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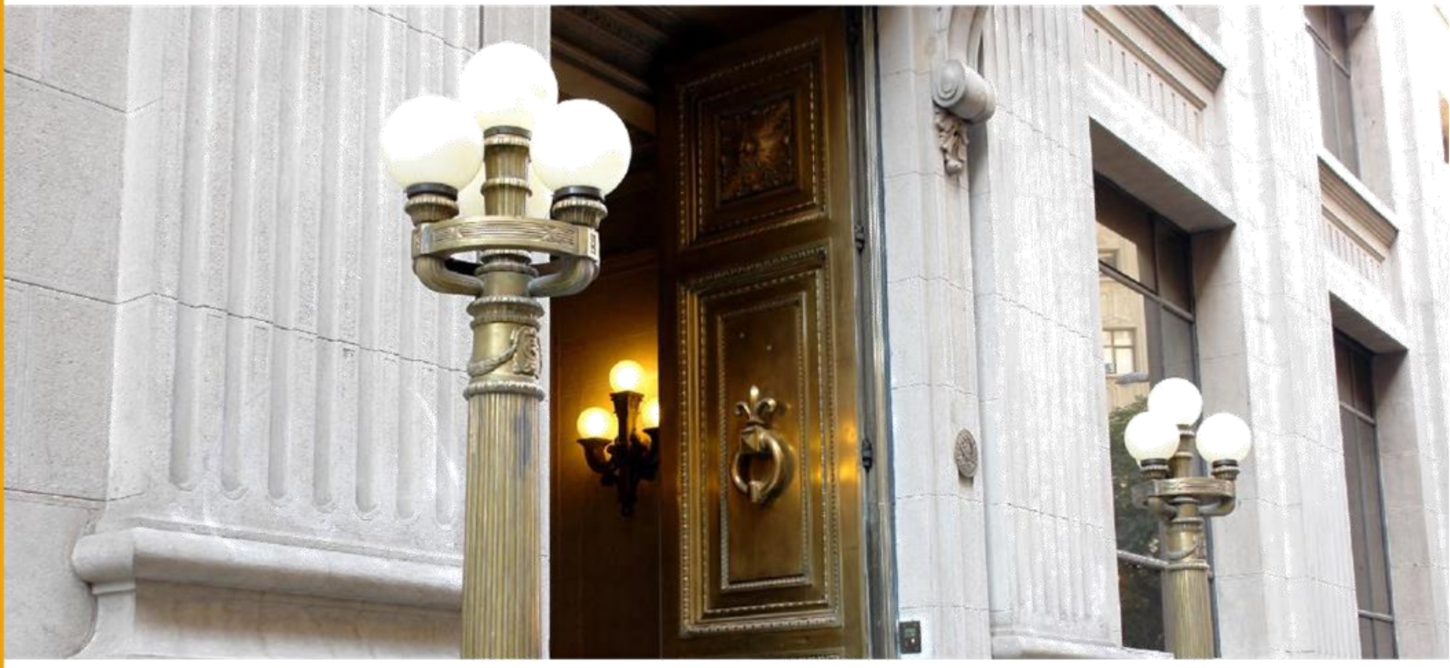

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Freight Costs and Substitution Among Import Regions: Implications for Domestic Prices*

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Abstract

How much do changes in the cost of international freight spill over into do-mestic inflation? Using Chilean customs data, we document a sharp, heteroge-neous increase in freight costs during 2019–2021. Exploiting differential expo-sure of importers to origins, we construct a shift-share instrument for import prices. Using this instrument, we estimate an elasticity of substitution among import origins of intermediate goods of 4.38. Incorporating this estimate into a general equilibrium model with nominal rigidities, we calculate that the ob-served increase in freight costs accounts for 13.3 percent of the inflation rate recorded in the 2019q4-2021q4 period.

Resumen

¿En qué medida los cambios en los costos de transporte internacional se traspasan a la inflación doméstica? Usando datos de Aduanas de Chile, documentamos un brusco y heterogéneo aumento en los costos de transporte del comercio internacional entre 2019-2021. Haciendo uso de las diferentes exposiciones de los importadores a distintos orígenes, construimos una variable instrumental shift-share para los precios de importación. Luego, usamos este instrumento para estimar una elasticidad de sustitución entre distintos orígenes para bienes intermedios de 4,38. Incorporando este valor estimado en un modelo de equilibrio general con rigideces nominales, calculamos que el aumento observado en los costos del transporte internacional explica un 13,3 por ciento de la tasa de inflación en el período 2019q4-2021q4.

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1 Introduction

The growing importance of international trade has raised new questions about how disruptions in the flow of goods across borders can affect the economy. The COVID-19 pandemic that severely disrupted supply chains, or the attacks on vessels in the Red Sea starting in 2023, highlighted how quickly freight costs can increase, driving up prices of imported goods. In the case of the pandemic, a worldwide resurgence of inflation coincided with disruptions in goods transportation. Understanding the way and the extent to which these disruptions can affect aggregate real and nominal variables is our task in this article.

This paper evaluates the impact of pandemic-induced disruptions to global trade logistics, a distinctive supply shock, on import sourcing decisions by firms and how this affects domestic inflation. We use detailed transaction-level Chilean customs data to document two facts. First, higher freight costs had a sizable incidence on the observed increase of import prices in 2021, contrasting with prior years when they played a minimal role. Second, imports from China—followed by the rest of Asia and Europe—experienced the most pronounced increases, while sub-regions in the Americas saw import prices climb mainly due to rising *free on board* (FOB) prices. The capacity of firms to substitute imports away from Asia should be critical in determining the effect of the sharp increase in freight costs on the domestic economy. The main novelty of our work is providing structural estimates of the elasticity of substitution to quantify, in partial and general equilibrium frameworks, the effect of the increase in freight costs on domestic inflation.

Motivated by the heterogeneous increases in freight costs from different sourcing regions in the world, we estimate the elasticity of substitution between intermediate inputs sourced from these regions—the Armington's elasticity of substitution.[1] If we were to estimate the elasticity of substitution by ordinary least squares (OLS), demand shocks that shift the relative demand for goods across origins while simultaneously affecting relative prices would contaminate the estimate. Health concerns and public health policy measures implemented during the period likely moved consumption preferences towards goods consumed at home. OLS estimates may thus be biased if any region is a primary provider of these goods. To circumvent the problem of estimating the elasticity through OLS, we employ a research design that instruments CIF prices in the spirit of Bartik (1991).

[1]Traditionally, Armington's elasticity refers to the elasticity of substitution between domestic and foreign products. More recently, the term has also been used to refer to the elasticity of substitution between goods of different origins (see Feenstra et al. (2018)).

We build the instrument by interacting the pre-pandemic exposure of firms to importing from different sourcing regions with the aggregate changes in freight costs from their respective origin. We argue that the change in freight costs observed in the period was exogenous to Chilean firms' decisions. Using this, our baseline estimate for the elasticity of substitution is 4.38.

In this setting, a natural question is whether the incidence of freight costs is shared between Chilean importers and foreign suppliers. As the endogeneity concerns of estimating the pass-through of freight prices to FOB import prices through OLS are similar to those of estimating the elasticity, we employ the same Bartik instrument to estimate this parameter using instrumental variables. We find that changes in freight prices do not affect FOB prices in this period, so the Chilean importer entirely bears the incidence of increases in freight cost.

Furthermore, the size of the elasticity of substitution, as well as the null pass-through from freight costs to FOB prices, are robust to using freight cost data from a third country to perform the instrumental variable estimation. Similar to the method used by Autor et al. (2013) to study the impact of Chinese imports on US labor markets, we analyze the effects of increased transportation costs using Colombian import data, due to their similar geographical network of suppliers. When computing the instrument using these shocks instead of the ones obtained from Chilean data sources, we find results statistically similar to our baseline.

To understand how freight cost changes affect domestic prices, we use a partial equilibrium framework in which we shut down the feedback loop from input cost changes to wages and aggregate income. Dealing with a shock in relative prices, the capacity of switching across supply sources determines how much the unit cost of imported materials is affected.[2] We characterize the pass-through of freight cost changes to inflation as the sum of two effects: a direct effect that measures how much the prices of imported consumption goods increase, and an indirect effect that arises from firms' limited capacity to substitute across intermediate imported inputs. Using our estimate for the elasticity of substitution and a partial equilibrium framework, we calculate that the shock in freight costs accounts for around 16.3 percent of the observed inflation during the 2019q4-2021q4 period.

[2]See the discussion in Baqaee and Farhi (2022) regarding the importance of substitutability in inputs for the transmission of supply shocks. In brief, the effect of small perturbations to input costs on product prices is well approximated by the initial cost share of that input. In contrast, considerable perturbations may also have non-negligible effects on cost shares.

We embed the partial equilibrium framework into a parsimonious two-period general equilibrium model of a small open economy featuring nominal rigidities. With this framework we measure the aggregate effect of freight cost changes on domestic prices and their importance relative to other perturbations. The framework is inspired in Baqaee and Farhi (2022) and is similar to di Giovanni et al. (2022). Households consume domestic and imported goods, supply labor with a positive and finite elasticity, and face sticky nominal wages. On the production side, intermediate firms combine labor with domestic and foreign materials to produce goods. Foreign intermediate inputs can be sourced from different regions of the world. Retail firms produce varieties with intermediate goods and face sticky product prices.

We consider a set of shocks in addition to those over freight costs to validate the model's structure and consider the most important developments of the period. These shocks include the impatience degree of households, foreign demand for domestic goods, the economy's total factor productivity (TFP), the nominal exchange rate, and FOB prices of imported consumption and intermediate goods. We find that freight shocks account for around 13.3 percent of inflation. Despite this, we also find that shocks primarily affecting the economy's aggregate demand are the most relevant in determining the period's inflation rate.

Our work builds upon the literature that estimates the Armington's elasticity of substitution. Broda and Weinstein (2006) and Feenstra et al. (2018) use structural econometric approaches to estimate elasticities of substitution for different types of goods. In particular, Feenstra et al. (2018) highlight the downward bias existent in simple OLS estimation via the application of both GMM and OLS on simulated data. Our approach intends to take these empirical challenges into account. An important methodological contribution of our work is that instead of using a GMM-type of estimation, we rest on a shift-share design that imposes less structure on the data. This approach allows us to address issues of simultaneous determination in the supply-demand system by leveraging supply-driven price shifts to identify the slope of the demand curve. In this sense, the paper closest to ours is Fajgelbaum et al. (2020), although we perform our estimation at a more granular level and our focus is different. In addition, we contribute to this literature by estimating the elasticity of substitution in the context of a significant price increase triggered by rising transportation costs. Ruhl (2008) discusses an "international elasticity puzzle," where real business cycle models need a low elasticity of substitution to align with observed trade volatility, while computable general equilibrium models require a higher elasticity to reflect trade volume changes following tariff adjustments. Within this second approach, Feenstra et al. (2018) note that, at the macro level, there is a lower elasticity of substitution between domestic and foreign inputs compared to a higher elasticity governing the substitution among varieties of foreign goods at the micro level. Hillberry and Hummels (2013) remark that the shocks and time responses over which the analysis is conducted are crucial for determining the applicability of elasticity estimates. Using quarterly data, we estimate the elasticity of intermediate imports to import prices, by using the sharp and heterogeneous increase of transportation costs across origins as a source of exogenous variation. We find a value that is on the lower end of the values used by the literature (4 to 15).[3]

Our work also contributes to the recent literature estimating the impact of the COVID-19 pandemic on macroeconomic outcomes. We build upon the work of Baqaee and Farhi (2022), who theoretically show the effect of supply and demand shocks on inflation in the context of a disaggregated economy, but with significant departures. We extend their setting to a small open economy framework that is more suitable for Chile. We introduce wage and price rigidities to generate a Phillips curve with positive and finite slope. Rather than using a common cross-country global indicator of supply chain pressures, as in di Giovanni et al. (2022) and Bai et al. (2024), our work relies on direct measures of supply-side transportation bottlenecks affecting the Chilean economy.[4] We measure the emergence of bottlenecks by the increase in transportation costs from different regions across the globe which is a direct measure of pressures in the supply chain from a particular region.

The increase in transportation costs allows us to pin down the source of the shock and track down its propagation throughout the economy. We ground our quantitative analysis on estimating the relevant elasticity of substitution between goods affected and unaffected by the increase in transportation costs. In this setting, we quantify the contribution of demand and supply forces to account for the drivers of inflation over the pandemic. Ferrante et al. (2023) studies the effect on inflationary pressures from shifting services' consumption to goods triggered by the reallocation of demand caused by the COVID-19 pandemic; di Giovanni et al. (2023) quantifies the effect of demand shock without paying

[3]The importance of the timing and characteristics of the shock can be seen by the null short-term elasticity of substitution of Japanese inputs estimated in the context of the Tōhoku earthquake/tsunami for Japanese multinational affiliates in the US (Boehm et al., 2019).

[4]di Giovanni et al. (2022) use the Federal Reserve Bank of New York global supply chain index and Bai et al. (2024) calculate an index that tracks the congestion of container ships at major ports worldwide using high-frequency maritime satellite data.

attention to the reallocation channel; Alessandria et al. (2023) and Bai et al. (2024) put emphasis on how shocks to restock inventories to satisfy the demand affect the response of prices during the episode. Our quantitative exercise is closer to di Giovanni et al. (2023), finding that forces that cannot be directly labeled as supply-side shocks account for approximately 71 percent of the economy's inflation, while supply-side shocks account for the rest.

The outline of the paper is as follows. In Section 2, we show the data and the evolution of freight costs during the COVID-19 pandemic. In Section 3.1 we lay out a simple model, which we then use in our empirical strategy in Section 3.2. In Section 3.3, we present our estimation results, measure the partial equilibrium effects that freight costs had on inflation. We study the general equilibrium effects in Section 4. Section 5 concludes.

2 Transportation costs during COVID-19

This section presents the data we use in the article and documents the rise of freight costs observed during 2021. We use data on imports at the product-firm-origin level and report a severe increase in freight costs, which is almost entirely explained by imports from Asia.

2.1 Data

The main data we use is Chile's Customs Import Declaration collected by the National Customs Service (*Aduanas* in Spanish), which we use for the period 2017-2021. Customs data contains information on the category of the imported product at the HS8 level,[5] country of origin, quantity traded, CIF value, the components of the CIF value (FOB value, freight cost and insurance), and a firm identifier. We do not observe prices, so we approximate them by computing unit import values. In addition, we use data from the Unemployment Fund Administrator (AFC) to obtain firms' number of workers,[6] and the registry of firms used by National Accounts at the CBC.[7] We restrict our sample to firms

[5]Our definition of product is based on its HS8 code unless otherwise noted.

[6]The Unemployment Fund Administrator is a publicly regulated private firm that manages the contributions that all formally employed workers in the private sector make to individual accounts, which are used to fund their unemployment insurance.

[7]This study was developed within the scope of the research agenda conducted by the CBC in economic and financial affairs of its competence. The CBC has access to anonymized information from various public and private entities, by virtue of collaboration agreements signed with these institutions. To secure the privacy of workers and firms, the CBC mandates that the development, extraction and publication of the results should not allow the identification, directly or indirectly, of natural or legal persons. Officials of

in the registry with at least two workers on average during the sample period[8]

We use data on imports to understand the dynamics of freight costs during the period. We focus on heterogeneity by sourcing regions. In particular, we collapse the data at five geographical regions: China, Asia excluding China (also referred to as Rest of Asia), Europe, North America and South/Central America.[9] We drop all observations where the sum of the FOB value, the freight cost and insurance is larger than the CIF value.

2.2 Descriptive Evidence

The international prices that domestic importers face at the dock are composed of the Free-On-Board (FOB) price, the freight cost (Fre), and the insurance cost (Ins). The total corresponds to the Cost, Freight, and Insurance (CIF) value, which is the relevant price for the domestic economy, as most tariffs and other taxes are calculated on this value.

To measure each CIF price component's evolution, we build indices spanning the period from 2017 to 2021. We calculate the annual growth rates of the index as follows:

$$g_{X,t} = \sum_i \frac{FOB_{i,2017}}{\sum_i FOB_{i,2017}} d\log\left(\frac{X_{it}}{Q_{it}}\right), \quad X = \{\text{CIF}, \text{FOB}, \text{Fre}, \text{Ins}\},$$

where $FOB_{i,2017}$ is the total FOB value of all imports of product i into Chile during 2017, and Q_{it} is total quantity of i imported by all firm in period t.

Figure 1 shows the growth rate of the CIF price index and that of its components. The CIF price index grew in 2018 and then decreased between 2019 and the end of 2020. In 2021, it grew very strongly, pushed by FOB prices and freight costs. Freight costs were relatively stable in 2018 and 2019, but they rose only during the second quarter of 2020 when COVID-19 hit. In 2021, freight costs rose between 15 and 45 percent during almost

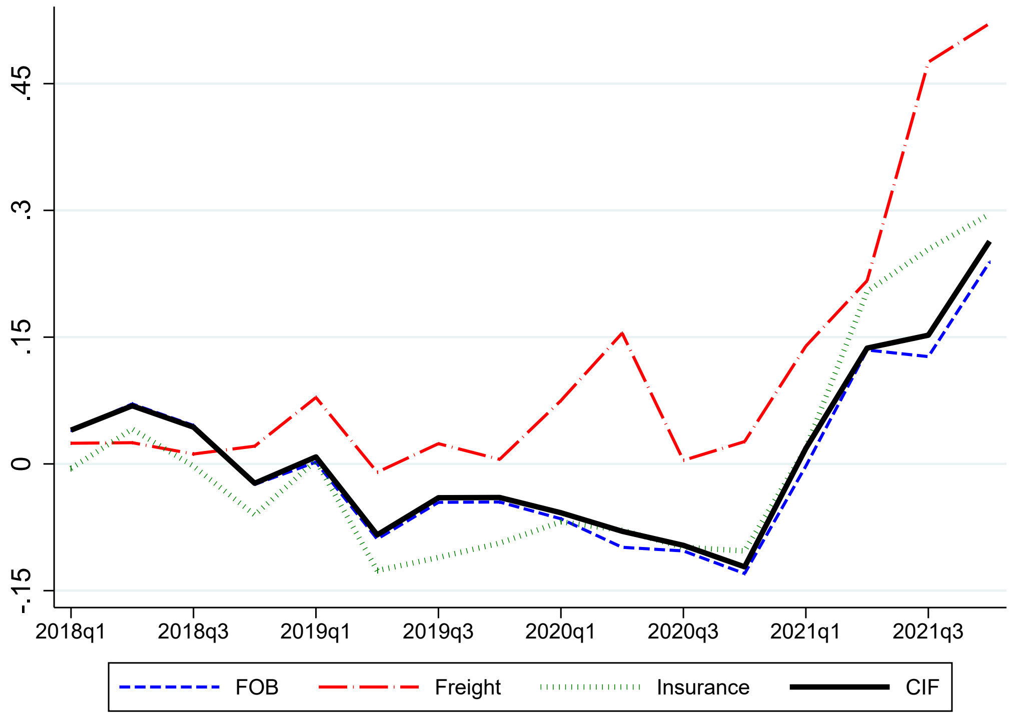
the CBC processed the disaggregated data. All the analysis was implemented by the authors and did not involve nor compromise the SII, Aduanas and AFC. The information contained in the databases of the Chilean IRS is of a tax nature originating in self-declarations of taxpayers presented to the Service; therefore, the veracity of the data is not the responsibility of the Service.

[8]All the data in this paper has been provided through the Central Bank of Chile. However, Customs data in Chile are publicly available at https://datos.gob.cl/organization/servicio_nacional_de_aduanas.

[9]Asia is defined following the Chilean customs definition. It considers Jordan, Saudi Arabia, Kuwait, Oman, Cyprus, Israel, Iraq, Afghanistan, Iran, Syria, Lebanon, Qatar, Bahrein, Sri Lanka, Cambodia, Laos, India, Bhutan, Thailand, Nepal, Bangladesh, Palestine, Pakistan, Vietnam, Myanmar, Maldives, Indonesia, Malaysia, Taiwan, Japan, Singapore, South Korea, North Korea, Philippines, China, Mongolia, EUA, Hong Kong, Macao, Brunei, and Yemen. North America includes Canada, United States and Mexico. We exclude imports from other regions such as Africa and Oceania, which represent less than 1 percent of total Chilean imports.

every quarter. It is reasonable to think that part of this sharp growth in freight costs was due to the global supply chain bottlenecks widely reported around the world (Celasun et al., 2022), especially in Asian ports and factories (Rees and Rungcharoenkitkul, 2021).

Figure 1: Growth rates of CIF and its components



Notes: This figure plots the annual growth rates of the CIF price index of Chilean imports and its components (FOB, Freight, Insurance). Annual growth rates are calculated as $g_{X,t} = \sum_i \frac{FOB_{i,2017}}{\sum_i FOB_{i,2017}} d\log\left(\frac{X_{it}}{Q_{it}}\right)$, where $X = \{\text{CIF}, \text{FOB}, \text{Fre}, \text{Ins}\}$ and $FOB_{i,2017}$ is the total FOB value of all imports of product i into Chile during 2017 (i is defined at the HS8 level), and Q_{it} is total quantity of i imported by all firm in period t.

To understand the contribution that the rise in freight costs had on import prices, we decompose the variations in CIF prices into the growth of its components:

$$d\log P_t^{\text{CIF}} \approx s_t^{\text{FOB}} d\log P_t^{\text{FOB}} + s_t^{\text{Fre}} d\log C_t^{\text{Fre}} + s_t^{\text{Ins}} d\log C_t^{\text{Ins}},$$

where $s_t^X = \frac{X_t}{\text{CIF}_t}$ and $X = \{\text{FOB,Fre,Ins}\}$. Panel A in Figure 2 shows this decomposition for all Chilean imports. Between 10 to 20 percent of the rise in import prices in the last three quarters of 2021 came from increases in freight costs, which starkly contrasts with the situation before 2021, where freight costs played a limited role in explaining the growth rates of CIF prices.

There are marked differences in the importance of freight costs when we apply the analysis to different sourcing regions. In Panels B-F in Figure 2, we replicate the decomposition above for imports from the five regions. The rise in freight costs during 2021 was largely explained by imports from China and, to a lesser extent, by imports from the Rest of Asia and Europe. In these regions, freight cost changes explained one-third to one-half of the rise in CIF prices. For South/Central America and North America, freight costs did not account for much of the rise in total import costs, which were almost entirely explained by rises in FOB prices. One can interpret these findings as the COVID-19 pandemic having affected different regions of the globe in different ways. In Asia and in Europe, product prices (i.e., FOB values) stayed flat during 2021, so pandemic-induced disruptions in international trade logistics seem to be the main driving force pushing CIF prices. On the other hand, logistics in the Americas do not show much evidence of distress in this period, so pandemic-induced disruptions in production are likely what determined the significant observed jump in the levels of product prices in 2021 for this region.

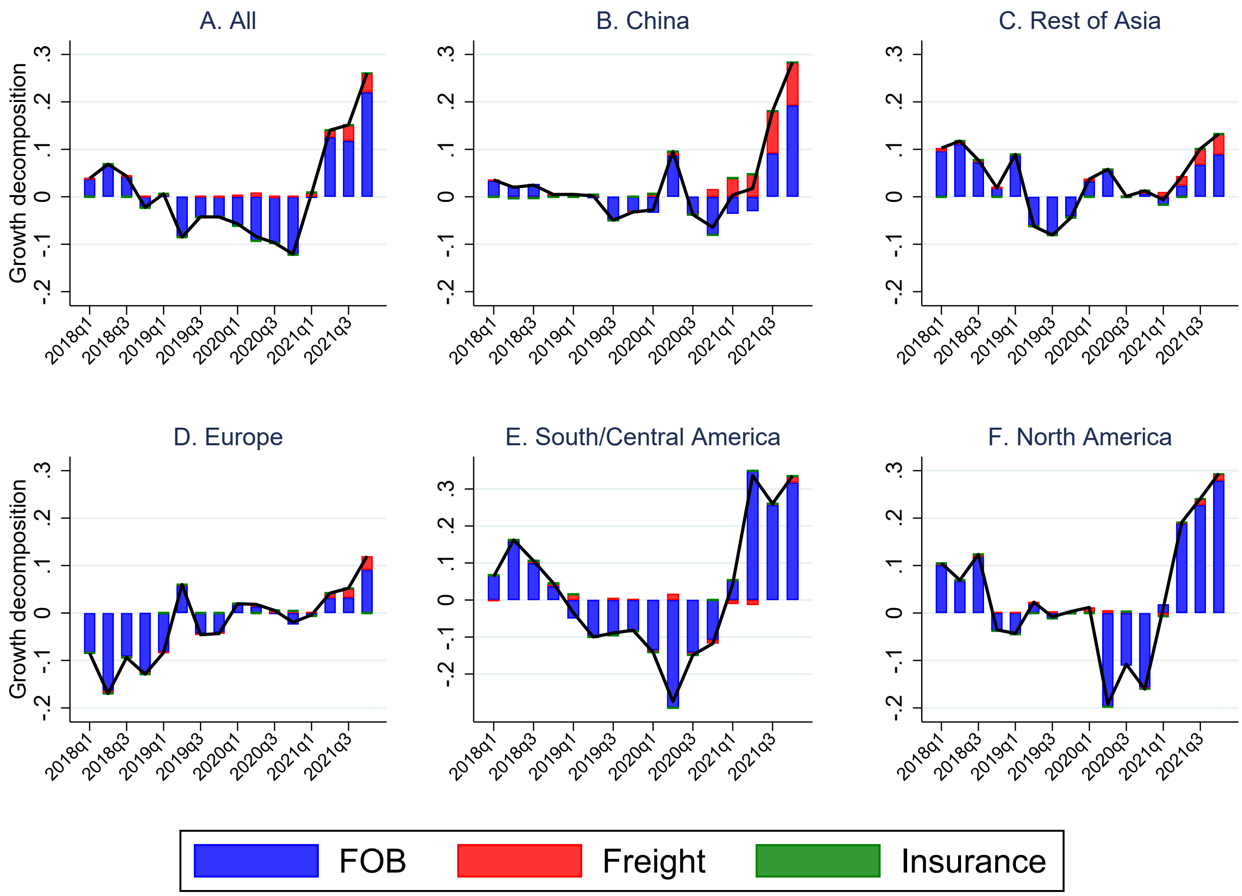
Appendix Figure A.1 conveys a similar message as it plots the growth rate of the CIF price index and that of its components by region. China stands out with freight costs more than doubling at the end of 2021. In the Rest of Asia, these costs grew by around 50 percent during this period.

Another way to visualize this is by looking at the ratio of freight costs to FOB values by region of origin. Figure 3 shows, for each origin, the ratio of total freight costs to total FOB. Until the first quarter of 2020, all regions displayed similar trends for this ratio, which hovers around 5 to 6 percent. When the pandemic hit, the ratio shot up in the Americas and subsequently fell in the following period, while it rose slightly in the other regions. However, in the last quarter of 2020, the ratio for imports from China rose exponentially, considerably for the Rest of Asia, Europe, and South/Central America, and stayed fairly flat for North America.[10]

We use these findings to design an empirical strategy to estimate the elasticity of substitution between imported intermediate inputs from different regions. The large rise in freight costs from China, and to a lesser extent from the Rest of Asia and Europe are unlikely to be determined by a particular Chilean firm importing a particular good. In addition, historic import purchases by firms provide a distribution of their exposition to

[10]The ratio could increase due to composition effects, i.e., specific firms or products facing steeper freight costs, and not because the region itself is. Appendix A.2 plots region-time fixed effects that control for this potential compositional effect, and the findings hold.

Figure 2: CIF prices decomposition by region



Notes: This figure plots the contribution each component of CIF has on its annual growth rate for different regions of origin: Asia and Rest of the world.

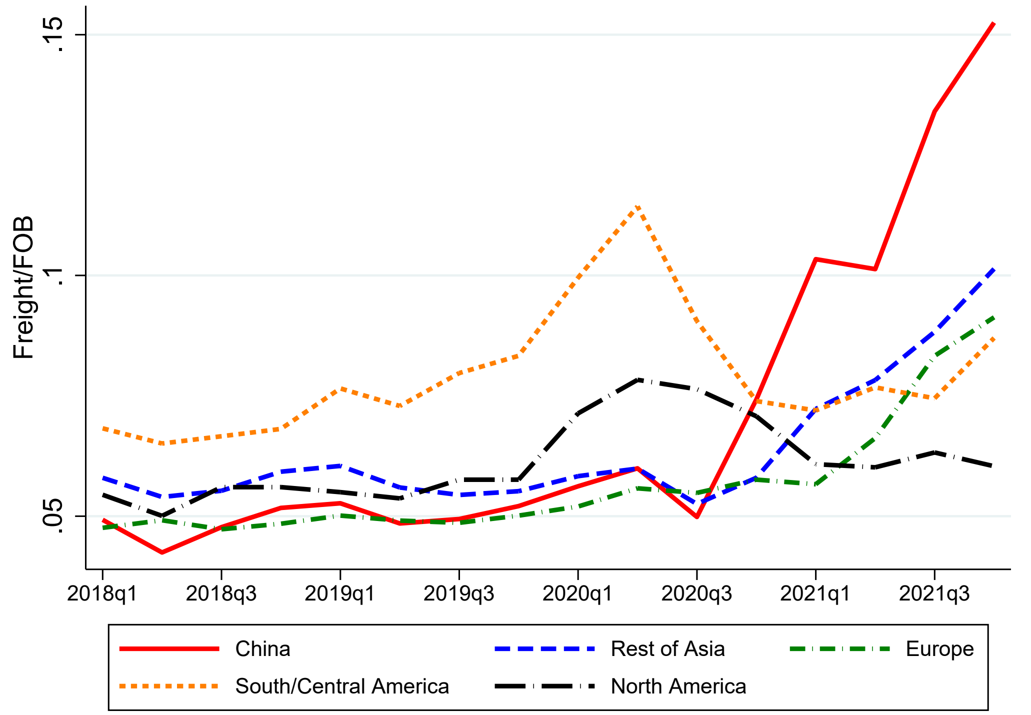
each region. Put together, they can provide enough exogenous variation in the prices faced when importing over the cross-section.[11]

3 Elasticity of substitution estimation

In this section, we present a partial equilibrium model that derives an estimating equation for the elasticity of substitution between intermediate inputs of different origins. We use this to estimate the effect of freight costs on consumer prices.

[11] Appendix B provides product evidence about the effect that rising freight costs had. We show that "Footwear" and "Leather and Skin" are the product categories most exposed to Asia, and when we measure the incidence which includes the magnitude of the freight cost shock, "Wood", "Stone, Ceramic, Glass" and "Other manufacturing" products.

Figure 3: Freight/FOB by region



Notes: This figure plots the ratio of the total freight cost of imports to the total FOB value for each quarter, and for each sourcing region.

3.1 Analytical Framework

We propose an analytical framework that describes the fundamental forces behind the effects from changes in freight costs to inflation. We assume that producers can substitute intermediate goods from different regions with a constant elasticity of substitution. We focus on partial equilibrium effects, so we shut down any labor market or aggregate income responses. We characterize the pass-through of freight costs changes to inflation as the sum of two effects: (i) a direct effect, that mechanically measures how much the prices of imported consumption goods increase, and (ii) an indirect effect, that arises from imported intermediate inputs used in the production process. The elasticity of substitution between imported materials and the share of imported inputs over total costs are crucial parameters for the size of the indirect effect.

Households. Households choose between consuming domestic or foreign goods, C_D and C_F, respectively, to optimize the following function:

$$
\begin{aligned}
\max_{C_D,\, C_F} \quad & C_D^{\eta} C_F^{1-\eta} \\
\text{s.t.} \quad & C_D P_D + C_F P_F^c = w,
\end{aligned}
\tag{1}
$$

where $\eta \in (0,1)$, P_D is the price of the domestic consumption good, and $P_F^c = \mathcal{E}\left(\tilde{p}_F^c + \tau_F\right)$ is the price of the foreign consumption good, which is the sum of a FOB price, $\tilde{p}_F^c$, and a freight cost, τ_F, expressed in domestic currency units. $\mathcal{E}$ is the US dollar (USD) to Chilean peso exchange rate and wages, w, are fixed throughout.[12]

Production. There is a competitive retailer firm that aggregates domestic manufacturing varieties, y_i, according to a constant returns technology to produce a domestic good, Y_D. The good produced domestically can be used for consumption or as an intermediate production input.

Manufacturing firms are heterogeneous and operate competitively in input markets. Firm i combines labor, l, which is in fixed supply, domestic intermediates, m_D, and a foreign composite of intermediate inputs, m_F, according to a constant returns to scale production function to maximize profits:

$$
\begin{aligned}
\max_{l_i,\, m_{iD},\, m_{iF}} \quad & p_{iD} y_i - w l_i - p_D m_{iD} - p_{iF}^m m_{iF}, \\
\text{s.t.} \quad & y_i = l_i^{\alpha} \left(m_{iD}^{\gamma} m_{iF}^{1-\gamma} \right)^{1-\alpha},
\end{aligned}
\tag{2}
$$

where $\alpha, \gamma \in (0,1)$. In turn, the foreign composite of intermediate inputs is made of region-specific intermediate imports. Regions are indexed by $k = \{1, ..., 5\}$. Imports from each origin result from the solution to the following cost-minimization problem:

$$
\begin{aligned}
\min_{\{m_{ik}\}} \quad & \sum_k p_k^m m_{ik}, \\
\text{s.t.} \quad & m_{iF} = \left[\sum_k \omega_{ik}^{\frac{1}{\epsilon}} m_{ik}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}},
\end{aligned}
\tag{3}
$$

where $\sum_k \omega_{ik} = 1$, m_{ik} are intermediate imports from origin k, p_k^m is the price of input from

[12] Over 90 percent of Chilean imports are invoiced in USD. For the remainder of the analysis we abstract from insurance costs, which are negligible relative to FOB price and freight costs.

origin k, and ϵ is the elasticity of substitution between intermediate goods of different regions. The unit cost of the imported materials bundle is firm-specific, and given by $p_{iF}^m = \left[\sum_k \omega_{ik}(p_k^m)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$, where p_k^m is defined as the sum of a FOB price, $\tilde{p}_k^m$, and a freight cost, τ_k, expressed in domestic currency units $p_k^m = \mathcal{E}\left(\tilde{p}_k^m + \tau_k\right)$.

Proposition 1. *In an economy characterized by* (1)–(3)*, the partial equilibrium adjustments of aggregate prices are as follows:*

(i) Domestically produced goods inflation: $d\log P_D = \dfrac{(1-\alpha)(1-\gamma)}{1-(1-\alpha)\gamma}\mathbb{E}[d\log p_{iF}^m]$,

(ii) Consumer Price Index inflation: $d\log P = \dfrac{\eta(1-\alpha)(1-\gamma)}{1-(1-\alpha)\gamma}\mathbb{E}[d\log p_{iF}^m] + (1-\eta)d\log p_F^c$,

where $P = \left(\frac{P_D}{\eta}\right)^{\eta}\left(\frac{P_F^c}{1-\eta}\right)^{1-\eta}$ *is the economy's consumer price level and* $\mathbb{E}[d\log p_{iF}^m] \equiv \sum_i \dfrac{p_{iD}y_i}{p_D Y} d\log p_{iF}^m$.

We provide a proof in Appendix C.

Inflation of domestically produced goods come from the average variation in the cost of imported inputs, amplified by their use of domestic production as inputs, $(1-(1-\alpha)\gamma)^{-1}$. In addition, CPI inflation is affected by the change in the cost of imported consumption goods. By using this proposition, we derive the effect of freight costs on CPI inflation:

$$\frac{d\log P}{d\log\tau} = \underbrace{\eta\frac{(1-\alpha)(1-\gamma)}{1-(1-\alpha)\gamma}\mathbb{E}\left[\frac{d\log p_{iF}^m}{d\log\tau}\right]}_{\text{Indirect Effect}} + \underbrace{(1-\eta)\frac{d\log p_F^c}{d\log\tau}}_{\text{Direct Effect}}. \tag{4}$$

Increases in freight costs thus affect CPI inflation through an indirect effect, that comes from the degree to which prices of domestic goods go up because of rising freight costs, and a direct effect, that comes from the extent to which prices of imported consumption goods rise. A key element in equation (4) is how much the unit cost of imported materials increases due to the increase in freight costs. This object in turn depends on the elasticity of substitution ϵ:

$$\Delta\log p_{iF}^m \equiv \log\left(\frac{p_{iF}^{m\prime}}{p_{iF}^m}\right) = \frac{1}{1-\epsilon}\log\left(\sum_k \omega_{ik}\left(\frac{p_k^{m\prime}}{p_k^m}\right)^{1-\epsilon}\right), \tag{5}$$

where x' corresponds to the future value for any variable x, and ω_{ik} is the share of imported materials from region k, $\frac{p_k^m m_{ik}}{p_{iF}m_{iF}}$. Note that this is an exact difference formula and, for that reason, the smaller the ϵ, the larger the impact on the price of the imported intermediates bundle of a change in the price of a given imported intermediate.

3.2 Elasticity of substitution

From the solution to the firm's problem we can obtain that the firm's demand of intermediates from a particular region is given by:

$$m_{ik} = \omega_{ik} \left(\frac{p_k^m}{p_{iF}^m} \right)^{-\epsilon} m_{iF}.$$

Taking logarithms, first differencing this expression, and considering the multi-product dimensions of the firm's decision problem, we arrive at the following structural equation:

$$d \log m_{ijk,t} = \lambda_i + \lambda_{j,t} + \lambda_k - \epsilon d \log p_{ijk,t}^{CIF} + \varepsilon_{ijk,t}, \tag{6}$$

where j denotes a product at the HS8 level, λ_i is a firm fixed effect, $\lambda_{j,t}$ is a product-time fixed effect, and $\lambda_{k,t}$ an origin-time fixed effect.

Estimating equation (6) by OLS is potentially contaminated by unobserved demand shocks that shift the relative quantities purchased while simultaneously affecting in the same direction relative prices among origins. For example, during the period, many governments implemented COVID-19-induced restrictions such as stay-at-home orders and quarantines. These policies likely move consumption preferences towards durable goods that could be used at home. If any region of the world disproportionately provides these goods to Chile, OLS estimates could be biased. In addition, as we are dealing with unit values rather than ideal prices within each HS8 product category, there could be measurement error. We propose an instrumental variable strategy to address these concerns.

3.2.1 Identification strategy

To address the endogeneity concerns in estimating the elasticity of substitution between origins we adopt an instrumental variables approach based on a shift-share design (Bartik (1991)). The instrument we propose combines two components: shifters, which are the changes in freight costs across regions, and shares, that correspond to the extent to which a firm initially imports intermediates from each region.

To improve granularity and variation, we define shocks and exposures at the HS4 product category level, denoted by h. We compute the exposure as the share of firm i's imports of intermediates belonging to product category h, from region k, at time t, relative to its total imports of intermediates in product category h, all valued at FOB prices:

$$\omega_{ihk,t} \equiv \frac{\sum_{j \in h} \text{FOB Value}_{ijk,t}}{\sum_k \sum_{j \in h} \text{FOB Value}_{ijk,t}}. \tag{7}$$

The shocks are constructed as:

$$d\theta_{hk,t} = \frac{\sum_i \sum_{j \in h} \text{Freight Costs}_{ijk,t}}{\sum_i \sum_{j \in h} \text{FOB Value}_{ijk,t}} - \frac{\sum_i \sum_{j \in h} \text{Freight Costs}_{ijk,t-T}}{\sum_i \sum_{j \in h} \text{FOB Value}_{ijk,t-T}}, \tag{8}$$

where $d\theta_{hk,t}$ represents the change in the share of freight cost expenses to FOB value across all Chilean firms that import inputs in product category h from region k. The aggregate level of these shocks by region of origin are shown in Figure 3.

Then, the instruments are as follows:

$$B_{ihk,t} \equiv \omega_{ihk,t-T} d\theta_{hk,t}, \tag{9}$$

where T denotes the number of periods elapsed from the base period.

Our instrument captures weighted changes in the aggregate share of freight costs relative to FOB-valued imports across sourcing regions, with weights determined by a firm's initial reliance on imports from each region. As described in Section 2.2, freight costs increases are substantially higher for imports from Asia, particularly China, than from other regions. Consequently, most of the variation in the instrument stems from changes in Asian freight costs, where the firm's initial exposure modulates the impact. This strategy generates variation in the relative CIF price of intermediate imports from Asia compared to other regions, ensuring that this variation is orthogonal to local preference shocks.

The validity of the instruments hinges on the exogeneity of either the individual share exposures (Goldsmith-Pinkham et al., 2020) or the exogeneity of the aggregate shocks (Borusyak et al., 2021). In our context, a firm's exposure to a specific region is determined by past decisions, which are likely correlated with current decisions. Consequently, the shares may not be exogenous, so the validity of our approach rests on the exogeneity of the shocks.

We want to make sure that these differences are not specific to Chile and do not reflect increased demand for transportation from domestic importers. Asia is one of the leading origins of Chilean imports, with China playing an outsized role. It represents roughly a third of Chilean exports and a quarter of Chilean imports. However, Chile represents an almost negligible share of Chinese exports. Then, it is unlikely that what we observe in Figure 2 or Figure 3 is due to a rise in demand from Chilean importers. In line with this, UNCTAD (2021) describes how freight costs from China increased dramatically at the beginning of 2021. In fact, the report shows that freight costs to South America increased by the most. Similarly, LaRocca (2021) documents freight costs of imports into the US West coast and shows they have increased worldwide, but especially from East Asia.

3.2.2 Regression results

We study the events that took place in 2021 and use 2019 as our baseline year, as international trade came to a halt for many Chilean importing firms during certain quarters of 2020. This means setting $T = 8$ as we consider data at a quarterly level. The same approach is considered in di Giovanni et al. (2022).

Table 1 presents estimates for the elasticity of substitution. Column 1 reports the OLS estimation, which yields an elasticity which is not statistically different from 1. This suggests that a one percentage point increase in input prices reduces input use by one percentage point, consistent with a Cobb-Douglas aggregator of foreign inputs. However, unobserved shocks—such as those induced by the pandemic—can bias this estimate upward by simultaneously driving both demand and prices.

The instrumental variable strategy yields a substantially larger elasticity of substitution, underscoring the importance of addressing endogeneity. Column 2 confirms the instrument's strength: the instrument correlates strongly with variations in import prices, and the high F-statistic verifies the relevance condition. Column 3 presents an estimate of 4.38, confirming the upward bias in OLS results. Hence, a one percentage point increase in relative imported input prices should lead to a relative decline of approximately four percentage points in imports of that input—an elasticity quantitatively and statistically larger than the Cobb-Douglas benchmark.

Table 1: Elasticity of substitution estimates

	(1)	(2)	(3)
	$d\log m_{ijkt}$	$d\log p^{CIF}_{ijkt}$	$d\log m_{ijkt}$
$d\log p^{CIF}_{ijkt}$	-1.026***		-4.377***
	(0.009)		(0.604)
B_{ihkt}		0.315***	
		(0.052)	
Observations	321,041	321,041	321,041
R^2	0.419	0.103	.
Firms	10,731	10,731	10,731
1st-stage F		37.28	

Notes: The table presents estimates of the elasticity of substitution, ϵ, from the regression $d\log m_{ijkt} = \lambda_i + \lambda_{jt} + \lambda_k - \epsilon d\log p^{CIF}_{ijkt} + \varepsilon_{ijkt}$ where λ_i, λ_{jt}, and λ_{kt} are firm, product (HS8)-time, and region fixed effects, respectively. Column 1 reports the OLS estimates. Column 2 is the first stage of an IV regression where the instrument is given by $B_{ihk,t} = \omega_{ihk,t-T} d\theta_{hk,t}$, where $\omega_{ihk,t} = \frac{\sum_{j\in h} \text{FOB Value}_{ijk,t}}{\sum_k \sum_{j\in h} \text{FOB Value}_{ijk,t}}$ and $d\theta_{hk,t} = \frac{\sum_i \sum_{j\in h} \text{Freight Costs}_{ijk,t}}{\sum_i \sum_{j\in h} \text{FOB Value}_{ijk,t}} - \frac{\sum_i \sum_{j\in h} \text{Freight Costs}_{ijk,t-T}}{\sum_i \sum_{j\in h} \text{FOB Value}_{ijk,t-T}}$ with h as HS4 product category. Column 3 is the IV estimate. The log-difference is computed using an 8-quarter lag between 2021q1-2021q4. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.3 Effects of freight costs on inflation

Equipped with estimates for the elasticity of substitution, we now compute the effect of freight costs on inflation. We need to assign values to parameters α and γ, which are obtained from model counterparts in the data. Parameter α is estimated as the aggregate ratio between wage bill and the sum of the wage bill and intermediate consumption. On the other hand, γ is calculated as the ratio of domestic intermediate consumption to aggregate intermediate consumption. These aggregates are obtained from Chilean National Accounts, yielding $\alpha = 0.33$ and $\gamma = 0.78$.

We proceed to compute the effect on inflation from the observed increase in freight costs between 2019q4 and 2021q4. Plugging equation (5) into (4), we derive our accounting expression for the effect of the increase in freight costs on inflation:[13]

$$d \log P_t = \frac{\eta(1-\alpha)(1-\gamma)}{1-(1-\alpha)\gamma} \frac{1}{1-\epsilon} \log \left[\sum_k \omega_{k,t-8} \left(\exp \left(s^{\tau}_{k,t-8} d \log \tau_{k,t} \right) \right)^{1-\epsilon} \right] + (1-\eta) \left[s^{\tau}_{t-8} d \log \tau_t \right],$$

where $\omega_{k,t} = \frac{\text{CIF Value}_{k,t}}{\sum_k \text{CIF Value}_{k,t}}$ is the share of region k on the total CIF value of materials imports, $s^{\tau}_{k,t} = \frac{\text{Freight Costs}_{k,t}}{\text{CIF Value}_{k,t}}$, s^{τ}_t defined similarly, and $d \log x_t \equiv \log x_t - \log x_{t-8}$ for any variable x_t. All these statistics can be computed directly from Customs data, and parameter $1-\eta$ is computed as the share of imports to GDP in Chile, which averaged 0.30 between 2011 and 2020.

Using the estimated parameters and values for 2021q4, we compute an indirect effect of 0.553 log points and a direct effect of 0.960, which add up to 1.513 log points.[14] CPI inflation between 2021q4 and 2019q4 was 9.26 log points, which means that the rise in freight costs explains approximately 16.3 percent of the increase in (log) CPI inflation registered during this period.

For this exercise, given the Cobb-Douglas nature of the production function at this input layer level, we have assumed that firms *do not* change their cost structure when they face these more expensive imported materials. One could expect that labor or domestic materials expenses would increase, alleviating the rise in costs. This constraint on this margin of adjustment implies that the effect we find is an upper bound.[15]

One important assumption we make here is that the pass-through from freight costs to CIF prices is complete. We verify this in the robustness section below.

3.4 Robustness checks

We address three potential threats to the validity of our results. First, the above analysis assumes that the increase in freight costs does not affect FOB prices, so we analyze whether this is the case. Second, instead of using freight cost information from Chile, which could potentially be endogenous, we consider freight cost information from Colombia and check whether our main results hold. Finally, we change our baseline spec-

[13] Here we use $\log \frac{p'^m_k}{p^m_k} \approx \frac{d \log p^m_k}{d \log \tau_k} = \frac{\tau_k}{p^m_k + \tau_k} d \log \tau_k$.

[14] For the indirect effect we use the values in Table 4. For the direct effect we use $s^{\tau}_{t-8} = 0.0577$ and $d \log \tau_t = 0.5477$

[15] This will later be confirmed by our general equilibrium model.

ification to test how much our results depend on our assumptions.

Freight costs and FOB prices. One potential threat to our previous estimates is our assumption that freight costs have zero effect on FOB prices. To rigorously test this assumption, we evaluate how much of the rise in freight costs passes through to FOB prices by estimating:

$$d \log p^{FOB}_{ijkt} = \lambda_i + \lambda_{j,t} + \lambda_k + \beta d \log \tau_{ijkt} + \varepsilon_{ijkt}, \tag{10}$$

where λ_i, $\lambda_{j,t}$ and λ_k are firm, product-time and sourcing region-time fixed effects, respectively. The left-hand side variable is the change in the unit FOB value of good j imported from region k by firm i defined as:

$$d \log p^{FOB}_{ijkt} = d \log \frac{\text{FOB Value}_{ijkt}}{\text{Quantity}_{ijkt}},$$

and the change in the freight unit cost for firm i importing product j from region k is:

$$d \log \tau_{ijkt} = d \log \frac{\text{Freight Costs}_{ijkt}}{\text{Quantity}_{ijkt}}.$$

In the face of potential firm-specific demand shocks that could cause FOB prices and freight costs to move simultaneously, the estimation of (10) by OLS may yield biased results.

To obtain consistent estimates of β, we instrument the freight unit cost change with (9). Again, the shifter and the exposure interaction should be exogenous to demand shocks specific to a particular firm that imports a product from a certain region, as it fuses an earlier – potentially endogenous – sourcing decision with an unexpected and exogenous aggregate shock.

Table 2 presents the estimates from equation (10). Column 1 shows that higher freight costs correlate with increased FOB prices, suggesting an elasticity of freight costs to FOB prices of 0.45. This observed positive elasticity should be interpreted cautiously, as it is likely influenced by the biases associated with the OLS estimates. Specifically, demand shocks, which simultaneously exert upward pressure on both product prices (i.e., FOB price) and transportation costs, may induce a positive correlation between freight costs and FOB prices.

Column 2 validates the relevance of our instrument, showing a strong correlation of it with freight costs, as evidenced by a high F-statistic. Column 3 indicates that freight costs do not significantly influence FOB prices when potential endogeneity is properly addressed. This result aligns with our baseline assumption of zero pass-through from freight costs to FOB import prices, suggesting a complete pass-through to CIF import prices instead. Thus, Chilean importers lack the bargaining power needed to shift any of the freight-cost increases back onto their foreign suppliers.

Table 2: Freight price pass-through to exports' FOB prices

	(1)	(2)	(3)
	$d\log p^{FOB}_{ijkt}$	$d\log \tau_{ijkt}$	$d\log p^{FOB}_{ijkt}$
$d\log \tau_{ijkt}$	0.449***		-0.0373
	(0.006)		(0.035)
B_{ihkt}		1.530***	
		(0.081)	
Observations	321,041	321,041	321,041
R^2	0.430	0.209	.
Firms	10,731	10,731	10,731
1st-stage F		356.1	

Notes: This table presents estimates of the pass-through from freight costs to FOB prices from the regression $d\log p^{FOB}_{ijkt} = \lambda_i + \lambda_{j,t} + \lambda_k + \beta d\log \tau_{ijkt} + \varepsilon_{ijkt}$, where λ_i, λ_{jt} and λ_{kt} are firm, product (HS8)-time, region fixed effects, respectively. Column 1 reports the OLS estimate. Column 2 is the first stage of an IV regression where the instrument is defined in (9). Column 3 is the IV estimate. The log difference is computed using an 8-quarter lag between 2021q1-2021q4. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Exogeneity of the freight costs. A potential issue in our analysis is the assumption that shocks to freight costs are exogenous to Chilean importers. For example, a higher domestic demand for goods produced in China could increase both the price of the goods and the associated freight costs. To assess the exogeneity of freight costs to Chilean firms, we employ a method similar to that used in Autor et al. (2013). We use Customs import data from Colombia, a country that, like Chile, is located in South America and features a significant Pacific port. Appendix Section D provides more details on this approach.

Appendix Figure C.1 replicates Figure 3 for Colombia, showing similar regional trends until the onset of the pandemic. Afterward, there is a slight increase, followed by heterogeneous regional responses, with Asia exhibiting the most significant rise in freight costs relative to FOB prices. Appendix Table C.1 replicates Table 1, revealing an elasticity of 3.331 that is not statistically different from that estimated using Chilean shocks, 4.135.[16] Furthermore, we confirm that the previously estimated pass-through of freight costs to FOB prices also holds in the Colombian data. As shown in Appendix Table C.2, the pass-through remains null, indicating that Chilean importers fully bear increases in freight costs.

Alternative specifications. To ensure that our results are not driven by the particular specifications of our regressions and aggregations of the data, we perform some additional exercises. First, we aggregate products into HS4 product categories, rather than using HS8 codes. We do this to verify that we are not restricting the sample excessively by requiring HS8 products to be continuously imported by a certain region for a given firm. Appendix Table A.1 shows that results are virtually the same, but with 10 percent more firms.

Second, the equation derived in (6) assumed that unobservable firm characteristics, beyond prices and product shocks, were fixed in time. Appendix Table A.2 shows the results of a specification that allows for time-varying shocks or unobservable firm characteristics. In this case, the estimated elasticity is 5.55, slightly higher than our baseline estimate but not statistically different.

Finally, we can check that the result of full pass-through from freight costs to CIF prices also holds when using an HS4 aggregation, and when allowing for firm-time fixed effects. Appendix Table A.3 and A.4 show each of those exercises respectively.

4 General equilibrium analysis

4.1 Model

We present a small open economy general equilibrium model that embeds the elements of the framework presented in Section 3.1. The model lasts two periods, present and fu-

[16]There is no complete overlap between the product-region-quarter tuples that Chile and Colombia import. When we use the same sample and the baseline approach we obtain an elasticity of 4.135.

ture. Agents take as given the price level in the future.[17] This simplifying assumption largely follows the same modeling choices as in Baqaee and Farhi (2022). There is no investment. There is a representative firm that produces a homogeneous domestic intermediate. A continuum of mass 1 of retailers sell differentiated varieties to a competitive final good producer that aggregates the varieties through a CES function. Finally, there is a continuum of mass 1 of households that consume domestic and imported products.

4.1.1 Households

Households, indexed by τ, live for two periods and supply a household-specific variety of labor to the market. They maximize a two-period utility function given by:

$$U^{\tau} = \sum_{t=0,1} \beta^t \left(\log(C_t^{\tau}) - \chi \frac{(L_t^{\tau})^{1+\psi}}{1+\psi} \right)$$

where β is the discount factor, C_t^{τ} is consumption, L_t^{τ} is labor, χ is a disutility of labor parameter, and ψ is the labor Frisch elasticity.

The household has access to an internationally traded risk-free bond, denominated in foreign-currency, that pays a nominal interest rate i_t. Households also have access to a full set of state-contingent domestically-traded securities to insure themselves against variations in household-specific labor income. As a result, labor income plus the net income received from the trading of the state-contingent securities, $w_t^{\tau} L_t^{\tau} + A_t^{\tau}$, will be equal across households and equal to aggregate labor income.

All households start out with zero wealth, an assumption which, jointly with the trading of state-contingent securities, will imply that the marginal utility of consumption (and thus consumption) will be identical across all households.

The budget constraints of household τ are thus given by:

$$\begin{aligned} \text{Period } 0: &\quad P_0 C_0^{\tau} + \mathcal{E}_0 B_1^{\tau} = w_0^{\tau} L_0^{\tau} + A_0^{\tau} + \Pi_0 \\ \text{Period } 1: &\quad P_1 C_1^{\tau} = w_1^{\tau} L_1^{\tau} + A_1^{\tau} + \Pi_1 + (1+i_1)\mathcal{E}_1 B_1^{\tau} \end{aligned}$$

where P_t is the price of consumption, $\mathcal{E}_t$ is the nominal exchange rate between the domestic and foreign currencies, w_t^{τ} is the household-specific wage rate per hour of labor,

[17] This is isomorphic to an infinite-horizon model where after an initial unexpected shock in period zero, the economy returns to a flexible price long-run equilibrium featuring market clearing and full employment.

A_t^τ is the net cash received from state-contingent securities, and Π_t is firms' profits, which are rebated lump-sum to all households.

From the solution to the dynamic problem we obtain the following Euler equation:

$$C_0^\tau = \frac{1}{\beta}\frac{1}{1+i_1}\frac{\mathcal{E}_0}{\mathcal{E}_1}\frac{P_1}{P_0}C_1^\tau \tag{11}$$

Given that the marginal utility of consumption is the same for every household, we have $C_t^\tau = C_t$. We drop the τ index from now on.

Consumption, C_t, is a Cobb-Douglas composite of a domestic (D) and an imported consumption good (F). Households solve the same intratemporal allocation problem displayed in (1).

Households supply their specific variety of labor to a competitive intermediary firm that then sells a CES labor bundle to intermediate goods firms. The CES aggregator is given by:

$$L_t = \left[\int_0^1 (L_t^\tau)^{\frac{\sigma_L - 1}{\sigma_L}} d\tau\right]^{\frac{\sigma_L}{\sigma_L - 1}}, \quad \sigma_L > 1$$

where σ_L is the elasticity of substitution between different labor varieties.

In period 0, a fraction $1 - \varrho_L$ of households can adjust the wage that they demand from the intermediary in order to supply a unit of labor. In period 1, every household can adjust. This implies that the aggregate wage rate in period 0 is given by:

$$W_0 = \left[(1-\varrho_L)(W_0^*)^{1-\sigma_L} + \varrho_L(W_{-1})^{1-\sigma_L}\right]^{\frac{1}{1-\sigma_L}}$$

where W_0^* is the wage rate associated to those households that can adjust their wages in period 0, and W_{-1} is the value of the wage index in the period previous to period 0, which would correspond to the no-shocks flexible price equilibrium. Households that can adjust conform to the following wage setting rule:

$$W_0^* = \frac{\sigma_L}{\sigma_L - 1}\chi(L_t^*)^\psi P_t C_t$$

4.1.2 Intermediate Good Firms

There is a competitive representative firm that produces a homogeneous intermediate good by combining labor, l, domestic materials, m_D, and a composite of foreign materials, m_F, according to a constant returns to scale Cobb-Douglas production function. The representative firm thus solves the following profit maximization problem:

$$\max_{l_t, m_{Dt}, m_{Ft}} \quad p_{Dt}^{int} y_t - w_t l_t - p_{D_t} m_{D_t} - p_{F_t}^m m_{F_t},$$

$$\text{s.t.} \quad y_t = z_t {l_t}^{\alpha} \left(m_{Dt}^{\gamma} m_{F_t}^{1-\gamma} \right)^{1-\alpha} \quad \text{where} \quad \alpha, \gamma \in [0,1],$$

where z_t is firm's productivity. All other variables and parameters follow the same definitions as in Section 3.1. The firm sources imported materials from the set of regions $\mathcal{K}$, and it chooses how much to demand from each source $k \in \mathcal{K}$ by solving the following cost minimization problem:

$$\min_{\{m_{kt}\}_{k \in \mathcal{K}}} \quad \sum_{k \in \mathcal{K}} p_{kt}^m m_{kt},$$

$$\text{s.t.} \quad m_{Ft} = \left[\sum_{k \in \mathcal{K}} \omega_k^{\frac{1}{\epsilon}} m_{kt}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

where $\omega_k \in (0,1)$ and $\sum_{k \in \mathcal{K}} \omega_k = 1$. The unit cost of the imported materials composite is thus given by $p_{Ft}^m \equiv \left[\sum_{k \in \mathcal{K}} \omega_k (p_{kt}^m)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$.

The CIF price of materials sourced from region k is defined as $p_{kt}^m = \mathcal{E}_t(\tilde{p}_{kt}^m + \tau_{kt}^m)$, where again all variables follow the same definitions as in Section 3.1.

4.1.3 Retailers

Domestic production, Y, is performed by competitive retailers, who aggregate a continuum of varieties of mass 1, indexed by f, according to a CES function:

$$Y = \left(\int_0^1 y_{ft}^{\frac{\sigma_C - 1}{\sigma_C}} df \right)^{\frac{\sigma_C}{\sigma_C - 1}},$$

where $\sigma_C > 1$ is the elasticity of substitution across domestic varieties.

Each variety is produced according to a linear function that only uses the homogeneous intermediate good as input. Hence, marginal cost is the same for all variety producers and is equal to p_{Dt}^{int}.

A variety producer is able to freely adjust its price with probability $1 - \varrho_C$. In period 1 all prices are flexible, so the pricing decision in period 0 is totally static. We can thus write the price level of domestic production at $t = 0$ in the following way:

$$p_{D0} = \left[(1-\varrho_C)(p^*_{D0})^{1-\sigma_C} + \varrho_C(p_{D,-1})^{1-\sigma_C}\right]^{\frac{1}{1-\sigma_C}},$$

where $p_{D,-1}$ is the ideal price index of the domestic good in the flexible price equilibrium, and p^*_{D0} is the optimal price set by those variety producers that can adjust prices at $t = 0$, which is given by:

$$p^*_{D0} = \frac{\sigma_C}{\sigma_C - 1} p^{int}_{D0}.$$

4.1.4 Market Clearing Conditions

The domestic good market is in equilibrium if:

$$C_{Dt} + m_{Dt} + X_t = Y_t,$$

where X_t is exports of the domestic good. We specify the following demand function for domestic exports:

$$X_t = b\left(\frac{\mathcal{E}_t}{p_{Dt}}\right)^{\epsilon},$$

where we have abstracted from the freight rates associated to moving goods from the domestic market to the exterior.[18] Additionally, we have imposed the estimated elasticity of substitution as the foreign demand elasticity for domestic goods. This implicitly assumes that Chilean exports are mostly intermediates, which seems like a plausible assumption, given that more than 50 percent of the value of Chilean exports is composed of raw materials (especially copper).

Labor market equilibrium requires that the total supply of the labor bundle offered by the labor intermediary has to be equal to the total labor demanded by the intermediate good firm:

$$\left[\int_0^1 (L^\tau_t)^{\frac{\sigma_L - 1}{\sigma_L}} d\tau\right]^{\frac{\sigma_L}{\sigma_L - 1}} = l_t.$$

Equilibrium. Given a foreign nominal interest rate $(1 + i_1)$; present and future nominal exchange rates, $\{\mathcal{E}_t\}_{t=0,1}$; future nominal consumption, P_1C_1; a foreign demand preference parameter for domestic goods, b; a productivity parameter, z; FOB prices in for-

[18]We found evidence that global changes in freight rates did not affect exporting behavior in Chile. Results can be provided upon request.

eign currency for foreign materials from each origin k, $\tilde{p}^m_{k0}$; freight costs in foreign currency for foreign materials from each origin k, τ^m_{k0}; FOB prices in foreign currency for the foreign consumption good, $\tilde{p}^c_{F0}$; and freight costs in foreign currency for the foreign consumption good, τ^c_0, an equilibrium is a set of prices, $\left\{p_{D0}, p^{int}_{D0}, p_{f0}, P_0\right\}$; wages, $\left\{\left\{w^\tau_0\right\}_{\tau\in[0,1]}, W_0\right\}$; quantities consumed, $\left\{\left\{C^\tau_0\right\}_{\tau\in[0,1]}, C_{D0}, C_{F0}, C_0\right\}$; assets accumulated, B_1; units of labor, $\left\{\left\{L^\tau_0\right\}_{\tau\in[0,1]}, l_0, L_0\right\}$; quantities of materials, $\left\{m_{D0}, m_{F0}, \{m_{k0}\}_{k\in\mathcal{K}}\right\}$; outputs, $\left\{y_0, \left\{y_{f0}\right\}_{f\in[0,1]}, Y_0\right\}$; and exports, X_0, such that each producer maximizes its profits subject to its technological constraint, consumers maximize their utility and markets for all goods and factors clear.

4.1.5 Shocks

We consider one-time shocks that only take place in period 0. Shocks and responses of endogenous variables are defined relative to the flexible price equilibrium benchmark. The perturbations in our analysis are to the households' impatience degree, $d\log\zeta$; to the shifter of foreign demand for domestic goods, $d\log b$; to the productivity parameter of intermediate good firms, $d\log z$; to the nominal exchange rate, $d\log\mathcal{E}$; to the FOB price in foreign currency of the imported consumption good, $d\log\tilde{p}^c_{Ft}$; to the FOB price in foreign currency of imported materials from each origin k considered, $d\log\tilde{p}^m_{kt}$; to the freight cost in foreign currency of the imported consumption good, $d\log\tau^c_t$; and to the freight cost in foreign currency of imported materials from each origin k considered, $d\log\tau^m_{kt}$.

We focus on the bi-annual period that goes from 2019q4 to 2021q4, as 2019q4 is a better approximation to normal times than 2020q4, and because the model's first period is quasi-static, so it is a more accurate representation of medium-run dynamics than short-run ones. Medium-run dynamics are more likely to take place in a two-year span than within a year or a quarter.

The shock to the household's impatience degree is defined after log-linearizing the Euler equation (11):

$$d\log P_0 C^\tau_0 = d\log\mathcal{E}_0 + \underbrace{d\log P_1 C^\tau_1 - d\log\beta - d\log(1+i_1) - d\log\mathcal{E}_1}_{\equiv d\log\zeta}.$$

We call this perturbation an impatience degree shock even though it comprises more than the change in the discount factor, as any changes in future nominal consumption, $P_1C^\tau_1$, international interest rates, $1+i_1$, or exchange rates, $\mathcal{E}_1$, are isomorphic to a unique change in β. We can also capture any demand-side stimulus such as government aid programs during COVID-19.

The foreign demand shifter, b, aims to capture any developments in the world that could have altered the demand curve for the domestic good, such as changes in preferences, production needs, or market size.

Changes in the nominal exchange rate, $\mathcal{E}$, will be considered structural shocks. This assumption has three implications. First, we implicitly assume uncovered interest parity. Changes in exchange rates affect the interest rate that is paid on risk-free assets in terms of domestic currency. Second, exchange rate changes do not respond to any other model variable, so monetary policy will be totally implicit and passive. This situation can be understood as one in which both domestic and foreign monetary policy rates are fixed, such as at the zero lower bound.[19] Finally, also due to their exogeneity, we are not able to assess the extent to which observed changes in exchange rates are due to endogenous responses to supply and demand shocks of different origins. In this sense, the model can only speak about supply and demand shocks net of exchange rate movements.

The change in the CIF price in foreign currency of the imported consumption good does not delve into the actual determinants of the variation of this price beyond the changes in FOB prices and freight costs. This is different from the change in the CIF price of imported materials, where we distinguish between origins and establish separate shocks for imports from each sourcing region.

4.2 Calibration

In the model, we have 16 shocks plus 23 parameters or shares to calibrate. We assign values either from the literature or from data counterparts as much as possible, leaving the rest for internal calibration. Appendix E discusses how we calibrate each model's parameter in detail. Our focus here is on explaining the calibration of the model's shocks.

We impose a change in the productivity parameter z equal to the measured change in Chilean TFP during 2019-2021 by the National Commission of Productivity (CNP, in Spanish), which is 3.4 percent. We also calculate the depreciation rate of the Chilean peso against the USD during the 2019q4-2021q4 period from the CBC webpage, and assign that number to the exchange rate depreciation shock of the model, $d \log \mathcal{E}$, which we set to

[19]Chile's monetary policy rate actually did change during the 2019q4-2021q4 period, from 1.81 to 2.82 percent, on average. However, it remained at its technical lower bound between 2020q2 to 2021q3, which is the period in which most of the shocks under analysis took place.

8.93 percent. From Customs data, we calculate average changes in FOB prices and freight rates from different sources and impose them on their model counterparts. In addition, we calculate the average share that the unit freight cost represents of the unit FOB price in USD. In the case of intermediate inputs, we focus on 5 different foreign regions from which firms source inputs: North America, Central and South America, Europe, Asia excluding China, and China. We set the preference parameter for each region k, ω_k, as the average share at CIF prices that intermediates imports from each origin represent of total imported inputs across these 5 regions, for non-retail firms, during 2019. For consumption goods, we consider the world as a single sourcing region.

We are still left with two shocks to be assigned values: the impatience shock, $d \log \zeta$, and the foreign demand shock, $d \log b$. We internally calibrate both perturbations. In the case of the impatience shock, we target the log change in the nominal value of internal absorption, which was equal to 28.8 percent in the 2019q4-2021q4 period. The foreign demand shock is calibrated to match the log change in the nominal value of exports, expressed in terms of USD, which was 17.7 percent.

A summary of the parameters, shares, and shocks that have been calibrated, jointly with their values, targets, and sources can be found in Tables 3 and 4.

4.2.1 Model Fit

The model has a good fit in terms of the targeted moments. Panel A of Table 5 summarizes the results of the targeted moments. The model correctly predicts the observed change in nominal absorption and the observed increase in the USD value of nominal exports.

We choose three moments to assess the out-of-sample fit of our theoretical framework: the log change in the absorption deflator, the log change in real absorption, and the log change in nominal wages per hour. In this sense, we evaluate the performance of the model in terms of its predictions regarding the split between the nominal and the real component of consumption, for which the data analog is absorption, and in terms of its implications for wage inflation. We take the information for the nominal and the real components of absorption from National Accounts, while the change in the nominal hourly wage is taken from the hourly wage index (*Índice de Remuneraciones*, in Spanish) elaborated by the National Institute of Statistics (*Instituto Nacional de Estadísticas*, in Spanish). The model does well in matching these two targets. It underpredicts the absorption deflator by about 0.28 percentage points at 9.23 versus 9.51 percent in the data, while it slightly overpredicts the real growth in absorption at 19.58 versus 19.30 percent in the data. Nom-

Table 3: Calibration

Parameter	Source/Target	Value
A. Externally Calibrated		
ϱ_C	Literature	0.25
ϱ_L	Literature	0.17
σ_L	Literature	12
ψ	Literature	3
σ_C	Markup = 1.2	6
η	National Accounts	0.70
α	National Accounts	0.33
γ	National Accounts	0.78
C_D/Y	National Accounts	0.4
X/Y	National Accounts	0.1
ϵ	Estimation	4.38
$\Delta\tilde{p}_F^c/\tilde{p}_F^c$	Customs	0.11
$\Delta\tau^c/\tau^c$	Customs	0.60
$\tau_c/\tilde{p}_F^c$	Customs	0.06
$d\log z$	CNP (2022)	0.03
$d\log\mathcal{E}$	CBC	0.09
B. Internally Calibrated		
$d\log\zeta$	Δ% in nominal absorption	0.199
$d\log b$	Δ% in USD value of nominal exports	0.003

Table 4: Calibration: Parameters per Sourcing Region

	$\Delta\tilde{p}_k^m/\tilde{p}_k^m$	$\Delta\tau_k^m/\tau_k^m$	$\tau_k^m/\tilde{p}_k^m$	ω_k
North America	14.3%	19.6%	5.97%	0.252
South and Central America	22.1%	11.7%	7.97%	0.235
Europe	5.65%	53.1%	4.57%	0.187
Asia excl. China	8.30%	65.8%	5.87%	0.100
China	9.90%	121.6%	5.29%	0.227

inal wage changes in the model and the data are quite close to one another, with 9.74 and 10.18 percent, respectively. The results are summarized in Panel B of Table 5.

Table 5: Moments

	Model	Data
A. Targeted		
Δ% in nominal absorption	28.81	28.81
Δ% in USD value of nominal exports	17.72	17.71
B. Untargeted		
Δ% in absorption deflator	9.23	9.51
Δ% in real absorption	19.58	19.30
Δ% in hourly nominal wage	9.74	10.18

4.3 Counterfactuals

We evaluate the importance of shocks for inflation and real consumption. To measure the contribution of a certain shock, we activate all shocks but the one in question. We group shocks into broad categories: supply and demand.

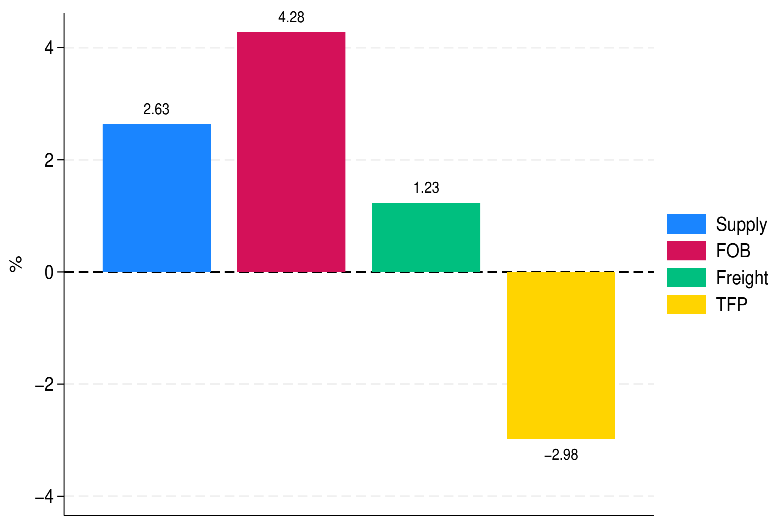
We include productivity, FOB price, and freight cost shocks in the supply shocks category. In the demand shocks category, we include impatience, foreign demand, and exchange rate shocks.

Relevance of freight cost shocks. To measure the contribution of freight cost shocks to inflation, we decompose the importance of each supply shock to the total contribution of supply shocks to inflation. Hence, we directly measure the contribution of TFP, FOB prices, and freight cost shocks.

In Figure 4, we display the results of this analysis. We can observe that freight cost shocks are not the most important contributor to the total effect on inflation of supply shocks. The explanation is that freight costs constitute, on average, around 5-7 percent of total CIF import value. Regarding its contribution to inflation, freight cost shocks explain approximately 13.3 percent of inflation in the model. This highlights the magnitude of the disruption to international trade during this period, because even though the importance of freight costs on total import costs could be considered low, shocks to them still amount to a relevant portion of the inflation figure.

The contribution of freight costs is 1.8 log points lower than the one found in Section 3.3, in the partial equilibrium analysis. This is due to labor demand being lower when freight costs go up, as firms produce less in response to a higher cost schedule. A lower labor demand creates a downward pressure on nominal wages, which helps to partially offset the initial impact of a higher cost of intermediates.

Figure 4: Supply Shocks and its Constituent Parts



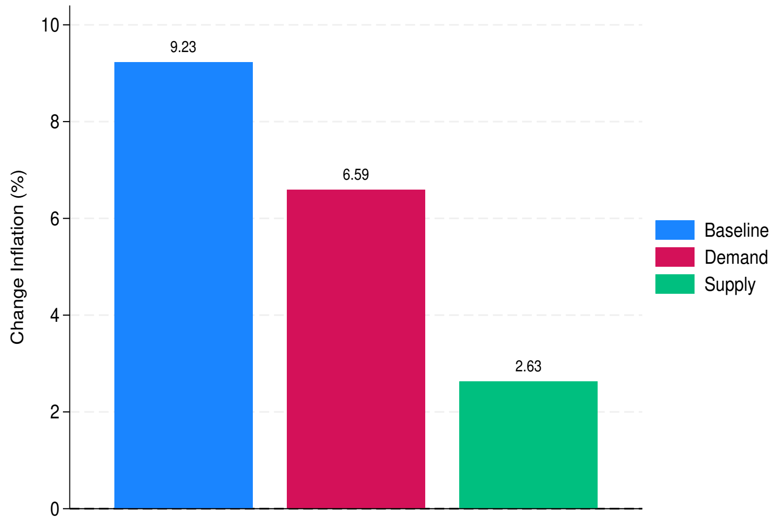
Notes: The "Supply" bar includes the total net contribution of shocks to FOB prices, freight costs and TFP.

Supply vs. Demand Shocks. To put the contribution of supply shocks to inflation in perspective, we decompose inflation during the period into the contributions of supply and demand shocks. Figure 5 shows that demand shocks play an important role in determining inflation in the model, accounting for 6.59 log points out of the total of 9.23 observed for the period, which is equivalent to 71.4. However, supply shocks are less relevant, representing 2.72 log points, or 28.5 percent, of inflation.[20]

The intuition is that an exchange rate depreciation, such as the one present in the period under analysis, increases the value of present consumption and induces households to substitute away from foreign consumption goods for domestic ones. This movement pushes up the demand for domestic production above and beyond the general expenditure increase induced by the change in relative prices over time. Supporting this force are the impatience and foreign demand shocks, which boost current domestic consumption

[20] As it was explained in Section 4.1.5, the analysis performed in this article only discusses responses to supply and demand shocks net of exchange rate movements. It might well be the case that a very large share of the responses to exchange rate movements are due to changes in exchange rates induced by demand shocks. This is actually the narrative put forward by the Central Bank of Chile, as it can be noted in its June 2022 Monetary Policy Report https://www.bcentral.cl/en/content/-/details/monetary-policy-report-june-2022

Figure 5: Decomposition of Inflation

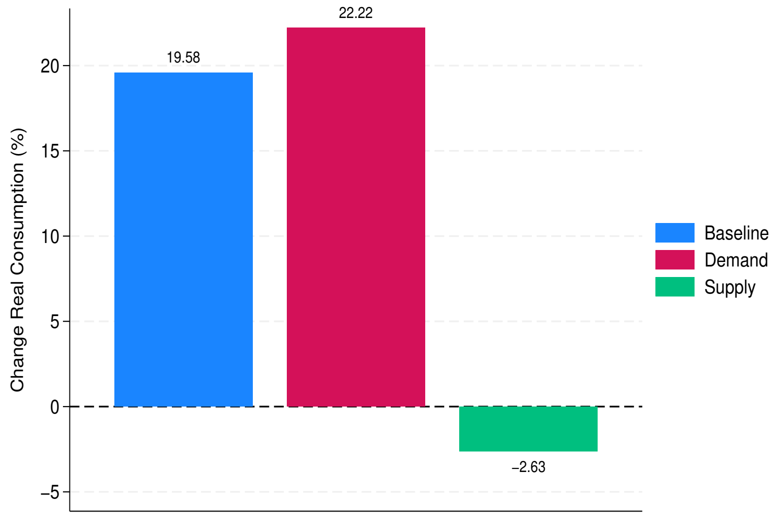


Notes: The "Baseline" bar includes demand and supply shocks. The "Demand" bar includes impatience, foreign demand, and exchange rate shocks. The "Supply" bar includes FOB price, freight cost, and TFP shocks.

and add foreign pressure over domestic production. Local firms respond in part by increasing prices. Supply shocks explain a less relevant portion of inflation in spite of their large size by historical standards. There are two reasons for this lower importance. First, although FOB price and freight cost shocks were large, firms had room to substitute away from more expensive origins toward relatively cheaper ones, cushioning in this way the impact of foreign shocks on the USD cost of the intermediate input bundle. Second, firm productivity increased during this period, which partially offset inflationary pressures by reducing costs.

For real consumption, the situation is similar. Figure 6 shows that demand shocks explain almost all the observed inflation, and supply shocks contribute negatively to the total. The intuition behind this result is as follows. On the one hand, exchange rate depreciation reduces the real interest rate, which should in part increase real consumption, although it should make goods more expensive. The prices of foreign consumption goods are affected one-to-one due to the law of one price assumption, while domestic consumption goods face higher costs due to imported intermediates. As the direct effect on foreign consumption goods gets passed through to households more directly than via domestic goods, there is a reallocation of consumption towards domestic goods, which also helps to sustain real production and income. Again, this process is reinforced by the increase in demand that comes from the lower impatience of households and the larger foreign de-

Figure 6: Decomposition of Real Consumption



Notes: The "Baseline" bar includes demand and supply shocks. The "Demand" bar includes impatience, foreign demand, and exchange rate shocks. The "Supply" bar includes FOB price, freight cost, and TFP shocks.

mand. Supply shocks, in this case, have the opposite effect of demand shocks. With the exception of TFP shocks, they increase costs for firms, leading to lower production. The total effect is much less relevant in magnitude than for demand shocks due to substitution effects and the higher productivity observed in this period.

5 Conclusions

We contribute to the understanding of the impact that pandemic-induced disruptions to global trade logistics had on domestic inflation. We document that importers faced a steep rise in freight costs from 2019-2021, and we show that imports from China and other Asian countries primarily drove this rise. The extent to which the negative shock affects firms depends on their ability to substitute imports away from the most affected regions. Leveraging the idiosyncratic exposure of firms to changes in freight costs among different origins, we implement an instrumental variable approach to estimate the elasticity of substitution across imported intermediate inputs from different regions. Our point estimate suggests that a one percentage point increase in an input's relative price reduces its relative demand by roughly four percentage points.

We use a parsimonious small open economy general equilibrium model featuring nominal rigidities to quantify the role that freight costs had over inflation during the period. We consider five regions of the world as foreign sources of intermediate goods and an imperfect degree of substitutability across goods from each region. We do counterfactual exercises through which we estimate that freight costs can explain 13.3 percent of CPI inflation. The significant size of the change in freight costs that occurred during 2019-2021 causes these shocks to play a non-trivial role in the revival of inflation. The joint occurrence of these perturbations with those of FOB price shocks accounts for more than half of the period's inflation, highlighting how disruptive the pandemic-induced perturbations to global trade were to macroeconomic conditions.

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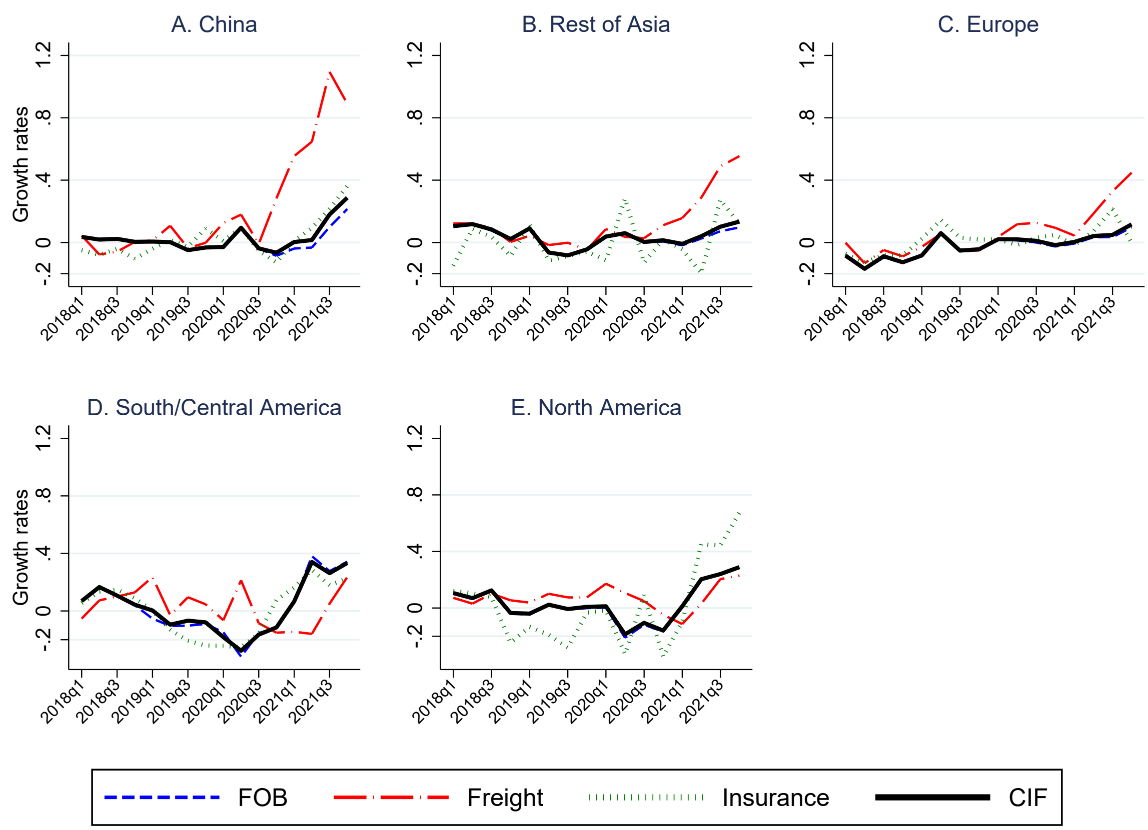
"Freight Costs and Substitution Among Import Regions: Implications for Domestic Prices"

by Gustavo González, Emiliano Luttini, and Marco Rojas

Online Appendix

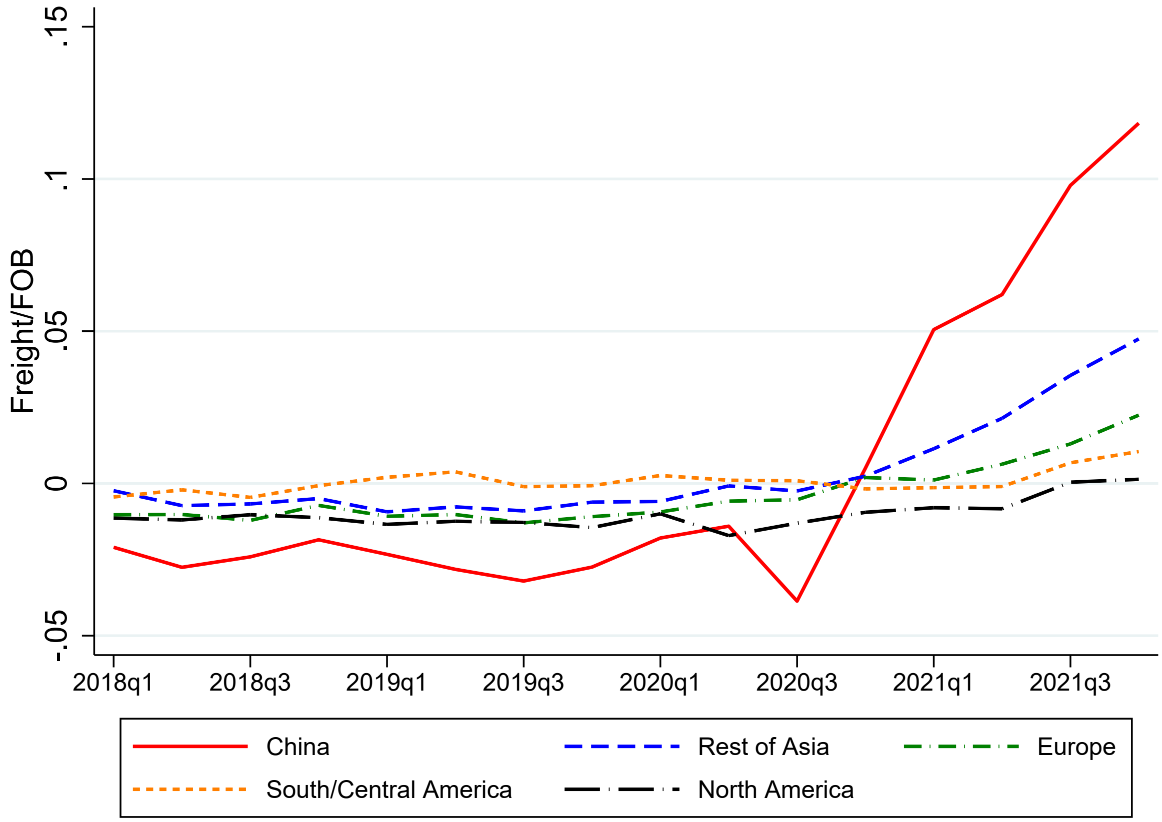
A Additional tables and figures

Figure A.1: Growth rates of CIF and its components – Quarterly, by region



Notes: This figure plots the absolute contribution each component of CIF has on its annual growth rate.

Figure A.2: Freight/FOB residuals by region



Notes: This figure plots region of origin-time fixed effects from the regression: $r_{ijkt} = \lambda_{kt} + \lambda_{it} + \lambda_{jt} + \varepsilon_{ijkt}$, where k is the region of origin, i the firm, j the product at HS8 code, and $r_{ijkt} = \text{Freight}_{ijkt}/\text{FOB}_{ijkt}$.

Table A.1: Estimates of (6) using HS4

	(1) $d\log m_{ihkt}$	(2) $d\log p^{CIF}_{ihkt}$	(3) $d\log m_{ihkt}$
$d\log p^{CIF}_{ihkt}$	-0.990***		-4.517***
	(0.007)		(0.593)
B_{ihkt}		0.307**	
		(0.052)	
N	260,382	260,382	260,382
R^2	0.434	0.0864	.
Firms	11,358	11,358	11,358
1st-stage F		35.12	

Notes: The table presents estimates for (6) when product is defined at the HS4 level. Column 1 reports the OLS estimate. Column 2 is the first-stage of an IV regression, where the instrument is defined in (9). Column 3 is the IV estimate. All specifications include firm, a product-time and region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2: Estimates of (6) with alternative specification

	(1) $d\log m_{ijkt}$	(2) $d\log p^{CIF}_{ijkt}$	(3) $d\log m_{ijkt}$
$d\log p^{CIF}_{ijkt}$	-1.020***		-5.553***
	(0.010)		(0.962)
B_{ihkt}		0.272***	
		(0.055)	
N	312,498	312,498	312,498
R^2	0.457	0.162	.
Firms	9,202	9,202	9,202
1st-stage F		24.64	

Notes: This table presents estimates for a modified (6): $d\log m_{ijkt} = \lambda_{it} + \lambda_{jt} + \lambda_k - \epsilon d\log p^{CIF}_{ijkt} + \varepsilon_{ijkt}$. Column 1 reports the OLS estimate. Column 2 is the ffirst-stage of an IV regression where the instrument is defined in (9). Column 3 is the IV estimate. All specifications include a firm-time, product-time and region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3: Estimates of (10) using HS4

	(1)	(2)	(3)
	$d\log p_{ijkt}^{FOB}$	$d\log \tau_{ijkt}$	$d\log p_{ijkt}^{FOB}$
$d\log \tau_{ijkt}$	0.506***		-0.0454
	(0.005)		(0.035)
B_{ihkt}		1.460 ***	
		(0.066)	
N	260,382	260,382	260,382
R^2	0.463	0.185	.
Firms	11,358	11,358	11,358
1st-stage F		259.6	

Notes: This table presents estimates for (10) when product is defined at the HS4 level. Column 1 reports the OLS estimate. Column 2 is the first stage of an IV regression, where the instrument is defined in (9). Column 3 is the IV estimate. All specifications include firm, product-time, and region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: Estimates of (10) with alternative specification

	(1)	(2)	(3)
	$d\log p_{ijkt}^{FOB}$	$d\log \tau_{ijkt}$	$d\log p_{ijkt}^{FOB}$
$d\log \tau_{ijkt}$	0.457***		-0.0649
	(0.007)		(0.039)
B_{ihkt}		1.495 ***	
		(0.085)	
N	312,498	312,498	312,498
R^2	0.473	0.272	.
Firms	9,202	9,202	9,202
1st-stage F		308.7	

Notes: This table presents estimates for a modified (10): $d\log p_{ijkt}^{FOB} = \lambda_{it} + \lambda_{jt} + \lambda_k + \beta d\log \tau_{ijkt} + \varepsilon_{ijkt}$. Column 1 reports the OLS estimate. Column 2 is the first stage of an IV regression where the instrument is defined in (9). Column 3 is the IV estimate. All specifications include a firm-time, product-time and region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

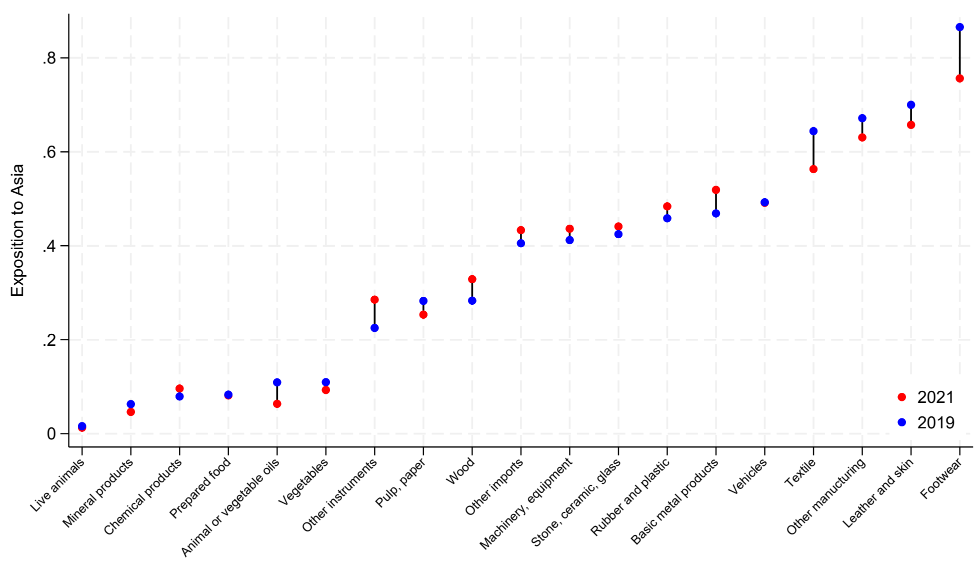
B Sectoral and product evidence

In this Appendix Section we show what products are more exposed to Asia, and potentially more affected by the freight cost shocks documented in this paper. The level of aggregation we consider for products is at the Section level of the HS classification.[21] For each Section, we compute the expenditure share of imports – measured by the FOB value – that come from Asia among all imports of that given Section. Figure B.1 shows this measure of exposition in 2019 and 2021. Footwear is the most exposed type of products and falls more than 10 percentage points. Something similar happens, albeit to a smaller extent, to other highly exposed products such as Leather and Textiles. Other Sections show smaller variations in their exposure or even some increase their exposure to Asia between 2019 and 2021.

Given the small variation observed in expenditure shares for certain type of products, this could be an indication that firms have Cobb-Douglas aggregators for their imported bundle. However, during this period strong preference shocks happen together with large rises in FOB price and freight costs, thus making it difficult to obtain such conclusions by just looking at expenditure shares. In Section 3.2 we use econometric techniques to disentangle confounding factors, and to estimate the actual elasticity.

Next, to see the direct incidence of increased freight costs in products, we combine the exposition with the shock in the freight cost. We compute this using the difference between the ratio of Freight-to-FOB in 2021 and 2019, multiplied by the exposition levels above in 2019.[22] Figure B.2 displays this incidence measure, where no product Sections have negative effects.

Figure B.1: Changes in the exposition to Asia between 2019-2021



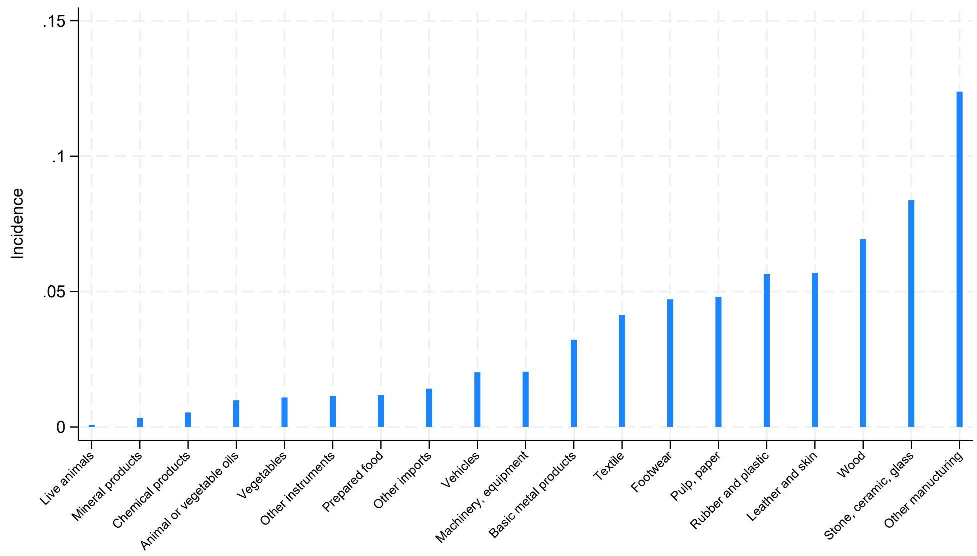
Notes: This figure plots the exposition to Asia in 2019 and 2021 for each HS Section. The measure corresponds to the imports from Asia as a share of total imports in that section.

[21]Sections for Chilean HS version are the same as the ones for the US, which are available at https://hts.usitc.gov/current.

[22]In practice, for each section j we combine the share and the shift or shock:

$$\frac{\text{FOB}_{2019,j,\text{Asia}}}{\text{FOB}_{2019,j,Asia} + \text{FOB}_{2019,j,\text{Rest of the world}}} \times \left(\frac{\text{Fre}_{2021,j,\text{Asia}}}{\text{FOB}_{2021,j,\text{Asia}}} - \frac{\text{Fre}_{2019,j,\text{Asia}}}{\text{FOB}_{2019,j,\text{Asia}}} \right).$$

Figure B.2: Incidence of freight costs in Asia by HS Section



Notes: This figure plots the incidence to Asia between 2019 and 2021 for each HS Section. The measure is computed as $\frac{\text{FOB}_{2019,j,\text{Asia}}}{\text{FOB}_{2019,j,Asia}+\text{FOB}_{2019,j,\text{Rest of the world}}} \times \left(\frac{\text{Fre}_{2021,j,\text{Asia}}}{\text{FOB}_{2021,j,\text{Asia}}} - \frac{\text{Fre}_{2019,j,\text{Asia}}}{\text{FOB}_{2019,j,\text{Asia}}}\right)$, where j is an HS Section.

C Proof of Proposition 1

Here we present the proof of Proposition 1. Let the following cost minimization problem be the associated one with the maximization problem in (2)

$$\begin{aligned} \min_{l_i, m_{iD}, m_{iF}} \quad & wl_i + p_D m_{iD} + p_{iF}^m m_{iF}, \\ \text{s.t.} \quad & y_i = l_i^{\alpha} \left(m_{iD}^{\gamma} m_{iF}^{1-\gamma}\right)^{1-\alpha}, \end{aligned}$$

where the indirect cost function for this problem is given by:

$$CT_i = y_i \left(\frac{w}{\alpha}\right)^{\alpha} \left(\frac{p_D}{\gamma\,(1-\alpha)}\right)^{\gamma(1-\alpha)} \left(\frac{p_{iF}}{(1-\gamma)\,(1-\alpha)}\right)^{(1-\gamma)(1-\alpha)}$$

In a competitive market, a manufacturing firm equates its price to its marginal cost, resulting in:

$$p_{iD} = \left(\frac{w}{\alpha}\right)^{\alpha} \left(\frac{p_D}{\gamma\,(1-\alpha)}\right)^{\gamma(1-\alpha)} \left(\frac{p_{iF}}{(1-\gamma)\,(1-\alpha)}\right)^{(1-\gamma)(1-\alpha)}$$

Taking the logarithm and total differentiation, its rate of change is determined by the following expression

$$d\log P_{iD} = \alpha(1-\gamma) d\log P_D + (1-\alpha)(1-\gamma) d\log p_{iF}^m. \tag{C.1}$$

This is because we abstract from changes in wages.

Next, consider a competitive domestic retailer sector that aggregates domestic varieties under constant returns to scale technology. The resulting indirect cost function is:

$$CT_{Retailer} = Y \times MC\left(p_{1D}, \ldots, p_{ID}\right),$$

where Y is the retailers' aggregate production, MC its marginal cost, and I the total number of manufacturing firms. Noting that $P_D = MC\left(\exp\left(\log p_{1D}\right), \ldots, \exp\left(\log p_{ID}\right)\right)$, taking logarithms on both sides of the equation and totally differencing it results in

$$d\log P_D = \sum_i \frac{\partial \log MC\left(\exp\left(\log p_{1D}\right), \ldots, \exp\left(\log p_{ID}\right)\right)}{\partial p_{iD}} \frac{\partial p_{iD}}{\partial \log p_{iD}} d\log P_{iD},$$

after applying Shephard's lemma and some algebraic manipulation one obtains $d\log P_D = \sum_i \frac{q_{iD} p_{iD}}{Y \times MC} d\log P_{iD}$ which can be further written as

$$d\log P_D = \sum_i \frac{p_{iD} y_i}{p_D Y} d\log p_{iD}. \tag{C.2}$$

Substituting equation (C.1) into equation (C.2), and some algebraic manipulations results in

$$d\log P_D = \frac{(1-\alpha)(1-\gamma)}{1-(1-\alpha)\gamma} \sum_i \frac{p_{iD} y_i}{p_D Y} d\log p^m_{iF},$$

with $\mathbb{E}[d\log p^m_{iF}] = \sum_i \frac{p_{iD} y_i}{p_D Y} d\log p^m_{iF}$, and so we prove (i) of Proposition 1.

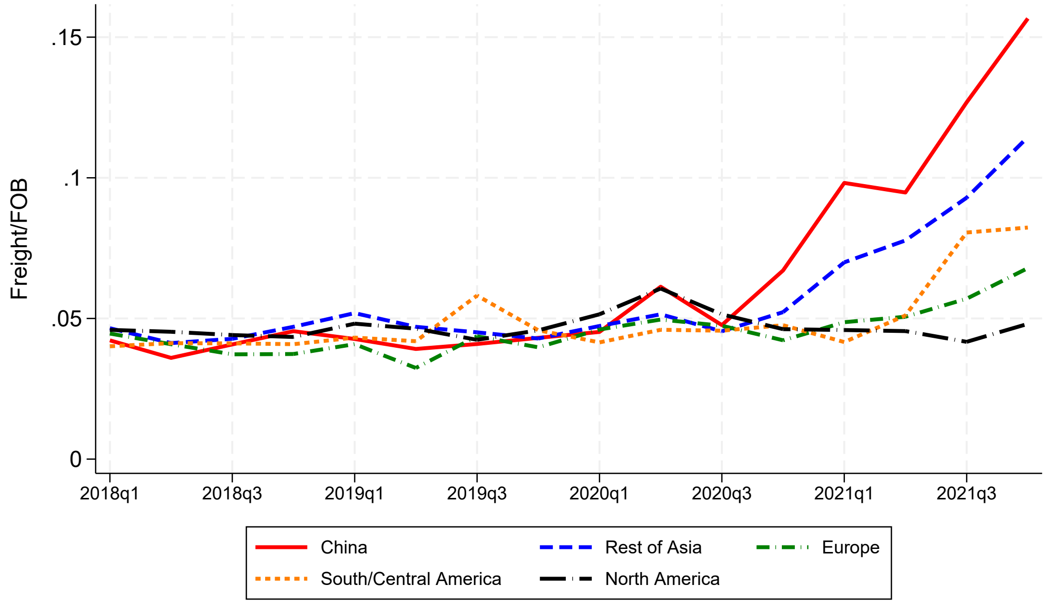
The second part of the proposition follows immediately by taking the logarithm and first-differencing the expression $\left(\frac{P_D}{\eta}\right)^{\eta} \left(\frac{P^c_F}{1-\eta}\right)^{1-\eta}$, and then substituting the above result into this expression.

D Results using Colombian freight costs

In this Appendix Section we replicate certain results using Colombian customs data, which is publicly available at https://www.dian.gov.co/dian/cifras/Paginas/Bases-Estadisticas-de-Comercio-Exterior-Importaciones-y-Exportaciones.aspx.

Figure C.1 replicates Figure 3 using Colombian data. The heterogeneous responses by regions is also shown here, and again Asian origins have a larger effect.

Figure C.1: Freight/FOB by region, Colombia



Notes: This figure plots the ratio of the total freight cost of imports to the total FOB value for each quarter, and for each importing region, using Colombian customs import data.

Table C.1 replicates Table 1, but using freight cost variations of Colombian imports when constructing the instrument instead of Chilean ones. This means replacing $d\theta_{hk,t}$ in (9) with data from Colombia, which can be structured in the same fashion. The results below confirm our baseline estimates for the elasticity of substitution. Similarly, Table C.2 replicates Table 2, and again the results of full pass-through from freight costs to CIF prices are unaffected by using these shocks.

Table C.1: Elasticity of substitution estimates using Colombian shocks

	(1) $d\log m_{ijkt}$	(2) $d\log p^{CIF}_{ijkt}$	(3) $d\log m_{ijkt}$	(4) $d\log m_{ijkt}$
$d\log p^{CIF}_{ijkt}$	-1.024***		-3.331***	-4.135***
	(0.009)		(0.449)	(0.523)
B_{ihkt}		0.320***		
		(0.052)		
Shocks	.	COL	COL	CHL
N	313,242	313,242	313,242	313,242
R^2	0.418	0.102	.	.
Firms	10,483	10,483	10,483	10,483
1st-stage F		37.89		

Notes: This table presents estimates for (6). Column 1 is the OLS estimate, which uses Chilean data. Column 2 is the first-stage of an IV regression, where the instrument is defined in (9) and the shocks $d\theta_{hk,t}$ are constructed from the Colombian data. Column 3 is the IV estimate using shocks from the Colombian data. Column 4 is the baseline IV estimate with the sample restricted to make it comparable to Column 3. All specifications include firm, product-time, and region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table C.2: Freight price pass-through to exports' FOB prices using Colombian shocks

	(1) $d\log p^{FOB}_{ijkt}$	(2) $d\log \tau_{ijkt}$	(3) $d\log p^{FOB}_{ijkt}$
$d\log \tau_{ijkt}$	0.451***		0.0672
	(0.006)		(0.047)
B_{ihkt}		1.025 ***	
		(0.080)	
N	313,242	313,242	313,242
R^2	0.431	0.206	.
Firms	10,483	10,483	10,483
1st-stage F		165.4	

Notes: This table presents estimates for (10). Column 1 reports the OLS estimate using Chilean data. Column 2 is the first-stage of an IV regression, where the instrument is defined in (9) and the shocks $d\theta_{hk,t}$ are constructed from the Colombian data. Column 3 is the IV estimate using shocks from the Colombian data. All specifications include a firm, product-time, region fixed effects. Standard errors clustered at the firm level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

E Calibration

We set the nominal rigidity parameters to bi-annual analogs of quarterly values found in estimated models in the DSGE literature, such as those in Smets and Wouters (2003) and Christiano et al. (2005). Specifically, we choose a value of 0.25 for ϱ_C and of 0.17 for ϱ_L, which are, respectively, equivalent to 0.93 and 0.80 at quarterly frequency. The price rigidity number corresponds to that estimated with the model without variable capital utilization in Christiano et al. (2005), while the wage rigidity value corresponds to that estimated in the model with no habit formation in the same paper.[23]

We choose the value of 12 for the elasticity of substitution between labor varieties, σ_L. This is the average between the number used in Christiano et al. (2005) ($\sigma_L = 21$) and the one used in Smets and Wouters (2003) ($\sigma_L = 3$). Sensitivity analysis to this value does not affect the results. The Frisch elasticity of labor, ψ, is set to 3, as in Galí and Monacelli (2005). We assign the value of 6 to the elasticity of substitution between good varieties, σ_C, in order to rationalize a markup of 1.2.

We calibrate the preference parameter for consuming domestic goods to 0.70, to reproduce the share of spending on domestic goods to total consumption expenditure. The production function parameter associated to labor, α, is set to to 0.33 in order to match the share that labor payments represent of total intermediate purchases in the 2019 Chilean national accounts. We set the value of γ to 0.78 to target the share of purchases of intermediates from domestic providers over total intermediate purchases in the same version of the national accounts. The last two statistics we take from Chilean national accounts to calibrate the model are the share that domestic consumption represents of gross production, C_D/Y, which is set to 0.4, and the share that exports represent of gross production, X/Y, which is set to 0.1.

More importantly, we set the elasticity of substitution between origins for intermediate product imports, ϵ, to the value we estimate in Section 3.2, which is 4.377.

[23] Numbers are displayed in Table 2 of Christiano et al. (2005)

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