Pandemic-induced increases in container freight rates: Assessing their domestic effects in a globalized world

José Pulido[1]

[1]Banco de la República - Colombia

XII BIS CCA Research Conference
Mexico, November 17

Introduction

- The Covid-19 pandemic disrupted the maritime international transportation industry, making container freight rates to skyrocket since late 2020
- I evaluate the macroeconomic effects of the observed increases in container freight rates all around the world on a particular country (Colombia)

Introduction

- The Covid-19 pandemic disrupted the maritime international transportation industry, making container freight rates to skyrocket since late 2020
- I evaluate the macroeconomic effects of the observed increases in container freight rates all around the world on a particular country (Colombia)
- For this, I use a quantitative model of international trade with a rirch set of features:
  - 40 countries, 33 sectors, input-output linkages, frictions to labor mobility, out-of-steady-state transitional dynamics;
  - Transportation costs depend on freights:
    - I estimate a trade elasticity to freights, using an IV estimator that takes advantage of metrics of quality of port infraestructure and the heterogeneous timing of the lockdowns

Overview of results

- I find that the observed increases in container freight rates worldwide caused:
  - Inflationary impact: Average increase of 2.4% in total annual inflation between 2020Q2 and 2022Q2 (4.2% for tradable goods; 1.8% for non-tradable goods)
  - Moderate reallocation of workers:
    - 0.12% of workers (28.6K) move towards non-employment
    - Within employment, reallocation towards non-tradable sectors
  - Welfare impact: Decrease of 1.3%

Overview of results

- I find that the observed increases in container freight rates worldwide caused:
  - Inflationary impact: Average increase of 2.4% in total annual inflation between 2020Q2 and 2022Q2 (4.2% for tradable goods; 1.8% for non-tradable goods)
  - Moderate reallocation of workers:
    - 0.12% of workers (28.6K) move towards non-employment
    - Within employment, reallocation towards non-tradable sectors
  - Welfare impact: Decrease of 1.3%
- By dividing the increases in freights into a subset that includes increases only for Colombian imports/exports and a subset that includes all remaining freights:
  - Inflationary impact is 79% due to remaining freights, pointing towards the importance of global trade networks
  - Reallocation of labor is moderate because each set of shocks triggers opposing forces to relative real wages

Related literature

- **Ricardian trade models with out-of-steady-state transitional dynamics:** Caliendo, Dvorkin and Parro (2019), Rodríguez-Clare, Ulate and Vásquez (2020), Dix-Carneiro et al. (2020), Caliendo et al. (2021)
- **Estimation of trade elasticities to transportation costs:** Limão and Venables (2001), Martínez-Zarzoso and Suárez-Burguet (2005) Jacks and Pendakur (2010), Shapiro (2016), Fraser (2018).
- **Maritime transportation during the Covid-19 pandemic:** Heiland and Ulltveit-Moe (2020*a*),Heiland and Ulltveit-Moe (2020*b*), UNCTAD (2021)
- **Assessing inflation / consumption / sectoral employment effects of the Covid-19 pandemic in Colombia:** Alfaro, Becerra and Eslava (2020), Bonilla-Mejía et al. (2022), Morales et al. (2022).

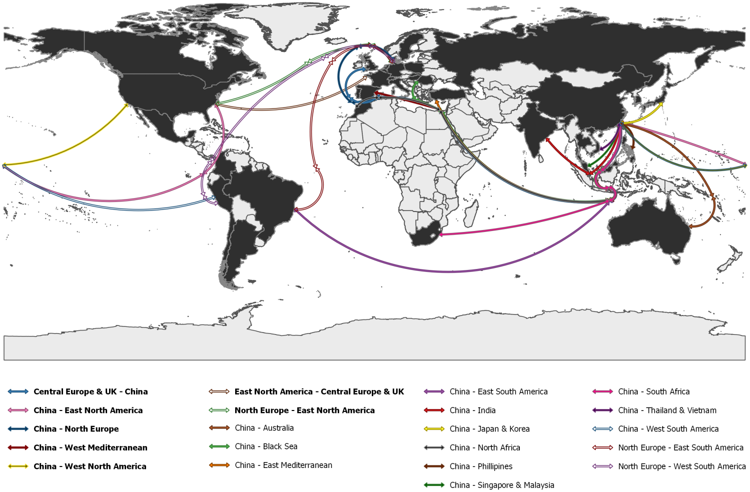
Outline

1. Motivation
2. A dynamic model of international trade
3. Solving the model
4. Results

Table of Contents

Available routes with time series of container freight rates

- I collect time series of container freight rates for more than 30 different routes all around the world from 3 different data providers*



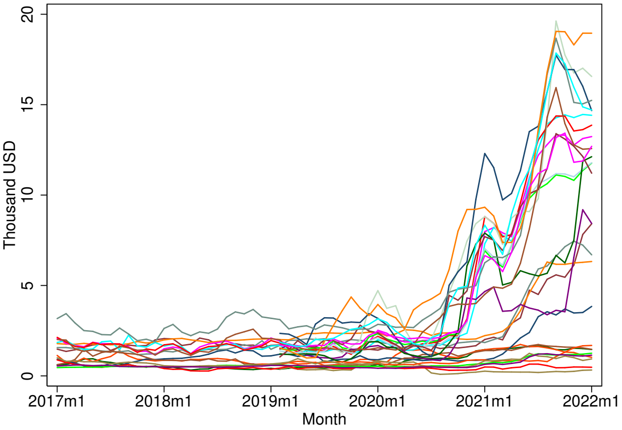
Note: Freights for routes in bold are available in both directions

*Drewry, Freightos and Ningbo container indexes, that collect information for spot carry rates (all reported in USD per forty foot container) from different freight forwarders.

Container freight rates during the pandemic

- Container freight rates exhibit a notorious increase, starting by late 2020

Figure: Container freight rates during the Covid-19 Pandemic*

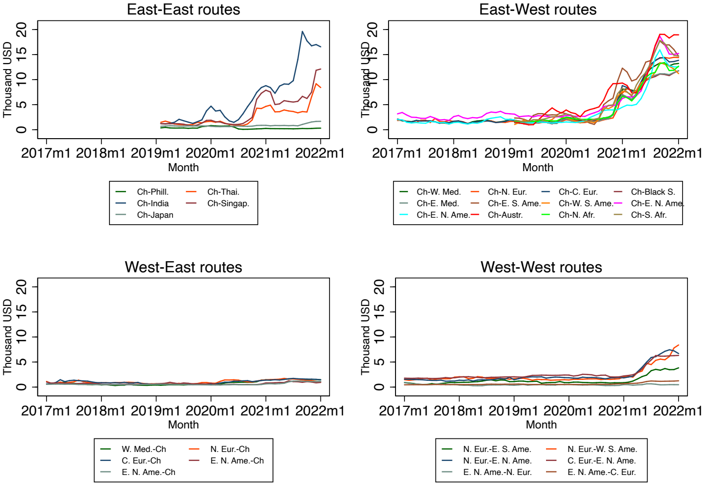


*All rates are reported in USD per forty foot container. Source: Drewry, Freightos and Ningbo indexes.

Heterogeneous increases in container freight rates

- The increases are heterogeneous, and more notorious in the routes departing from the East (Asia)

Figure: Container freight rates by west/east direction*



*All rates are reported in USD per forty foot container. Source: Drewry, Freightos and Ningbo indexes.

Challenge for quantitative trade models

- Standard approach relies on modeling consumer prices of a good of sector j in country n originated in country i in time t as:

$$p_t^{ni,j} = \left(1 + \tau_t^{ni,j}\right) \psi^{ni,j} p_t^{i,j}$$

where $\psi^{ni,j} > 1$ is the (iceberg) transportation cost component, $\tau_t^{ni,j}$ is the ad-valorem tariff on the CIF price and $p_t^{i,j}$ is the before-duty and transport-cost price at country i's border (FOB price).

Challenge for quantitative trade models

- Standard approach relies on modeling consumer prices of a good of sector j in country n originated in country i in time t as:

$$p_t^{ni,j} = \left(1 + \tau_t^{ni,j}\right) \psi^{ni,j} p_t^{i,j}$$

  where $\psi^{ni,j} > 1$ is the (iceberg) transportation cost component, $\tau_t^{ni,j}$ is the ad-valorem tariff on the CIF price and $p_t^{i,j}$ is the before-duty and transport-cost price at country i's border (FOB price).

- Usually $\psi^{ni,j}$ is unobservable and is modeled as a function of distance (e.g. Hummels, 2007; Fontagné, Guimbard and Orefice, 2022), or as a set of time-invariant characteristics of the country-pair relation, or as an exporter-importer fixed effect
- But during the pandemic,
  - Transportation costs are time-variant
  - Even in a cross-section the distance effect is asymmetric between West-East inbound/outbound routes

Modeling transportation costs as function of freight

- I make $\psi^{ni,j}$ time-variant and use observable container freight rates from country i to n (F_t^{ni}) to inform the model about its evolution
- Particularly, I assume:

$$\psi_t^{ni,j} = \Upsilon^{ni,j} \left(F_t^{ni} \right)^{\rho_F^j} \varepsilon_t^{ni,j} \tag{1}$$

where:

- $\Upsilon^{ni,j}$ represents any time-invariant determinant of transportation costs between i and n in sector j (e.g. transactions costs due to language, etc. or the distance effect that is not accounted by freights);
- $\varepsilon_t^{ni,j}$ collapses other time-variant determinants of transportation costs apart from container freights and orthogonal to them; plus measurement errors.
- ρ_F^j is a key elasticity of transportation costs to freights, to be estimated

Table of Contents

A quantitative dynamic trade model with freight rates

- I use a standard quantitative model of international trade that features:
  - Multiple countries and sectors and an input-output structure as in Caliendo and Parro (2015)
  - Consumers deciding in which sector supply their labor in order to maximize their lifetime utility, subject to idiosyncratic shocks and barriers to mobility across sectors, as in Caliendo, Dvorkin and Parro (2019)
- Building on those frameworks, I model international trade costs as in equation (1) ▸ Model

Table of Contents

Strategy

- I use the dynamic version of "exact hat algebra" (DEH, developed by Caliendo, Dvorkin and Parro, 2019), to solve the model (in relative time differences - RTD) and to evaluate counterfactuals.

Strategy

- I use the dynamic version of "exact hat algebra" (DEH, developed by Caliendo, Dvorkin and Parro, 2019), to solve the model (in relative time differences - RTD) and to evaluate counterfactuals.
- **Strategy:**
  1. Construct a baseline economy starting in an observed pre-pandemic period and whose fundamentals (productivities, frictions, other transp. costs) evolve according a given assumption (constant fundamentals)
     - Model is solved in RTD ▸ Solution: do not need to know the "levels" of the fundamentals

Strategy

- I use the dynamic version of "exact hat algebra" (DEH, developed by Caliendo, Dvorkin and Parro, 2019), to solve the model (in relative time differences - RTD) and to evaluate counterfactuals.
- **Strategy:**
  1. Construct a baseline economy starting in an observed pre-pandemic period and whose fundamentals (productivities, frictions, other transp. costs) evolve according a given assumption (constant fundamentals)
     - Model is solved in RTD ▸ Solution: do not need to know the "levels" of the fundamentals
  2. Construct a counterfactual economy in which the only change wrt the baseline is the shock in the economy
     - Model is solved in double differences (RTD baseline vs RTD counterfactual) ▸ Solution
     - Only need the relative change in transportation costs:

$$\frac{\left\{\frac{\psi_t^{ni,j}}{\psi_{t-1}^{ni,j}}\right\}_{t=1,counterfactual}^{\infty}}{\left\{\frac{\psi_t^{ni,j}}{\psi_{t-1}^{ni,j}}\right\}_{t=1,baseline}^{\infty}} = \left\{\frac{\left(F_t^{ni}\right)^{\rho_F^j}}{\left(F_{t-1}^{ni}\right)^{\rho_F^j}}\right\}_{t=1}^{\infty}$$

Strategy

- I use the dynamic version of "exact hat algebra" (DEH, developed by Caliendo, Dvorkin and Parro, 2019), to solve the model (in relative time differences - RTD) and to evaluate counterfactuals.
- **Strategy:**
  1. Construct a baseline economy starting in an observed pre-pandemic period and whose fundamentals (productivities, frictions, other transp. costs) evolve according a given assumption (constant fundamentals)
     - Model is solved in RTD ▸ Solution: do not need to know the "levels" of the fundamentals
  2. Construct a counterfactual economy in which the only change wrt the baseline is the shock in the economy
     - Model is solved in double differences (RTD baseline vs RTD counterfactual) ▸ Solution
     - Only need the relative change in transportation costs:

$$\frac{\left\{ \frac{\psi_t^{ni,j}}{\psi_{t-1}^{ni,j}} \right\}_{t=1, counterfactual}^{\infty}}{\left\{ \frac{\psi_t^{ni,j}}{\psi_{t-1}^{ni,j}} \right\}_{t=1, baseline}^{\infty}} = \left\{ \frac{\left(F_t^{ni}\right)^{\rho_F^j}}{\left(F_{t-1}^{ni}\right)^{\rho_F^j}} \right\}_{t=1}^{\infty}$$

  3. Compare paths of endogenous variables between baseline and counterfactual

Estimating ρ_F^j from the gravity equation

- Taking logs of the gravity equation of the model, we obtain a reduced-form:

$$\ln X_t^{ni,j} = \delta_t^{i,j} + \delta_t^{n,j} + \delta^{ni,j} - \theta^j \rho_F^j \ln F_t^{ni} + \left(-\theta^j - 1\right) \ln \left(1 + \tau_t^{ni,j}\right) + \varepsilon_t^{ni,j} \quad (2)$$

  where we have:
  - The usual set of FE (exporter-industry-time FE, $\delta_t^{i,j}$, importer-industry-time FE, $\delta_t^{n,j}$, exporter-importer-industry FE $\delta^{ni,j}$).
  - The estimated coefficient on tariffs $\left(1 + \tau_t^{ni,j}\right)$ identifies $\left(-\theta^j - 1\right)$
  - The estimated coefficient on freight rates F_t^{ni} identifies $-\theta^j \rho_F^j$

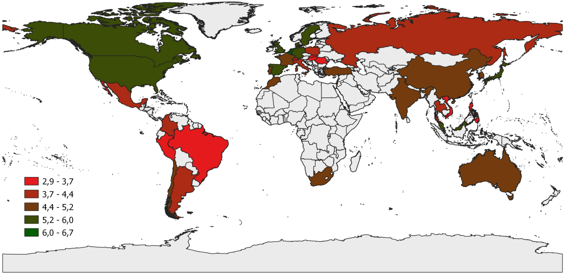
Estimating the gravity equation

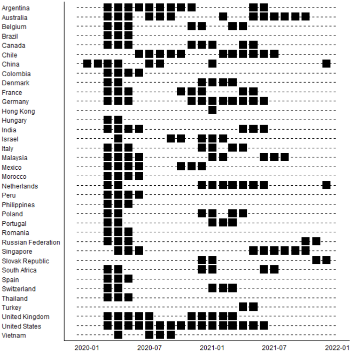
- To estimate (2) by focusing in the pandemic period and taking advantage of the temporal variation of freight rates, I use monthly trade data for the period 2017m1 to 2021m9 for a selection of 40 countries (▸ countries) and 15 tradable sectors (TiVA aggregation, ▸ sectors) that will be used in the model.
- Main identification threat: Endogeneity of freight rates to bilateral flows
  - For dealing with endogeneity, I estimate equation (2) using IV
  - The instrument is a measure that combines the pre-pandemic indexes of quality of port infrastructure (from the WB) for both countries in each country-pair, interacted with an indicator of whether both countries have lockdowns in a month.

Instrument Z_t^{ni}

$$Z_t^{ni} = PortQua_{2019}^{n} * PortQua_{2019}^{i} * \mathbb{D}_t^{ni}, \;\; with\; \mathbb{D}_t^{ni} \begin{cases} 0 & n \wedge i \; are\; in\; lockdown\; in\; t \\ 1 & otherwise \end{cases}$$

Left: $PortQua_{2019}^{n}$: Quality of port infrastructure (WB) - **Right:** Timing of lockdowns for $\mathbb{D}_t^{ni}$





Baseline results

	$\Upsilon^{ni,j}$ = **Exp x Imp x Ind FE**		
	IV	First stage	Reduced form
Dependent variable	ln(Trade)	ln(Freight)	ln(Trade)
ln(Freight)	-1.035**		
	(0.508)		
Instrument		-0.014***	0.014**
		(0.001)	(0.007)
Importer x Industry x Time FE	Yes	Yes	Yes
Exporter x Industry x Time FE	Yes	Yes	Yes
Exporter x Importer x Industry FE	Yes	Yes	Yes
Observations	80,787	80,787	80,787
F first stage (Kleibergen-Paap)		101.0	

*The regression control for tariffs. Industries where tankers or bulk dry ships are the main trasportation modes are excluded (oil, chemicals, pharmaceutical, and agriculture/food). Heteroskedasticity robust errors in parentheses.
* p<0.1, ** p<0.05, *** p<0.01

Clustered SE | OLS | LPM | PPML (rf)

Combining the estimated $\hat{\beta}_F$ with the elasticities θ^j estimated at the HS-6dig product-level and aggregated for the same 15 sectors by Fontagne et al. (2022) (elasticities), I obtain ρ_F^j.

Table of Contents

Setup and data requirements

Setup:

- 40 regions: 39 countries + RoW (▸ regions)
- 33 sectors: non-employment + 15 trad. + 17 non-trad. (▸ sectors)
- Baseline economy: Period 0 = 2018, $Q4$ (2018 last IO data)
- Counterfactual constructed using $\left\{ \frac{\left(F_t^{ni}\right)^{\rho_F^j}}{\left(F_{t-1}^{ni}\right)^{\rho_F^j}} \right\}_{t=2019,Q1}^{2021,Q3}$ and 1 hereafter

Setup and data requirements

Setup:

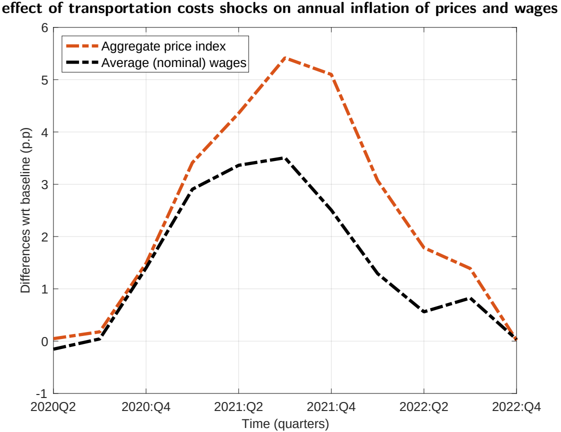
- 40 regions: 39 countries + RoW (▸ regions)
- 33 sectors: non-employment + 15 trad. + 17 non-trad. (▸ sectors)
- Baseline economy: Period 0 = 2018, $Q4$ (2018 last IO data)
- Counterfactual constructed using $\left\{ \frac{\left(F_t^{ni}\right)^{\rho_F^j}}{\left(F_{t-1}^{ni}\right)^{\rho_F^j}} \right\}_{t=2019,Q1}^{2021,Q3}$ and 1 hereafter

Data requirements:

- $\left\{ L_{2018}^{Col,j}, \mu_{2017}^{Col,jk} \right\}$: From GEIH (Colombia's household survey) + transition probabilities (2017-2018) from PILA (administrative data). Sample is limited to 25-65 years old individuals ($\approx 23'8$ individuals)
- $\left\{ \pi_{2018}^{ni,j}, X_{2018}^{n,j} \right\}$: Constructed from ICIO tables-TiVA
- Coefficients/parameters:
  - That match exactly the data in 2018:
    - I-O coefficients ($\gamma^{n,jk}$) and VA shares ($\gamma^{n,j}$): From ICIO-TiVA
    - Share of structures in value added (ξ^n): From PWT
  - Calibrated (from literature):
    - Trade elasticities (θ^j) from Fontagné et al (2022) (▸ elasticities)
    - Discount factor $\beta = 0.99$ & mobility elasticity $\nu = 5.34$ (from CDP).

Results: Inflationary impacts (I)

- The impact on the annual growth of the Colombian aggregate price index is on average 2.4%, between the start of the pandemic (2020Q2) and the end of 2022
- Nominal wages also increase, but in a lesser extent than prices

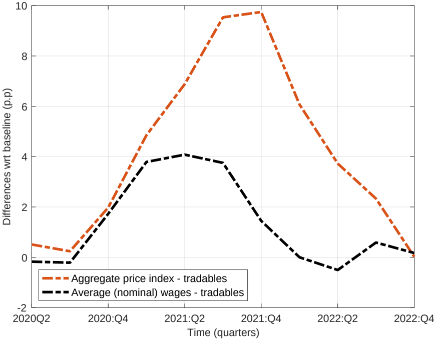


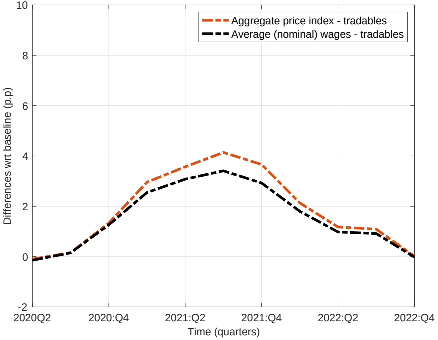
Notes: The Figure shows the impact on the annual growths of the Colombian aggregate price index and average wages (weigthed by initial labor shares), defined as the difference between its values in the counterfactual and in the baseline.

Results: Inflationary impacts (II)

- Naturally, the aggregate impact is led by larger increases in inflation of tradable goods (4.2% on average); however, given I-O linkages, there are non-negligible increases in prices of non-tradable goods (1.8% on average)

Effect of transportation costs shocks on annual inflation of prices and wages: Tradables (Left) vs non-tradables (Right)

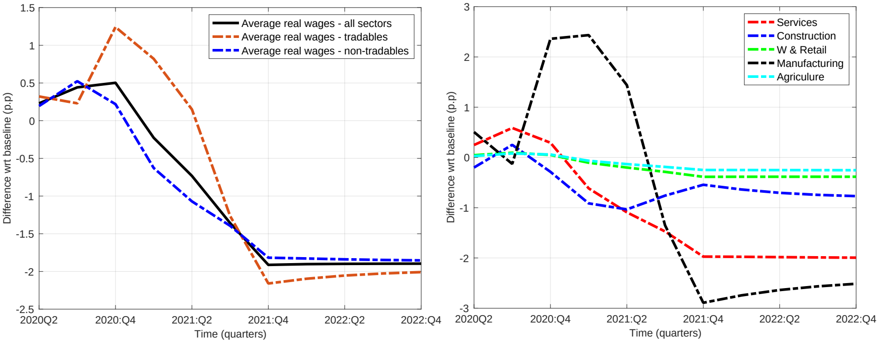




Results: Real wages

- Real wages decrease in both tradable and non-tradable sectors. Real wages in manufacturing display the largest losses.

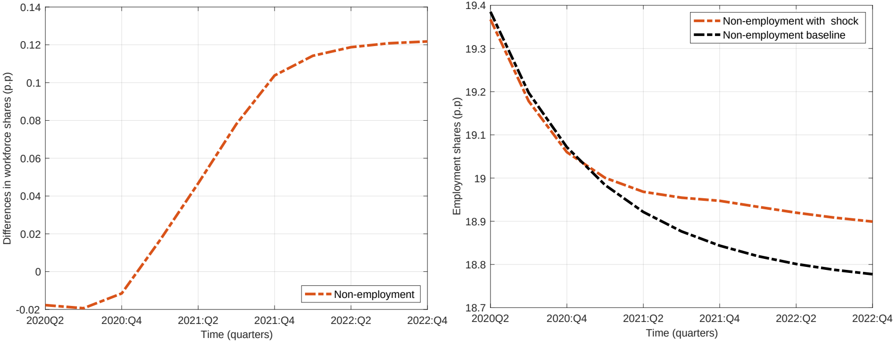
Effect of transportation costs shocks in the levels of real wages



Results: Employment reallocation effects (I)

- The shock lead to 0.12% of the individuals (28.6K) to move towards non-employment (LEFT)
- Given the stronger decreasing trend in the baseline economy (RIGHT), the impact is somewhat moderate.

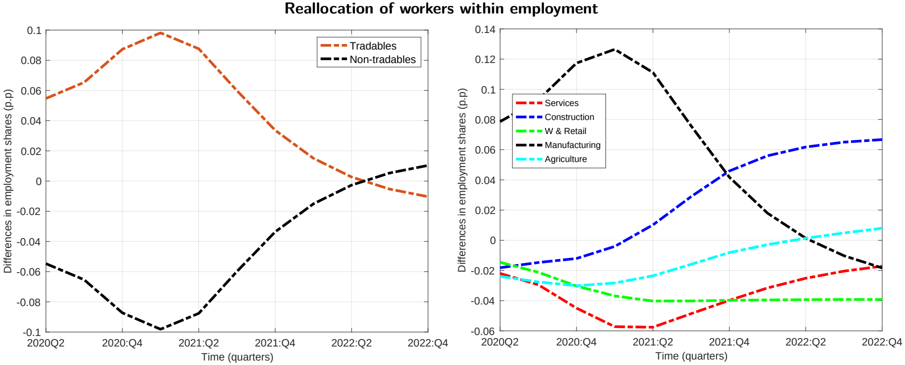
Reallocation of workers towards non-employment



Notes: LEFT: impact on the share of workers in non-employment. RIGHT: Paths of the share of workers in non-employment in the baseline and the cunterfactual economies

Employment reallocation effects (II)

- Within employment, there is reallocation towards non-tradable-sectors, particularly construction, but the impact is moderate.



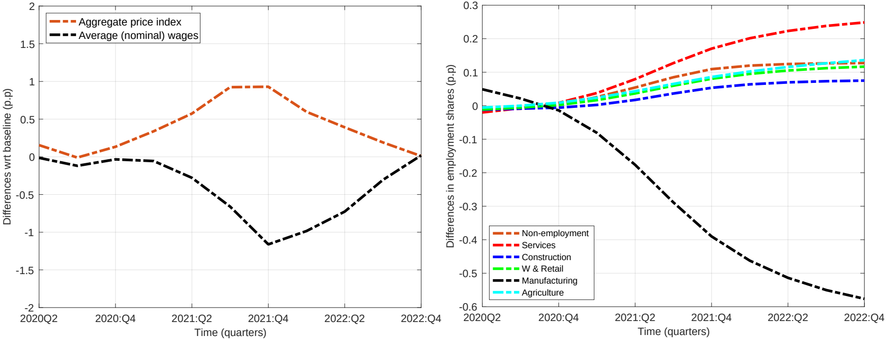
Disentangling channels

- To understand the importance of global trade networks and the mechanisms behind the latter results, I divide the full set of shocks into a subset that includes shocks only for Colombian imports/exports, and other with all remaining freights

Disentangling channels: Freights only for Colombian trade

- If container freights increase **only for Colombian imports and exports**, the average impact on inflation is only 0.4%. The job loss would have been similar (0.13%), but there is a larger reallocation towards non-tradables (0.6%): Colombia moves towards autarky.

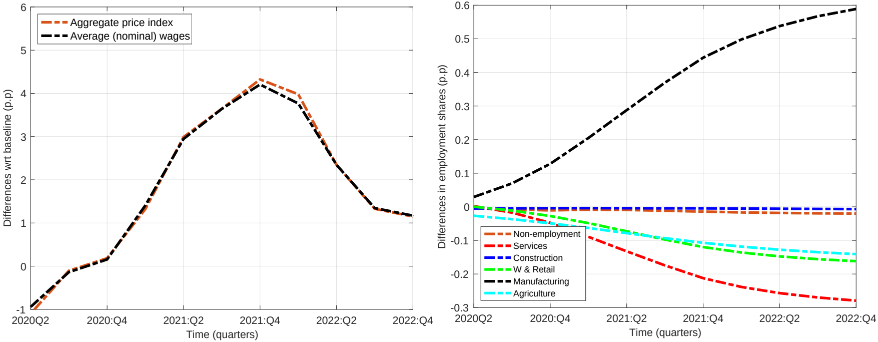
Nominal impacts (LEFT) and job losses (RIGHT) for shock on freights only for Colombian exports/imports



Disentangling channels: Worldwide freights (except Col)

- Instead, if **freights would have increased worldwide except for Colombian trade** (making Colombia relatively more open), the model delivers an impact on price inflation of 1.9% on average (79% of the full impact), negligible job gains (0.01%) and an expansion of the tradable sector, 0.6%.

Nominal impacts (LEFT) and job losses (RIGHT) for shock on worlwide freights except for Colombian exports/imports



Real consumption - welfare

- A model-consistent measure of change in welfare can be computed as the present discounted value of the expected change in real consumption (relative to the change in the workers' option value, $\hat{\mu}^{n,jj}$):

$$\hat{Welfare}^{Col,j} = \sum_{t=1}^{\infty} \beta^t \ln \left(\frac{\hat{C}_t^{Col,j}}{(\hat{\mu}^{Col,jj})^{\nu}} \right) \tag{3}$$

- Evaluating equation 3 by weighting by the initial share of workers in each sector j, the decrease in welfare related to the worldwide transportation cost shock is 1.35%.

Robustness checks

- Changes in calibrated parameters:
  - (inverse of) Sectoral reallocation elasticity ν go
  - Discount factor β

Conclusions

- By using a quantitative model of international trade with rich features the g.e. effects of the increases in freight rates can be evaluated in a comprehensive way
  - Key input: Trade elasticity to freights - Empirical strategy takes advantage of the heterogeneous timing of the lockdowns during the pandemic
- Several aspects are still under exploration...(current agenda):
  - Checking robustness of trade elasticity to freights by using Colombian custom data (disadvantage: only one importer; advantage: exact freights at the transaction-level)
  - Simultaneous country-pair general lockdowns could still be problematic for exclusion restriction: Moving towards measures of port-specific restrictions would improve identification (e.g. crew-change, see Heiland and Ulltveit-Moe, 2020*b*)
  - Explore consequences of paths of normalization of freights

References

Alfaro, Laura, Oscar Becerra, and Marcela Eslava. 2020. "EMEs and COVID-19: Shutting Down in a World of Informal and Tiny Firms." National Bureau of Economic Research Working Paper 27360.

Bonilla-Mejía, Leonardo, Juan Esteban Carranza, Mariana Fuentes, Felipe González, Stiven Perez, and Mauricio Villamizar-Villegas. 2022. "Covid-19 y consumo de los hogares: hechos estilizados a partir de datos del Grupo Éxito." In *Covid-19 consecuencias y desafíos en la economía colombiana. Una mirada desde las universidades*. Chapter 9, 173–192. Banco de la Republica de Colombia.

Caliendo, Lorenzo, and Fernando Parro. 2015. "Estimates of the trade and welfare effects of NAFTA." *The Review of Economic Studies*, 82(1 (290)): 1–44.

Caliendo, Lorenzo, Luca David Opromolla, Fernando Parro, and Alessandro Sforza. 2021. "Goods and Factor Market Integration: A Quantitative Assessment of the EU Enlargement." *Journal of Political Economy*, 129(12): 3491–3545.

Caliendo, Lorenzo, Maximiliano Dvorkin, and Fernando Parro. 2019. "Trade and labor market dynamics: General equilibrium analysis of the China trade shock." *Econometrica*, 87(3): 741–835.

Dix-Carneiro, Rafael, Joao Paulo Pessoa, Ricardo Reyes-Heroles, and Sharon Traiberman. 2020. "Globalization, trade imbalances, and labor market adjustments." Unpublished.

Fontagné, Lionel, Houssein Guimbard, and Gianluca Orefice. 2022. "Tariff-based product-level trade elasticities." *Journal of International Economics*, 137: 103593.

Fraser, Alastair. 2018. "The Choice of Transportation Mode in International Trade." In *Essays in Environmental Economics and International Trade*. Vancouver School of Economics, University of British Columbia.

Heiland, Inga, and Karen Ulltveit-Moe. 2020*a*. "An unintended crisis in sea transportation due to COVID-19 restrictions." In *COVID-19 and Trade Policy: Why Turning Inward Won't Work*. , ed. Simon Evenett and Richard Baldwin, Chapter 11, 151–162. CEPR Press.

Heiland, Inga, and Karen Ulltveit-Moe. 2020*b*. "Cumulative COVID-19 restrictions and the global maritime network." In *Revitalising multilateralism: Pragmatic ideas for the new WTO director-general*. , ed. Simon Evenett and Richard Baldwin, Chapter 7, 109–117. CEPR Press.

Jacks, David S, and Krishna Pendakur. 2010. "Global Trade and the Maritime Transport Revolution." *The Review of Economics and Statistics*, 92(4): 745–755.

Limão, Nuno, and Anthony J. Venables. 2001. "Infrastructure, geographical disadvantage, transport costs, and trade." *The World Bank Economic Review*, 15(3): 451–479.

Martínez-Zarzoso, Inmaculada, and Celestino Suárez-Burguet. 2005. "Transport costs and trade: Empirical evidence for Latin American imports from the European Union." *Journal of International Trade and Economic Development*, 14(3): 353 – 371.

Morales, Leonardo Fabio, Leonardo Bonilla-Mejía, Jose Pulido, Luz A. Flórez, Didier Hermida, Karen L. Pulido-Mahecha, and Francisco Lasso-Valderrama. 2022. "Effects of the COVID-19 pandemic on the Colombian labour market: Disentangling the effect of sector-specific mobility restrictions." *Canadian Journal of Economics*, 55(S1): 308–357.

Rodríguez-Clare, Andrés, Mauricio Ulate, and José P. Vásquez. 2020. "New Keynesian trade: Understanding the employment and welfare effects of sectoral shocks." Unpublished.

Appendix

Model: Consumers

- Consumers decide in which sector supply their labor in order to maximize their lifetime utility $\mathrm{v}_t^{n,j}$, subject to idiosyncratic shocks ϵ_t^k and barriers to mobility across sectors m^{jk}

$$\mathrm{v}_t^{n,j} = \ln C_t^{n,j} + \max_{\{k\}_{k=0}^{J}} \left\{ \beta E\left[\mathrm{v}_{t+1}^{n,k}\right] - m^{jk} + \nu \epsilon_t^k \right\}$$

$$\text{s.t. } C_t^{n,j} \equiv \begin{cases} b^n & \text{if } j = 0 \\ w_t^{n,j} / P_t^n & \text{otherwise} \end{cases}$$

- If shocks $\epsilon_t^k \sim$ Type-I extreme value, the share of workers in n that reallocate from sector j to k in time t is:

$$\mu_t^{n,jk} = \frac{\exp\left(\beta V_{t+1}^{n,k} - m^{jk}\right)^{1/\nu}}{\sum_{h=0}^{J} \exp\left(\beta V_{t+1}^{n,h} - m^{jh}\right)^{1/\nu}}. \tag{4}$$

where $V^{n,k} \equiv E\left[\mathrm{v}_{t+1}^{n,k}\right]$ is the expected lifetime utility for working in sector k.

Firms producing varieties

- Firms produce varieties of intermediate goods using labor ($l_t^{n,j}$), structures ($h_t^{n,j}$) and materials from all sectors $\prod_{k=1}^{J}(M_t^{n,jk})^{\gamma^{n,jk}}$.
- Their productivity depends on a sectoral component ($A^{n,j}$) and a firm-specific component ($z^{n,j}$) distributed Fréchet (shape θ^j).
- Their technology is:

$$q_t^{n,j} = z^{n,j}(A_t^{n,j}(h_t^{n,j})^{\xi^n}(l_t^{n,j})^{1-\xi^n})^{\gamma^{n,j}} \prod_{k=1}^{J}(M_t^{n,jk})^{\gamma^{n,jk}}$$

Firms producing composite goods

- There are also producers of composite intermediate goods used either as materials for varieties or for final consumption.
- They purchase intermediate varieties from the lowest cost suppliers across countries; there are trade costs $\kappa_t^{in,j}$ as in (**??**).
- By solving for the price paid by those producers, standard Fréchet properties imply that the share of total expenditure in country n on goods j from market i is:

$$\pi_t^{ni,j} \equiv \frac{X_t^{ni,j}}{X_t^{n,j}} = \frac{(x_t^{i,j}\kappa_t^{ni,j})^{-\theta^j}(A_t^{i,j})^{\theta^j\gamma^{i,j}}}{\sum_{m=1}^{N}(x_t^{m,j}\kappa_t^{nm,j})^{-\theta^j}(A_t^{m,j})^{\theta^j\gamma^{m,j}}} = \frac{(x_t^{i,j}\kappa_t^{ni,j})^{-\theta^j}(A_t^{i,j})^{\theta^j\gamma^{i,j}}}{\Psi_t^{n,j}} \tag{5}$$

  with $x_t^{i,j}$ the unit price of an input bundle and $\kappa_t^{in,j}$ as in (**??**). Eq.(5) is the gravity equation, and will guide the estimation of ρ_F
- Model is closed with market clearing conditions ▸ Conditions

Market clearing conditions

- For goods (total expenditure = value of the demand for intermediates + value of the final demand):

$$X_t^{n,j} = \sum_{k=1}^{J} \gamma^{n,kj} \sum_{i=1}^{N} \pi_t^{in,k} X_t^{ik} + \alpha^j \left(\sum_{k=1}^{J} w_t^{nk} L_t^{nk} + \iota^n \chi_t \right)$$

  with $\chi_t = \sum_{i=1}^{N} \sum_{k=1}^{J} r_t^{i,k} H^{i,k}$ and ι^n is the constant share that structure renters of country n obtain from a global portfolio in which they invest their local rents (to accommodate observed trade imbalances).

- For labor (labor supply=labor demand):

$$L_t^{n,j} = \frac{\gamma^{n,j}(1-\xi^n)}{w_t^{n,j}} \sum_{i=1}^{N} \pi_t^{in,j} X_t^{i,j}$$

- For structures (structures supply=structures demand):

$$H^{n,j} = \frac{\gamma^{n,j}\xi^n}{r_t^{n,j}} \sum_{i=1}^{N} \pi_t^{in,j} X_t^{i,j}$$

Clustered SE - results (IV)

	(1) ln(Trade)	(2) ln(Trade)	(3) ln(Trade)
ln(Freight)	-1.035**	-1.035*	-1.035**
	(0.508)	(0.550)	(0.497)
Importer x Industry x Time FE	Yes	Yes	Yes
Exporter x Industry x Time FE	Yes	Yes	Yes
Exporter x Importer x Industry FE	Yes	Yes	Yes
Observations	80,787	80,787	80,787
F first stage (Kleibergen-Paap)	101.0	54.1	81.0

Notes: All regressions control for tariffs. (1) Corresponds to the baseline results. (2) Clustered standard errors at the exporter-importer-industry level in parentheses (3) Clustered standard errors at the exporter's region-importer's region-industry level in parentheses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Return

OLS results

	$\Upsilon^{ni,j}$ **= observables**	$\Upsilon^{ni,j}$ **= Exp x Imp x Ind FE**
	ln(Trade)	ln(Trade)
ln(Freight)	-0.276***	0.108***
	(0.045)	(0.035)
Importer x Industry x Time FE	Yes	Yes
Exporter x Industry x Time FE	Yes	Yes
Additional controls	Yes	
Exporter x Importer x Industry FE		Yes
Observations	80,787	80,787

*All regressions control for tariffs. Additional controls include dummies for a common language, a common land border and a past colonial relationship. Heteroskedasticity robust errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Return

LPM (for influence of zeros in the data)

	Second stage		Reduced form	
	IV	LPM	IV	LPM
Dependent variable	ln(Trade)	Binary trade	ln(Trade)	binary trade
ln(Freight)	-1.035**	-0.005		
	(0.508)	(0.026)		
Instrument			0.014**	0.000
			(0.007)	(0.000)
Importer x Industry x Time FE	Yes	Yes	Yes	Yes
Exporter x Industry x Time FE	Yes	Yes	Yes	Yes
Exporter x Importer x Industry FE	Yes	Yes	Yes	Yes
Observations	81,200	81,200	81,200	81,200
F first stage (Kleibergen-Paap)	101.0	101.0		

All regressions control for tariffs. Heteroskedasticity robust errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Return

PPML (reduced form) - results

	Reduced form	
	IV	PPML
Dependent variable	ln(Trade)	Trade
Instrument	0.014**	0.017***
	(0.007)	(0.006)
Importer x Industry x Time FE	Yes	Yes
Exporter x Industry x Time FE	Yes	Yes
Exporter x Importer x Industry FE	Yes	Yes
Observations	80,787	80,980

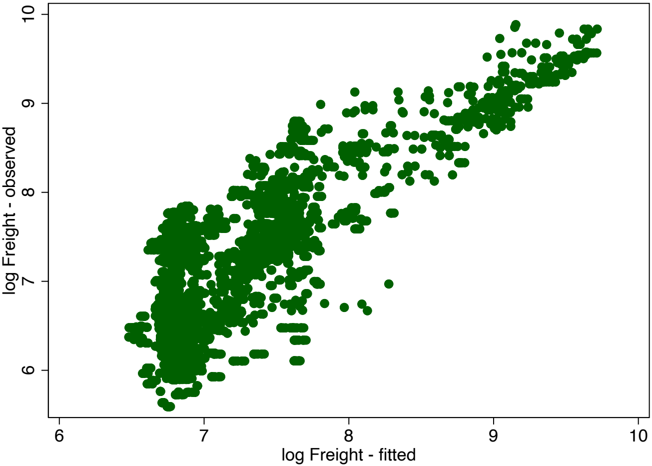
*All regressions control for tariffs. Heteroskedasticity robust errors in parentheses

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Return

Fit of the model for missing freights

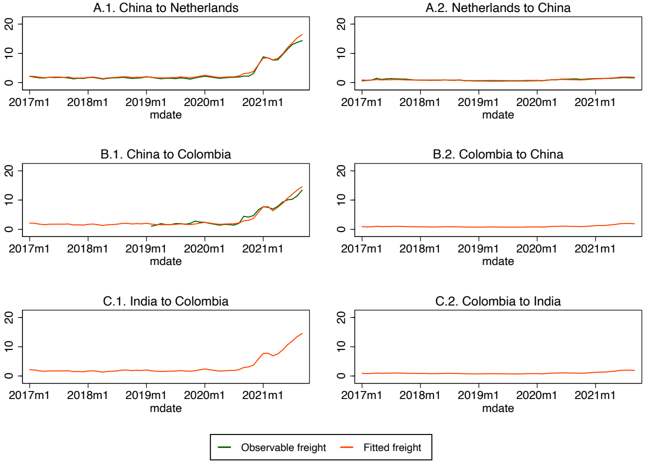
Figure: Fit of the estimated equation



Return

Examples of forecasts from the model for missing freights

Figure: Examples of forecasts for three country-pairs



*Note: Panel A includes a country-pair with information of freights for both directions; Panel B includes a country-pair with information of freights in only one-direction; Panel C includes a country-pair with no freight information.

Return

Solving the model - baseline economy (I)

- The system to be solved is:

$$\mu_{t+1}^{n,jk} = \frac{\mu_t^{n,jk}(\dot{u}_{t+2}^{n,k})^{\beta/\nu}}{\sum_{h=0}^{J} \mu_t^{n,jh}(\dot{u}_{t+2}^{n,h})^{\beta/\nu}}$$

$$\dot{u}_{t+1}^{n,j} = \dot{\omega}_{t+1}^{n,j} \left(\sum_{k=0}^{J} \mu_t^{n,jk}(\dot{u}_{t+2}^{n,k})^{\beta/\nu} \right)^{\nu}$$

$$L_{t+1}^{n,j} = \sum_{k=0}^{J} \mu_t^{n,kj} L_t^{n,k}$$

- where $\dot{y}_{t+1} \equiv \left(\frac{y_{t-1}}{y_t}\right)$ denotes the proportional change in a variable; $u_t^{n,k} \equiv \exp\left(V_t^{nj}\right)$ and $\omega_{t+1}^{n,j} = \frac{w_{t+1}^{n,j}}{P_{t+1}^{n}}$ is the solution for real wages of the "temporary equilibrium" at $t+1$ given by...

Solving the model - baseline economy (I)

- ... (temporary equilibrium):

$$\dot{x}^{n,j}_{t+1} = (\dot{L}^{n,j}_{t+1})^{\gamma^{n,j}\xi^n} (\dot{w}^{n,j}_{t+1})^{\gamma^{n,j}} \prod_{k=1}^{J} (\dot{P}^{n,k}_{t+1})^{\gamma^{n,jk}}$$

$$\dot{P}^{n,j}_{t+1} = \left(\sum_{i=1}^{N} \pi^{ni,j}_t (\dot{x}^{i,j}_{t+1} \dot{\kappa}^{ni,j}_{t+1})^{-\theta^j} (\dot{A}^{i,j}_{t+1})^{\theta^j \gamma^{i,j}} \right)^{-1/\theta^j}$$

$$\pi^{ni,j}_{t+1} = \pi^{ni,j}_t \left(\frac{\dot{x}^{i,j}_{t+1} \dot{\kappa}^{ni,j}_{t+1}}{\dot{P}^{n,j}_{t+1}} \right)^{-\theta^j} (\dot{A}^{i,j}_{t+1})^{\theta^j \gamma^{i,j}}$$

$$\dot{w}^{n,j}_{t+1} \dot{L}^{n,j}_{t+1} w^{n,j}_t L^{n,j}_t = \gamma^{n,j} (1 - \xi^n) \sum_{i=1}^{N} \pi^{in,j}_{t+1} X^{i,j}_{t+1}$$

$$X^{nj}_{t+1} = \sum_{k=1}^{J} \gamma^{n,kj} \sum_{i=1}^{N} \pi^{in,k}_{t+1} X^{i,k}_{t+1} + \alpha^j \left(\sum_{k=1}^{J} \dot{w}^{n,k}_{t+1} \dot{L}^{n,k}_{t+1} w^{n,k}_t L^{n,k}_t + \iota^n \chi_{t+1} \right)$$

$$\textit{where } \chi_{t+1} = \sum_{i=1}^{N} \sum_{k=1}^{J} \frac{\xi^i}{1 - \xi^i} \dot{w}^{i,k}_{t+1} \dot{L}^{i,k}_{t+1} w^{i,k}_t L^{i,k}_t$$

Return

Solving the model - counterfactual economy (I)

- The system to be solved is:

$$\mu_t^{\prime n,j,k} = \frac{\mu_{t-1}^{\prime n,jk} \dot{\mu}_t^{n,jk} \left(\hat{u}_{t+1}^{n,k}\right)^{\beta/\nu}}{\sum_{h=0}^{J} \mu_{t-1}^{\prime n,jh} \dot{\mu}_t^{n,jh} \left(\hat{u}_{t+1}^{n,h}\right)^{\beta/\nu}}$$

$$\hat{u}_t^{nj} = \hat{\omega}_t{}^{nj} \left(\sum_{i=1}^{N} \sum_{k=0}^{J} \mu_{t-1}^{\prime nj,ik} \dot{\mu}_t^{nj,ik} \left(\hat{u}_{t+1}^{ik}\right)^{\beta/\nu} \right)^{\nu}$$

$$L_{t+1}^{\prime nj} = \sum_{i=1}^{N} \sum_{k=0}^{J} \mu_t^{\prime ik,nj} L_t^{\prime ik}$$

where y_t' denotes that y belongs to the counterfactual solution and $\hat{y}_t \equiv \left(\frac{\dot{y}_t'}{\dot{y}_t}\right)$ denotes the proportional change in a variable in the counterfactual economy relative to the proportional change in the same variable in the baseline economy. $\hat{\omega}_t{}^{nj}$can be obtained by solving...

Solving the model - counterfactual economy (I)

- ...(for solution of $\hat{\omega}_t{}^{nj}$):

$$\hat{x}^{n,j}_{t+1} = (\hat{L}^{n,j}_{t+1})^{\gamma^{n,j}\xi^n} (\hat{w}^{n,j}_{t+1})^{\gamma^{n,j}} \prod_{k=1}^{J} (\hat{P}^{n,k}_{t+1})^{\gamma^{n,jk}}$$

$$\hat{P}^{n,j}_{t+1} = \left(\sum_{i=1}^{N} \pi'^{ni,j}_{t} \dot{\pi}^{ni,j}_{t+1} (\hat{x}^{i,j}_{t+1} \hat{\kappa}^{ni,j}_{t+1})^{-\theta^j} (\hat{A}^{i,j}_{t+1})^{\theta^j \gamma^{i,j}} \right)^{-1/\theta^j}$$

$$\pi'^{n,ij}_{t+1} = \pi'^{ni,j}_{t} \dot{\pi}^{ni,j}_{t+1} \left(\frac{\hat{x}^{i,j}_{t+1} \hat{\kappa}^{ni,j}_{t+1}}{\hat{P}^{n,j}_{t+1}} \right)^{-\theta^j} (\hat{A}^{i,j}_{t+1})^{\theta^j \gamma^{i,j}}$$

$$\hat{w}^{n,k}_{t+1} \hat{L}^{n,k}_{t+1} = \frac{\gamma^{n,j}(1-\xi^n)}{w'^{n,k}_{t} L'^{n,k}_{t} \dot{w}^{n,k}_{t+1} \dot{L}^{n,k}_{t+1}} \sum_{i=1}^{N} \pi'^{in,j}_{t+1} X'^{i,j}_{t+1}$$

$$X'^{n,j}_{t+1} = \sum_{k=1}^{J} \gamma^{n,kj} \sum_{i=1}^{N} \pi'^{in,k}_{t+1} X'^{i,k}_{t+1} + \alpha^j \left(\sum_{k=1}^{J} \hat{w}^{n,k}_{t+1} \hat{L}^{n,k}_{t+1} w'^{n,k}_{t} L'^{n,k}_{t} \dot{w}^{n,k}_{t+1} \dot{L}^{n,k}_{t+1} + \iota^n \chi'_{t+1} \right)$$

$$\textit{where } \chi'_{t+1} = \sum_{i=1}^{N} \sum_{k=1}^{J} \frac{\xi^i}{1-\xi^i} \hat{w}^{i,k}_{t+1} \hat{L}^{i,k}_{t+1} w'^{i,k}_{t} L'^{i,k}_{t} \dot{w}^{i,k}_{t+1} \dot{L}^{i,k}_{t+1}$$

Return

List of countries

Europe		Asia		Americas	
BEL	Belgium	CHN	China	ARG	Argentina
DNK	Denmark	IND	India	BRA	Brazil
FRA	France	HKG	Hong Kong	CAN	Canada
DEU	Germany	ISR	Israel	CHL	Chile
HUN	Hungary	JPN	Japan	COL	Colombia
ITA	Italy	KOR	Rep. of Korea	PER	Peru
ROU	Romania	MYS	Malaysia	MEX	Mexico
NLD	Netherlands	PHL	Philippines	USA	United States
POL	Poland	SGP	Singapore		
PRT	Portugal	THA	Thailand	**Africa / Oceania**	
RUS	Russian Federation	TUR	Turkey	AUS	Australia
SVK	Slovak Republic	VNM	Vietnam	MAR	Morocco
ESP	Spain			ZAF	South Africa
SWE	Sweden				
CHE	Switzerland			**Other**	
GBR	United Kingdom			ROW	Rest of the World

Return to regression Return to data

List of sectors

Tradable sectors			Non-tradable sectors		
No.	2-dig ISIC*	Sector	No.	2-dig ISIC*	Sector
1	01 to 03	Agriculture, hunting, forestry, fishing and aquaculture	16	35 to 39	Public serv. supply; sewerage, waste management
2	10 to 12	Food products, beverages and tobacco	17	41 to 43	Construction
3	13 to 15	Textiles, textile products, leather and footwear	18	45 to 47	Wholesale and retail trade; repair of motor vehicles
4	16 to 18	Wood, products of wood and corck, paper products and printing	19	49 to 53	Transport, warehousing, and postal/courier activities
5	19	Coke and refined petroleum products	20	55 to 56	Accommodation and food service activities
6	20	Chemical and chemical products	21	58 to 60	Publishing, audiovisual and broadcasting activities
7	21	Pharmaceuticals, medicinal and chemical and botanical prod.	22	61	Telecomunications
8	22 to 23	Rubber, plastics prod. and other non-methalic mineral prod.	23	62 to 63	IT and other information services
9	24	Basic metals	24	64 to 66	Financial and insurance activities
10	25	Fabricated metal products	25	68	Real estate sctivities
11	26	Computer, electronic and optical equipment	26	69 to 75	Professional, scientific and technical activities
12	27	Electric equipment	27	77 to 82	Administrative and support services
13	28	Machiney and equipment, nec	28	84	Public administration and defense; compulsory s.s.
14	29 to 30	Motor vehicles, trailers, and other transport equipment	29	85	Education
15	31 to 33	Manufacturing nec; repair and installation of machinery equip.	30	86 to 88	Human health and social work activities
			31	90 to 93	Arts, entertaiment and recreation
			32	94 to 96	Other service activities

*Revision 4 of ISIC

Return to regression Return to data

Trade elasticities from Fontagné et al. (2022)

No.	Sector	$1/\theta^j$
1	Agriculture, hunting, forestry, fishing and aquaculture	2.91
2	Food products, beverages and tobacco	4.17
3	Textiles, textile products, leather and footwear	4.71
4	Wood, products of wood and cork, paper products and printing	8.51
5	Coke and refined petroleum products	3.67
6	Chemical and chemical products	10.56
7	Pharmaceuticals, medicinal and chemical and botanical prod.	10.56
8	Rubber, plastics prod. and other non-methalic mineral prod.	5.77
9	Basic metals	7.39
10	Fabricated metal products	4.22
11	Computer, electronic and optical equipment	5.14
12	Electric equipment	4.11
13	Machiney and equipment, nec	5.00
14	Motor vehicles, trailers, and other transport equipment	8.95
15	Manufacturing nec; repair and installation of machinery equip.	4.06

Return to shocks Return to data

Robustness to changes in ν

	(1) Baseline	(2) Low ν	(3) High ν
Calibrated parameters			
ν	5.34	4.00	7.00
β	0.99	0.99	0.99
Results of counterfactual exercises			
Cumulative effect in prices	2.97%	2.96%	2.98%
Job losses	0.12%	0.16%	0.09%
Welfare impact	-1.35%	-1.33%	-1.38%

Return