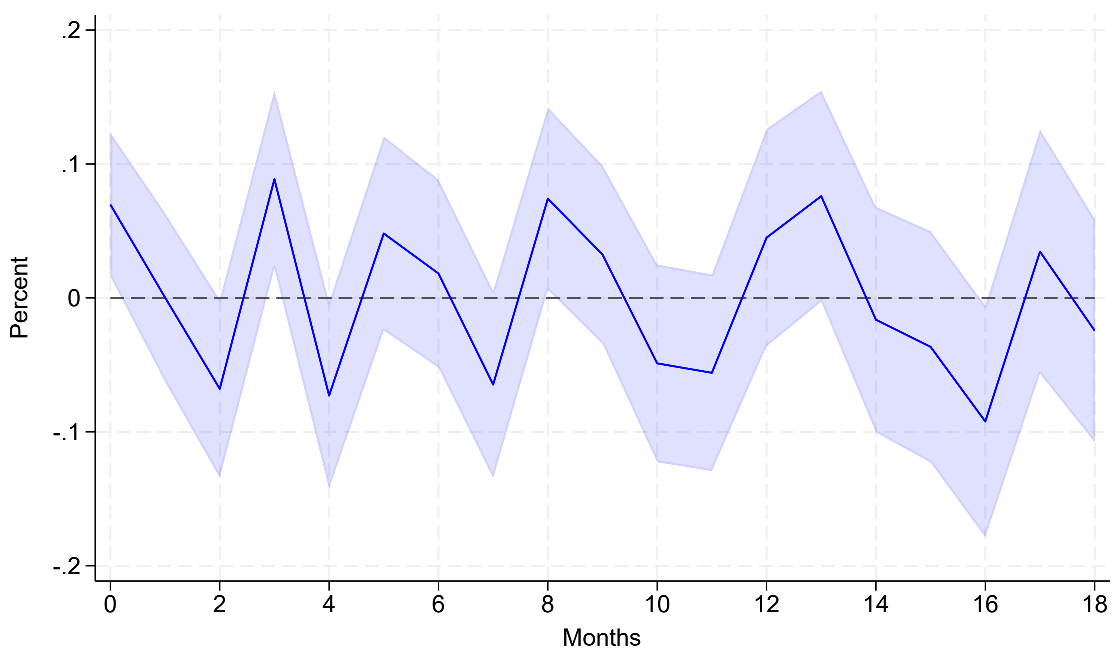
	6	7	8	9	10	11	12
Transport	0.07562**	0.00750	0.12193***	0.11832***	0.08066**	0.03234	0.08671**
	(0.03571)	(0.03804)	(0.03474)	(0.03638)	(0.03842)	(0.04058)	(0.04411)
Obs	98730	96562	94404	92267	90121	87972	85800
R^2	0.404	0.398	0.392	0.384	0.369	0.347	0.368

	13	14	15	16	17	18
Transport	0.18523***	0.16540***	0.12510***	0.04356	0.06726	0.01538
	(0.04430)	(0.04379)	(0.04512)	(0.04681)	(0.04440)	(0.04369)
Obs	83649	81526	79394	77281	75148	72954
R^2	0.385	0.403	0.415	0.420	0.419	0.420

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. This specification includes industry (ISIC 2 digits) x time and country x product (cn8) fixed effects.

Figure 26: First difference local projection estimates, industry x time fixed effects



Notes: This figures presents the first-difference local projection coefficients and their 95% confidence interval. If the air and sea weights sum to 1, after a 1% cost in transport cost at $t = 0$, import prices are likely to increase by 0.09% between the second and the third month, after the shock. The full regression table is given in appendix (Table 12.17). Standard errors are clustered at the country x product (cn8) level. This specification include industry (ISIC 2 digits) x time and country x product (cn8) fixed effects.

Table 12.17: First-difference local projection method, industry x time fixed effects

	0	1	2	3	4	5
Transport	0.06970	0.00034	-0.06786**	0.08866***	-0.07289**	0.04812
	(0.02742)	(0.03210)	(0.03393)	(0.03389)	(0.03545)	(0.03695)
Obs	114371	109791	105464	103296	101041	98821
R^2	0.311	0.026	0.023	0.024	0.023	0.022

	6	7	8	9	10	11	12
Transport	0.01821	-0.06470*	0.07410**	0.03237	-0.04886	-0.05591	0.04500
	(0.03583)	(0.03561)	(0.03475)	(0.03398)	(0.03765)	(0.03744)	(0.04140)
Obs	96628	94463	92316	90198	88077	85993	83880
R^2	0.022	0.021	0.021	0.022	0.022	0.021	0.020

	13	14	15	16	17	18
Transport	0.07599*	-0.01626	-0.03654	-0.09224**	0.03457	-0.02440
	(0.04019)	(0.04296)	(0.04406)	(0.04407)	(0.04647)	(0.04255)
Obs	81758	79706	77646	75588	73530	71413
R^2	0.020	0.020	0.020	0.021	0.021	0.021

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Standard errors are clustered at country x product (cn8) level. Standard errors are given in parentheses. We add country x product (cn8) and industry (ISIC, 2 digits) x time-fixed effects.

12.5 Model: Comparative statics

Table 12.18: Market power at the firm level (1)

	Cournot		Bertrand	
	Benchmark	Autarky	Benchmark	Autarky
All firms				
Market shares				
Mean	0.0250	0.0500	0.025	0.0500
p10	0.0001	0.0005	$3.12e^{-5}$	0.0001
p25	0.0006	0.0025	0.0002	0.0006
p50	0.0044	0.0164	0.0016	0.0047
p75	0.0260	0.0684	0.0129	0.0343
p90	0.0812	0.1542	0.0720	0.1606
p99	0.2185	0.3177	0.3500	0.5657
$\frac{p90}{p10}$	788.65	333.17	2305.34	1580.41
Standard errors	0.0463	0.0726	0.0645	0.1121
Skewness	2.97	2.12	4.02	3.38
Markups				
Mean	1.142	1.177	1.115	1.120
p10	1.111	1.112	1.111	1.111
p25	1.112	1.114	1.111	1.111
p50	1.116	1.129	1.111	1.112
p75	1.140	1.192	1.113	1.115
p90	1.208	1.311	1.120	1.132
p99	1.417	1.620	1.171	1.255
$\frac{p90}{p10}$	1.087	1.179	1.007	1.019
Standard errors	0.064	0.110	0.011	0.031
Skewness	3.78	3.04	5.42	8.23

Notes: This table gives the unconditional distribution of market shares and markups, including foreign and domestic firms. The model was simulated for 1000 sectors, a total of 40,000 firms. The parameters and the productivity draws used for the Cournot and the Bertrand specifications were identical. Skewness is Type 1 definition according to Joanes and Gill (1998).

Table 12.19: Market power at the firm level (2)

	Cournot		Bertrand	
	Benchmark	Autarky	Benchmark	Autarky
Domestic firms				
Market shares				
Mean	0.0274	0.0500	0.0285	0.0500
p10	0.0001	0.0005	$3.784e^{-5}$	0.0001
p25	0.0007	0.0025	0.0002	0.0006
p50	0.0052	0.0164	0.0019	0.0047
p75	0.0296	0.0684	0.0154	0.0343
p90	0.0897	0.1542	0.0842	0.1606
p99	0.2287	0.3177	0.3770	0.5657
$\frac{p90}{p10}$	725.20	333.17	2224.53	1580.41
Standard errors	0.0491	0.0726	0.0712	0.1121
Skewness	2.82	2.12	3.81	3.39
Markups				
Mean	1.145	1.177	1.115	1.120
p10	1.111	1.112	1.111	1.111
p25	1.112	1.114	1.111	1.111
p50	1.117	1.129	1.111	1.112
p75	1.145	1.192	1.113	1.115
p90	1.219	1.311	1.121	1.132
p99	1.436	1.620	1.178	1.256
$\frac{p90}{p10}$	1.097	1.179	1.009	1.019
Standard errors	0.068	0.110	0.012	0.031
Skewness	3.61	3.04	5.15	8.23
Foreign firms				
Market shares				
Mean	0.0226	0	0.0215	0
p10	8.694e^{-5}	0	2.658e^{-5}	0
p25	0.0005	0	0.0002	0
p50	0.0037	0	0.0014	0
p75	0.0223	0	0.0109	0
p90	0.0736	0	0.0607	0
p99	0.2065	0	0.3052	0
$\frac{p90}{p10}$	847.03	-	2279.54	-
Standard errors	0.0433	0	0.0567	0
Skewness	3.12	-	4.16	-
Markups				
Mean	1.139	1.111	1.114	1.111
p10	1.111	1.111	1.111	1.111
p25	1.112	1.111	1.111	1.111
p50	1.115	1.111	1.111	1.111
p75	1.136	1.111	1.112	1.111
p90	1.198	1.111	1.118	1.111
p99	1.396	1.111	1.160	1.111
$\frac{p90}{p10}$	1.078	1.0	1.006	1.0
Standard errors	0.059	0	0.009	0
Skewness	3.95	-	5.38	-

Notes: This table gives the unconditional distribution of market shares and markups, for foreign and domestic firms separately. The model was simulated for 1000 sectors, a total of 40,000 firms. The parameters and the productivity draws used for the Cournot and the Bertrand specifications under the benchmark model or autarky were identical. Skewness is a type 1 definition according to Joanes and Gill (1998).

Table 12.20: Market power at the sector level

	Cournot		Bertrand	
	Benchmark	Autarky	Benchmark	Autarky
Conditional distribution (sector level)				
Standard errors, sectoral productivity				
Mean	2.09	1.97	2.09	1.97
p10	1.77	1.67	1.77	1.67
p25	1.87	1.77	1.87	1.77
p50	2.04	1.92	2.04	1.92
p75	2.23	2.10	2.23	2.10
p90	2.53	2.38	2.53	2.38
p99	3.03	2.86	3.03	2.86
$\frac{p90}{p10}$	1.43	1.43	1.43	1.43
Standard error	0.31	0.30	0.31	0.30
Skewness	1.18	1.17	1.18	1.17
HHI				
Mean	1107.58	1553.88	1911.55	3015.36
p10	678.10	1117.61	920.49	1685.39
p25	811.89	1257.03	1176.84	2099.73
p50	1013.14	1477.34	1669.33	2803.13
p75	1281.75	1763.56	2375.90	3664.52
p90	1634.61	2086.59	3390.13	4622.89
p99	2674.05	2795.82	4804.59	6672.11
$\frac{p90}{p10}$	2.41	1.87	3.68	2.74
Standard error	432.95	403.35	972.87	1204.82
Skewness	1.68	1.03	1.17	0.98
Sectoral markups				
Mean	1.285	1.396	1.143	1.191
p10	1.201	1.270	1.123	1.136
p25	1.221	1.306	1.127	1.145
p50	1.259	1.362	1.136	1.166
p75	1.317	1.444	1.151	1.202
p90	1.398	1.557	1.178	1.273
p99	1.666	1.923	1.218	1.552
$\frac{p90}{p10}$	1.164	1.226	1.049	1.121
Standard error	0.0968	0.136	0.0229	0.0810
Skewness	2.13	2.01	1.57	3.13

Notes: This table gives the conditional distribution of market shares and markups, all firms separately. The model was simulated for 1000 sectors, a total of 40,000 firms. The parameters and the productivity draws used for the Cournot and the Bertrand specifications under the benchmark model or autarky were identical. Skewness is a type 1 definition according to Joanes and Gill (1998).

Table 12.21: Market power at the aggregate level

	Cournot		Bertrand	
	Benchmark	Autarky	Benchmark	Autarky
Aggregate implications				
Market power				
HHI	1107.56	1553.87	1911.52	3015.33
Aggregate markup	1.282	1.390	1.143	1.189
Sales-weighted markup	1.259	1.334	1.142	1.183
Sales-weighted domestic markup	1.266	1.334	1.146	1.065
Sales-weighted foreign markup	1.251	1.111	1.183	1.111
Ratio domestic/foreign markup	1.012	1.201	1.007	1.066
Import share (%)	45.22	0	43.10	0

Notes: This table gives the aggregate variables for the Cournot and Bertrand models under autarky and in the benchmark model. The model was simulated for 1000 sectors, a total of 40,000 firms. The parameters and the productivity draws used for the Cournot and the Bertrand specifications under the benchmark model or autarky were identical.

13 Mathematical appendix

13.1 The inverse demand functions and the theoretical price indexes

At the aggregate level

Solving for the inverse demand function at the aggregate level:

We can find the inverse demand function by solving the household's minimization problem.

The expenditure minimisation problem is such that the household wants to find the right mix among different sectors such that he minimizes his expenditure while still achieving the same level of utility (so the same consumption level as utility is strictly increasing in consumption). The expenditure is given by:

$$\int_0^1 P_j^i c_j^i dj$$

The minimisation problem can be rewritten as:

$$\min_{c_j^i} \int_0^1 P_j^i c_j^i dj$$

$$\text{s.t.} \quad \left[\int_0^1 {c_j^i}^{1-\frac{1}{\eta}} dj\right]^{\frac{\eta}{\eta-1}} \geq \bar{c}$$

The constraint should be binding at the optimum, as the utility function is strictly increasing in consumption.

Then the Lagrangian of this problem would be:

$$\mathcal{L} = \int_0^1 P_j^i c_j^i dj - \lambda \left(\left[\int_0^1 {c_j^i}^{1-\frac{1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}} - \bar{c} \right)$$

The first order condition gives

$$\frac{\partial \mathcal{L}}{\partial c_j^i} = 0 \Leftrightarrow P_j^i = \lambda \left(\frac{\eta - 1}{\eta} \right) {c_j^i}^{-\frac{1}{\eta}} \left(\frac{\eta}{\eta - 1} \right) \left[\int_0^1 {c_j^i}^{1-\frac{1}{\eta}} dj \right]^{\frac{1}{\eta-1}}$$

$$\Leftrightarrow P_j^i = \lambda {c_j^i}^{-\frac{1}{\eta}} {c^i}^{\frac{1}{\eta}} \quad \text{because} \quad c^i = \left[\int_0^1 {c_j^i}^{1-\frac{1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}}$$

$$\Leftrightarrow \frac{P_j^i}{\lambda} = \left(\frac{c_j^i}{c^i} \right)^{-\frac{1}{\eta}}$$

$\lambda = P^i$ as the Lagrangian multiplier is equal to the price index.

Finally, we get an expression the inverse demand functions for the output of individual tradeable sectors :

$$\frac{P_j^i}{P^i} = \left(\frac{c_j^i}{c^i} \right)^{-\frac{1}{\eta}}$$

Solving for the price index :

The expenditure is given by:

$$P^i c^i = \int_0^1 P_j^i c_j^i dj = \int_0^1 P_j^i c^i \left(\frac{P_j^i}{P^i} \right)^{-\eta} dj$$

$$P^i c^i = c^i {P^i}^{\eta} \int_0^1 {P_j^i}^{1-\eta} dj$$

$$P^i = \left[\int_0^1 {P_j^i}^{1-\eta} dj \right]^{\frac{1}{1-\eta}}$$

At the sector level

Inverse demand function within sectors

We set the minimization problem:

The expenditure is given by:

$$\sum_{k=1}^{2K} c_{jk}^i P_{jk}^i$$

The minimisation problem can be rewritten as:

$$\min_{c^i_{jk}} \sum_{k=1}^{2K} c^i_{jk} P^i_{jk}$$
$$\text{s.t.} \quad \left[\sum_{k=1}^{2K} {c^i_{jk}}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \geq \tilde{c}_j$$

The constraint should be binding at the optimum.

Then the Lagrangian of this problem would be:

$$\mathcal{L} = \sum_{k=1}^{2K} c^i_{jk} P^i_{jk} - \lambda \left(\left[\sum_{k=1}^{2K} {c^i_{jk}}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} - \tilde{c}_j \right)$$

The first order condition gives

$$\begin{aligned}
\frac{\partial \mathcal{L}}{\partial c^i_{jk}} = 0 \Leftrightarrow c^i_{jk} &= \lambda \left(\frac{\rho-1}{\rho}\right) {c^i_{jk}}^{-\frac{1}{\rho}} \left(\frac{\rho}{\rho-1}\right) \left[\sum_{k=1}^{2K} {c^i_{jk}}^{\frac{\rho-1}{\rho}}\right]^{\frac{1}{\rho-1}} \\
\Leftrightarrow P^i_{jk} &= \lambda {c^i_{jk}}^{-\frac{1}{\rho}} {c^i_j}^{\frac{1}{\rho}} \quad \text{because} \quad c^i_j = \left[\sum_{k=1}^{2K} {c^i_{jk}}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \\
\Leftrightarrow \frac{c^i_{jk}}{\lambda} &= \left(\frac{c^i_{jk}}{c^i_j}\right)^{-\frac{1}{\rho}}
\end{aligned}$$

$\lambda = P_{ij}$ as the Lagrangian multiplier is equal to the sectoral price index.

Finally, we get an expression for the inverse demand functions for goods within a sector:

$$\frac{P^i_{jk}}{P^i_j} = \left(\frac{c^i_{jk}}{c^i_j}\right)^{\frac{-1}{\rho}}$$

<u>Theoretical price index within sectors</u>

The expenditure is given by :

$$P^i_j c^i_j = \sum_{k=1}^{2K} P^i_{jk} c^i_{jk}$$
$$P^i_j c^i_j = \sum_{k=1}^{2K} P^i_{jk} \left(\frac{P^i_{jk}}{P^i_j}\right)^{-\rho} c^i_j$$

We deduce the price index at the sectoral level:

$$P_j^i = \left(\sum_{k=1}^{2K} {P_{jk}^i}^{1-\rho} \right)^{\frac{1}{1-\rho}}$$

13.2 Equilibrium prices: Cournot and Bertrand competition

We solve for the equilibrium prices for a domestic firm located in i, serving the domestic market. First, we derive the inverse demand function multiplying the two we derived above

$$\frac{P_j^i}{P^i} = \left(\frac{c_j^i}{c^i} \right)^{-\frac{1}{\eta}}$$

$$\frac{P_{jk}^i}{P_j^i} = \left(\frac{c_{jk}^i}{c_j^i} \right)^{\frac{-1}{\rho}}$$

$$\left(\frac{P_{jk}^i}{P^i} \right) = \left(\frac{c_{jk}^i}{c_j^i} \right)^{\frac{-1}{\rho}} \left(\frac{c_j^i}{c^i} \right)^{\frac{-1}{\eta}}$$

Good markets clear so: $c_{jk}^i = q_{jk}^i$, $c_j^i = y_j^i$, $c^i = Y^i$

Cournot competition

Firms recognize that the sectoral production y_j^i and price level P_j^i change when they solve for the maximization problem. They take into account the strategic interraction with the other firms in sector j. The quantities from the other firms q_{jl}^i operating in the sector and country of interest, with $l \neq k$, the final consumption price P^i, the wage level W and aggregate quantity Y^i are taken as given. We take the derivative according to y_j^i and q_{jk}^i.

The firm wants to maximise its profit (revenue minus total cost) subject to the inverse demand function by choosing the optimal level of production: q_{jk}^i for the market in country i. We solve for the domestic firm serving the domestic market.

$$\max_{q_{jk}^i} P_{jk}^i q_{jk}^i - q_{jk}^i MC_{jk}^i$$

With $MC_{jk}^i = \frac{W}{z_{jk}}$, the marginal cost of the firm

subject to:

$$\left(\frac{P_{jk}^i}{P^i} \right) = \left(\frac{q_{jk}^i}{y_j^i} \right)^{\frac{-1}{\rho}} \left(\frac{y_j^i}{Y^i} \right)^{\frac{-1}{\eta}}$$

We can rearrange the inverse demand function of the firm:

$$P^i_{jk} = q^i_{jk}{}^{\frac{-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} P^i Y^i{}^{\frac{-1}{\eta}}$$

I denote $X^i = P^i Y^i{}^{\frac{-1}{\eta}}$, for clarity as they are taken as given by the firm (no need to take the derivative).

The firms choose quantity. Substituting the constraint into the objective function, the problem can be rewritten as:

$$\max_{q^i_{jk}} \Pi^i_{jk} = q^i_{jk}{}^{\frac{-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i q^i_{jk} - q^i_{jk} MC^i_{jk}$$
$$\max_{q^i_{jk}} \Pi^i_{jk} = q^i_{jk}{}^{\frac{\rho-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i - q^i_{jk} MC^i_{jk}$$

Taking the first order condition:

$$\frac{\partial \Pi^i_{jk}}{\partial q^i_{jk}} = 0 \Leftrightarrow MC^i_{jk} = \left(1-\frac{1}{\rho}\right) q^i_{jk}{}^{\frac{-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i + \left(\frac{1}{\rho}-\frac{1}{\eta}\right) q^i_{jk}{}^{1-\frac{1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}-1} \frac{\partial y^i_j}{\partial q^i_{jk}} X^i$$
$$\Leftrightarrow MC^i_{jk} = \left(1-\frac{1}{\rho}\right) q^i_{jk}{}^{\frac{-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i + \left(\frac{1}{\rho}-\frac{1}{\eta}\right) q^i_{jk}{}^{\frac{-1}{\rho}} \left[\frac{\partial y^i_j}{\partial q^i_{jk}} \frac{q^i_{jk}}{y^i_j}\right] y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i$$

Under CES demand systems, $\left[\frac{\partial y^i_j}{\partial q^i_{jk}} \frac{q^i_{jk}}{y^i_j}\right] = s^i_{jk}$ and $P^i_{jk} = q^i_{jk}{}^{\frac{-1}{\rho}} y^i_j{}^{\frac{1}{\rho}-\frac{1}{\eta}} X^i$

$$MC^i_{jk} = \left(1-\frac{1}{\rho}\right) P^i_{jk} + \left(\frac{1}{\rho}-\frac{1}{\eta}\right) P^i_{jk} s^i_{jk}$$

Rearranging we get :

$$P^i_{jk} = \left[1-\frac{1}{\rho} + s^i_{jk}\left(\frac{1}{\rho}-\frac{1}{\eta}\right)\right]^{-1} MC^i_{jk}$$

The vector of equilibirum price (19) is then obtained:

$$P^i_{jk} = \left[1-\frac{1}{\epsilon(s^i_{jk})}\right]^{-1} MC^i_{jk}$$
$$P^i_{jk} = \frac{\epsilon(s^i_{jk})}{\epsilon(s^i_{jk})-1} MC^i_{jk}$$

with $\epsilon(s^i_{jk}) = \left[\frac{1}{\rho}(1-s^i_{jk}) + \frac{1}{\eta} s^i_{jk}\right]^{-1}$ and $MC^i_{jk} = \frac{W}{z_{jk}}$ The market share, is given by $s^i_{jk} = \frac{P^i_{jk} q^i_{jk}}{\sum_{l=1}^{2K} P^i_{jl} q^i_{jl}}$ and can be rewritten as a function of prices using $\frac{P^i_{jk}}{P^i_j} = \left(\frac{q^i_{jk}}{y^i_j}\right)^{\frac{-1}{\rho}}$ and $P^i_j = \left[\sum_{k=1}^{2K} P^i_{jk}{}^{1-\rho}\right]^{\frac{1}{1-\rho}}$ to get (17):

$$s^i_{jk} = \frac{P^i_{jk} q^i_{jk}}{\sum_{l=1}^{K} P^i_{jl} q^i_{jl} + \sum_{l=1}^{K} P^{*i}_{jl} q^{*i}_{jl}} = \left(\frac{P^i_{jk}}{P^i_j}\right)^{1-\rho}$$

Solving for the foreign firm operating in the domestic market is straight forward. Only the marginal cost is scaled by the iceberg trade cost: $MC^i_{jk} = \tau \frac{W}{z_{jk}}$

Bertrand competition

Now, we solve the equilibrium prices under Bertrand competition. Firms, instead of choosing quantities, choose prices. Firms recognize that the sectoral production y^i_j and price level P^i_j change when they solve for the maximization problem. They take into account the strategic interaction with the other firms in sector j. The quantities from the other firms q^i_{jl} operating in the sector and country of interest, with $l \neq k$, the final consumption price P^i, the wage level W^i and aggregate quantity Y^i are taken as given. We take the derivative according to P^i_j and P^i_{jk}.

We rearrange the inverse demand function:

$$q^i_{jk} = \left(\frac{P^i_{jk}}{P^i_j}\right)^{-\rho} \left(\frac{P^i_j}{P^i}\right)^{-\eta} Y^i$$

Now, we solve the problem for a domestic firm serving the domestic market

The firm wants to maximise its profit (revenue minus total cost)

$$\max_{P^i_{jk}} P^i_{jk} q^i_{jk} - q^i_{jk} MC^i_{jk}$$

subject to the inverse demand function:

$$q^i_{jk} = \left(\frac{P^i_{jk}}{P^i_j}\right)^{-\rho} \left(\frac{P^i_j}{P^i}\right)^{-\eta} Y^i$$

With $MC^i_{jk} = \frac{W}{z^i_{jk}}$, the marginal cost of the firm

Firms choose prices. We substitute q^i_{jk} in the objective function using the inverse demand function. The maximization problem can be rewritten as:

$$\max_{P^i_{jk}} \left(P^i_{jk} - MC^i_{jk}\right) \left(\frac{P^i_{jk}}{P^i_j}\right)^{-\rho} \left(\frac{P^i_j}{P^i}\right)^{-\eta} Y^i$$
$$\max_{P^i_{jk}} \left(P^i_{jk} - MC^i_{jk}\right) {P^i_{jk}}^{-\rho} {P^i_j}^{\rho-\eta} {P^i}^{\eta} Y^i$$
$$\max_{P^i_{jk}} \left(P^i_{jk} - MC^i_{jk}\right) {P^i_{jk}}^{-\rho} {P^i_j}^{\rho-\eta} X^i$$

I denote $X^i = P^{i\eta} Y^i$, for clarity as they are taken as given by the firm (no need to take the derivative).

For the rest of the derivations, note that:

$$P^i_j = \left[\sum_{k=1}^{2K} {P^i_{jk}}^{1-\rho} \right]^{\frac{1}{1-\rho}}$$
$$\frac{\partial P^i_j}{\partial P^i_{jk}} = {P^i_{jk}}^{-\rho} \left[\sum_{k=1}^{2K} {P^i_{jk}}^{1-\rho} \right]^{\frac{1}{1-\rho}-1} = \left(\frac{P^i_{jk}}{P^i_j} \right)^{-\rho}$$

Moreover, the revenue is:

$$r^i_{jk} = P^i_{jk} q^i_{jk}$$
$$r^i_{jk} = P^i_{jk} ({P^i_{jk}}^{-\rho} P^{i\rho-\eta}_j) X^i$$
$$r^i_{jk} = {P^i_{jk}}^{1-\rho} P^{i\rho-\eta}_j X^i$$

This implies that the revenue shares are:

$$s^i_{jk} = \frac{r^i_{jk}}{\sum_{l=1}^{2K} r^i_{jl}} = \frac{{P^i_{jk}}^{1-\rho} P^{i\rho-\eta}_j X^i}{\sum_{l=1}^{2K} {P^i_{jl}}^{1-\rho} P^{i\rho-\eta}_j X^i} = \frac{{P^i_{jk}}^{1-\rho}}{\sum_{l=1}^{2K} {P^i_{jl}}^{1-\rho}}$$
$$s^i_{jk} = \frac{{P^i_{jk}}^{1-\rho}}{P^{i1-\rho}_j} \quad \text{by definition of } P^i_j$$

Finally we have:

$$s^i_{jk} = \left(\frac{P^i_{jk}}{P^i_j} \right)^{1-\rho} = \frac{\partial P^i_j}{\partial P^i_{jk}} \frac{P^i_{jk}}{P^i_j}$$

We derive the first order condition of the firm:

$$\frac{\partial \pi^i_{jk}}{\partial P^i_{jk}} = 0 \Leftrightarrow {P^i_{jk}}^{-\rho} P^{i\rho-\eta}_j X^i - \rho(P^i_{jk} - MC^i_{jk}) {P^i_{jk}}^{-\rho-1} P^{i\rho-\eta}_j X^i + (\rho-\eta)(P^i_{jk} - MC^i_{jk}) {P^i_{jk}}^{-\rho} P^{i\rho-\eta-1}_j \frac{\partial P^i_j}{\partial P^i_{jk}} X^i = 0$$
$$\Leftrightarrow {P^i_{jk}}^{-\rho} P^{i\rho-\eta}_j - \rho(P^i_{jk} - MC^i_{jk}) {P^i_{jk}}^{-\rho-1} P^{i\rho-\eta}_j + (\rho-\eta)(P^i_{jk} - MC^i_{jk}) {P^i_{jk}}^{-\rho} P^{i\rho-\eta-1}_j \frac{\partial P^i_j}{\partial P^i_{jk}} = 0$$
$$\Leftrightarrow P^i_{jk} - \rho(P^i_{jk} - MC^i_{jk}) + (\rho-\eta)(P^i_{jk} - MC^i_{jk}) \frac{P^i_{jk}}{P^i_j} \frac{\partial P^i_j}{\partial P^i_{jk}} = 0$$
$$\Leftrightarrow P^i_{jk} - \rho(P^i_{jk} - MC^i_{jk}) + (\rho-\eta)(P^i_{jk} - MC^i_{jk}) s^i_{jk} = 0$$
$$\Leftrightarrow -P^i_{jk} + \rho(P^i_{jk} - MC^i_{jk}) - (\rho-\eta)(P^i_{jk} - MC^i_{jk}) s^i_{jk} = 0$$
$$P^i_{jk} = \frac{\rho - (\rho-\eta) s^i_{jk}}{\rho - 1 - (\rho-\eta) s^i_{jk}} MC^i_{jk}$$

Which can be rewritten as:

$$P^i_{jk} = \frac{\epsilon(s^i_{jk})}{1 - \epsilon(s^i_{jk})} MC^i_{jk} \quad \text{with} \quad \epsilon(s^i_{jk}) = \rho(1 - s^i_{jk}) + \eta s^i_{jk}$$

13.3 Concavity of the markup

For Cournot:

The markup is a strictly increasing function of the market share, as long as $\rho > \eta > 1$:

$$\frac{\partial \mu(s)}{\partial s} = \left(\frac{1}{\eta} - \frac{1}{\rho}\right) \frac{1}{\left(1 - \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right)\right)^2} > 0$$

The markup is a strictly convex function of the market share, as long as $\rho > \eta > 1$:

$$\frac{\partial^2 \mu(s)}{\partial^2 s} = \left(\frac{1}{\eta} - \frac{1}{\rho}\right) . \frac{2\left(\frac{1}{\eta} - \frac{1}{\rho}\right)\left(1 - \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right)\right)}{\left(1 - \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right)\right)^4} > 0$$

Indeed, this ratio is positive if:

$$1 - \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right) > 0$$

We can show that: $\frac{\partial}{\partial s}\left(1 - \left(\frac{1}{\eta}s + (1-s)\frac{1}{\rho}\right)\right) = \frac{1}{\rho} - \frac{1}{\eta} < 0$ This ratio is strictly decreasing with s. Moreover, $s \in [0, 1]$. When $s = 1$, this ratio is minimized and reduced to $1 - \frac{1}{\eta} > 0$ So $\frac{\partial^2 \mu(s)}{\partial^2 s} > 0$

For Bertrand:

The markup is a strictly increasing function of the market share, as long as $\rho > \eta > 1$:

$$\frac{\partial \mu(s)}{\partial s} = \frac{\rho - \eta}{(\rho - 1 - (\rho - \eta)s)^2} > 0$$

The markup is a strictly convex function of the market share, as long as $\rho > \eta > 1$:

$$\frac{\partial^2 \mu(s)}{\partial^2 s} = (\rho - \eta) . \frac{2(\rho - \eta)(\rho - 1 - (\rho - \eta)s)}{(\rho - 1 - (\rho - \eta)s)^4} > 0$$

Indeed, this ratio is positive if:

$$\frac{\rho - 1}{\rho - \eta} > s$$

which is always true as $\rho > \eta > 1$.

13.4 Derivation of the markup

At the sector level:

From the definition of the theoretical price index at the sector level:

$$P_j^i = \left[\sum_{k=1}^{2K} {P_{jk}^i}^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

Which can be reexpressed, using the definition of the equilibrium prices and the symmetry argument for sectoral productivity:

$$P_j^i = \left[\sum_{k=1}^{K}\left(\mu_{jk}^i \frac{W}{z_{jk}}\right)^{1-\rho} + \sum_{k=1}^{K}\left(\tau\mu_{jk}^{*i}\frac{W}{z_{jk}^*}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

$$P_j^i = \left[\sum_{k=1}^{K}\left(\mu_{jk}^i \frac{z_j}{z_{jk}}\frac{W}{z_j}\right)^{1-\rho} + \left(\mu_{jk}^{*i}\frac{z_j}{z_{jk}^*}\tau\frac{W}{z_j}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

$$P_j^i = \left[\sum_{k=1}^{K}\left(\mu_{jk}^i \frac{z_j}{z_{jk}}\right)^{1-\rho} + \tau^{1-\rho}\sum_{k=1}^{K}\left(\mu_{jk}^{*i}\frac{z_j}{z_{jk}^*}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}\frac{W}{z_j}$$

$$P_j^i = \left(\sum_{k=1}^{K}\left(\frac{z_{jk}}{z_j}\right)^{\rho-1}\left(\frac{1}{\mu_{jk}^i}\right)^{\rho-1} + \tau^{1-\rho}\sum_{k=1}^{K}\left(\frac{z_{jk}^*}{z_j}\right)^{\rho-1}\left(\frac{1}{\mu_{jk}^{*i}}\right)^{\rho-1}\right)^{\frac{1}{1-\rho}}\frac{W}{z_j}$$

So, we can deduce the expression for the markup:

$$\mu_j = \left(\sum_{k=1}^{K}\left(\frac{z_{jk}}{z_j}\right)^{\rho-1}\left(\frac{1}{\mu_{jk}^i}\right)^{\rho-1} + \tau^{1-\rho}\sum_{k=1}^{K}\left(\frac{z_{jk}^*}{z_j}\right)^{\rho-1}\left(\frac{1}{\mu_{jk}^{*i}}\right)^{\rho-1}\right)^{\frac{1}{1-\rho}}$$

At the aggregate level

From the definition of the theoretical price index at the aggregate level and the symmetry argument for sector and aggregate productivity, we can deduce the aggregate markup:

$$P^i = \left[\int_0^1 P_j^{i\,1-\eta} dj\right]^{\frac{1}{1-\eta}}$$

$$P^i = \left[\int_0^1 \left(\mu_j^i \frac{W}{z_j}\right)^{1-\eta} dj\right]^{\frac{1}{1-\eta}}$$

$$P^i = \left[\int_0^1 \left(\mu_j^i \frac{Z}{z_j}\frac{W}{Z}\right)^{1-\eta} dj\right]^{\frac{1}{1-\eta}}$$

$$P^i = \left[\int_0^1 \left(\mu_j^i \frac{Z}{z_j}\right)^{1-\eta} dj\right]^{\frac{1}{1-\eta}} \frac{W}{Z}$$

$$\mu^i = \left(\int_0^1 \left(\frac{z_j}{Z}\right)^{\eta-1} \left(\frac{1}{\mu_j^i}\right)^{\eta-1} dj\right)^{\frac{1}{1-\eta}}$$

Sales-weighted average markup

$$\bar{\mu^i} = i^i(\mu_{for}) + (1-i^i)(\mu_{dom})$$

$$\bar{\mu^i} = i^i(\int_0^i \sum_{k=1}^K \frac{p_{jk}^{*i} q_{jk}^{*i} \mu_{jk}^{*i}}{\int_0^i \sum_{k=1}^K p_{jk}^{*i} q_{jk}^{*i} dj} dj) + (1-i^i)(\int_0^i \sum_{k=1}^K \frac{p_{jk}^{i} q_{jk}^{i} \mu_{jk}^{i}}{\int_0^i \sum_{k=1}^K p_{jk}^{i} q_{jk}^{i} dj} dj)$$

$$\bar{\mu^i} = \frac{\int_0^1 \left(\sum_{k=1}^K p_{jk}^{*i} . q_{jk}^{*i}\right) dj}{P^i Y^i} . (\int_0^i \sum_{k=1}^K \frac{p_{jk}^{*i} q_{jk}^{*i} \mu_{jk}^{*i}}{\int_0^i \sum_{k=1}^K p_{jk}^{*i} q_{jk}^{*i} dj} dj) + \frac{\int_0^1 \left(\sum_{k=1}^K p_{jk}^{i} . q_{jk}^{i}\right) dj}{P^i Y^i} . (\int_0^i \sum_{k=1}^K \frac{p_{jk}^{i} q_{jk}^{i} \mu_{jk}^{i}}{\int_0^i \sum_{k=1}^K p_{jk}^{i} q_{jk}^{i} dj} dj)$$

$$\bar{\mu^i} = \int_0^i \sum_{k=1}^K \left(\frac{p_{jk}^i q_{jk}^i}{P^i Y^i} \mu_{jk}^i\right) + \sum_{k=1}^K \left(\frac{p_{jk}^{*i} q_{jk}^{*i}}{P^i Y^i} \mu_{jk}^{*i}\right) dj$$

With μ_{for} and μ_{for} respectively the sales-weighted average foreign and domestic markups:

$$\mu_{for} = \int_0^i \sum_{k=1}^K \frac{p_{jk}^{*i} q_{jk}^{*i} \mu_{jk}^{*i}}{\int_0^i \sum_{k=1}^K p_{jk}^{*i} q_{jk}^{*i} dj} dj$$

$$\mu_{dom} = \int_0^i \sum_{k=1}^K \frac{p_{jk}^{i} q_{jk}^{i} \mu_{jk}^{i}}{\int_0^i \sum_{k=1}^K p_{jk}^{i} q_{jk}^{i} dj} dj$$

and the import share:

$$i^i = \frac{\int_0^1 \left(\sum_{k=1}^{K} p_{jk}^{*i}.q_{jk}^{*i}\right) dj}{P^i Y^i} = 1 - \frac{\int_0^1 \left(\sum_{k=1}^{K} p_{jk}^{i}.q_{jk}^{i}\right) dj}{P^i Y^i}$$

13.5 Algorithm for the benchmark model

The algorithm to simulate the benchmark model is based on the following steps:

1. Idiosyncratic productivities are drawn from a log normal distribution. Countries are perfectly symmetric in terms of sectoral, aggregate productivities and number of firms in each sectors. Wages and labor supply are normalized to one in both countries.

2. Given the equation (19) defining the equilibrium prices, we solve for the market shares, the markups and the prices. We checked that the market shares sum to one.

3. We calculate the sector and aggregate markups from equations (29-30). We checked that the values obtained satisfies the equilibrium conditions (26)

4. We calculate the aggregate prodution in both countries normalizing labor and wages to one.
From the sectoral labor clearing condition, we have:

$$l_j^i = \sum_{k=1}^{K} l_{jk}^i + \sum_{k=1}^{K} l_{jk}^{*-i}$$

Using the definition of the production function, this expression can be reexpressed:

$$l_j^i = \sum_{k=1}^{K} \frac{q_{jk}^i}{z_{jk}} + \sum_{k=1}^{K} \frac{q_{jk}^{*-i}}{z_{jk}}$$

From the equilibrium quantities:

$$l_j^i = \sum_{k=1}^{K} \frac{1}{z_{jk}} \left(\frac{P_{jk}^i}{P_j^i}\right)^{-\rho} \left(\frac{P_j^i}{P^i}\right)^{-\eta} Y^i + \sum_{k=1}^{K} \frac{1}{z_{jk}} \left(\frac{P_{jk}^{-i}}{P_j^{-i}}\right)^{-\rho} \left(\frac{P_j^{-i}}{P^{-i}}\right)^{-\eta} Y^{-i}$$

Normalizing the aggregate labor supply $l^i = 1$, and using the symmetry argument $Y^i = Y^{-i}$, gives the expression for Y^i:

$$Y^i = \left(\int_0^1 \left(\sum_{k=1}^{K} \frac{1}{z_{jk}} \left(\frac{P_{jk}^i}{P_j^i}\right)^{-\rho} \left(\frac{P_j^i}{P^i}\right)^{-\eta} + \sum_{k=1}^{K} \frac{1}{z_{jk}} \left(\frac{P_{jk}^{*-i}}{P_j^{-i}}\right)^{-\rho} \left(\frac{P_j^{-i}}{P^{-i}}\right)^{-\eta}\right) dj\right)^{-1}$$

5. Given the aggregate production in each country, we can calculate the quantity produced by each firm with equation (24) and sectors with equation (7). We checked possible mistakes by ensuring that the aggregate

quantities given by equation (6) is equal to the one found in point 4.

6. Finally, we checked that the labor market clears. We calculate the labor demand at the disaggregated level then we sum to get the sectoral labor demand. We sum the sectoral labor demand to ensure that it is equal to the labor supply normalized to 1.