Online Appendix — Not for Publication

Navigating the Waves of Global Shipping: Drivers and Aggregate Implications[1]

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Part I

Data

1 Shipping disruptions during COVID-19

The COVID-19 pandemic caused significant disruptions to global shipping, leading to a contraction in effective shipping capacity. This section provides additional context on the shipping efficiency shock modeled in our quantitative exercise. We present both empirical evidence from key shipping indicators and anecdotal reports from major ports to highlight the nature and extent of these disruptions.

1.1 Quantitative evidence

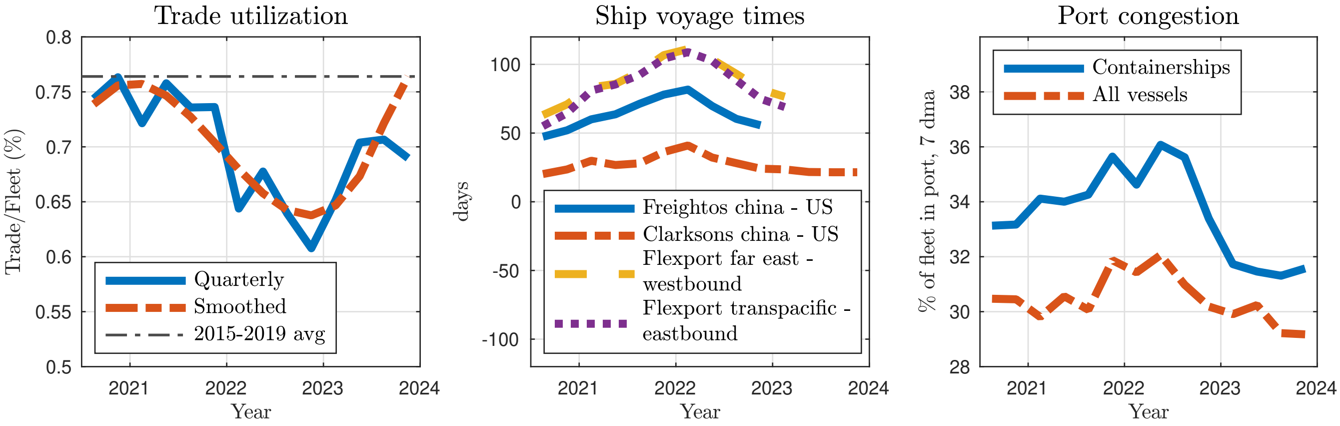
Figure 1 presents three key indicators of shipping disruptions during the pandemic: trade utilization, voyage times, and port congestion.

The left panel shows trade utilization, calculated as the ratio of global trade volume to total fleet capacity. This measure proxies the effective use of global shipping capacity. The observed decline in trade utilization during COVID-19, despite higher demand for tradable goods, reflects widespread reduced effective shipping capacity caused by port congestion, shipping delays, and labor shortages. This is the variable we use in the paper to back out the productivity shock $\bar{g}$ to shipping efficiency.

The middle panel shows average voyage times across major shipping routes, illustrating a significant increase during the pandemic. Ships were delayed at ports due to health restrictions, crew shortages, and longer turnaround times, reducing the availability of shipping services and contributing to the decline in effective capacity.

The right panel displays port congestion data for containerships and all vessel types. Ports around the world experienced unprecedented delays, with ships waiting offshore for extended periods before being processed. This congestion further constrained the shipping industry's ability to meet rising demand and drove up shipping costs.

Figure 1: Shipping disruptions during COVID-19



Data details

Data from Clarkson's *Shipping Intelligence Network*, Flexport, and Freightos. **Trade utilization** is measured using Clarksons data on total containership trade and fleet capacity, both expressed in TEUs, examining changes relative to the 2015–2019 average. **Clarksons China to US** West Coast Containership Voyage - Average Duration (Beta) Basis data derived from AIS vessel movements data. **Flexport**'s Ocean Timeliness Indicator measures the amount of time taken to ship freight from the point at which cargo is ready to leave the exporter to when it is collected from its destination port. Measures are shown for Far East Westbound (e.g., China-to-Europe) and Transpacific Eastbound (e.g., China-to-US) routes. **Freightos**: Door to Door shipping from China to U.S. Clarksons **Port Congestion** Index - % fleet capacity, 7dma Data based on the proportion of vessels (in terms of TEU) in the fleet in a defined port or anchorage location based on vessel's closest to midday AIS signal on the date specified.

1.2 Anecdotal evidence of port restrictions and crew shortages

Anecdotal evidence from major ports provides further insight into the specific disruptions that reduced shipping capacity. For example, Chinese ports implemented stringent quarantine measures for incoming vessels. The port of Fuzhou, for instance, imposed a requirement for ships arriving from certain countries to wait up to 14 days before docking, significantly delaying ship processing.[2] In the United States, the ports of Los Angeles and Long Beach faced significant operational challenges due to labor shortages and increased cargo volumes. COVID-19 infections among dockworkers led to slowdowns in operations, with dozens of cargo ships anchored offshore and waiting to be offloaded.[3]

Additionally, the pandemic caused a global crew change crisis, with an estimated 400,000 seafarers stranded on vessels due to international travel restrictions. In China, for example, returning seafarers were subjected to mandatory quarantine periods of up to seven weeks, further delaying shipping operations.[4]

The combination of quantitative indicators and anecdotal evidence provides broad support for our interpretation of the shipping efficiency shock that we consider in the paper. The disruptions observed during the pandemic played a crucial role in driving the supply chain bottlenecks and trade slowdowns that significantly impacted global shipping capacity.

2 Shipping costs: Spot vs. effective rates

In this section, we contrast the shipping cost measure that we use throughout the paper relative to other ways of measuring shipping costs. The benchmark series we use for comparison and analysis is the Global Drewry average spot rate for 20-foot TEU containers. It is important to note that while spot rates are

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[2] TTNews, "Chinese Port Restricts Ships From Virus-Hit Nations for 14 Days," available at `https://www.ttnews.com/articles/chinese-port-restricts-ships-virus-hit-nations-14-days`

[3] NewsNation, "COVID-19 Infections Among Hundreds of Workers Lead to Cargo Ship Traffic Jam," available at `https://www.newsnationnow.com/business/covid-19-infections-among-hundreds-of-workers-lead-to-cargo-ship-traffic-jam`

[4] Supply Chain Digital, "7-Week Quarantine for Ship Crew in China Hits Supply Chain," available at `https://supplychaindigital.com/logistics/7-week-quarantine-ship-crew-china-hit-supply-chain`

among the most cited measures of shipping costs, they may not be representative of overall effective shipping costs given that some carriers engage in longer-term contracts that do not adjust immediately in response to shocks.

To evaluate whether spot rates reflect effective shipping costs, we compare the Drewry spot rates to U.S. trade cost data from the U.S. Census. Specifically, Figure 2 shows four series: the Drewry container index for U.S. ports, the U.S. Census measure of freight and insurance charges per kilogram of trade, and the ratio of CIF (cost, insurance, and freight) to FOB (free on board) values, with and without insurance.[5] Critically, these alternative measures of shipping costs capture the effective shipping cost paid, combining both spot rates and long-term contracts. Each series is expressed as a percentage change relative to 2020Q1. We restrict attention to U.S. imports given that data limitations prevent us from computing these variables systematically across countries — this is why we focus on global spot rates in the paper.

The comparison suggests that the effective shipping costs measured using U.S. Census data and the CIF/FOB ratio exhibit similar trends as the Drewry spot rates during the pandemic, albeit with less pronounced fluctuations. The freight and insurance charges per kilogram and the CIF/FOB ratio (with and without insurance) both increased significantly during the pandemic, but their increases were milder in magnitude than spot rates. This difference is consistent with the notion that spot rates are more sensitive to immediate supply and demand shocks, whereas aggregate shipping costs capture a broader set of shipping arrangements, including longer-term contracts.

Overall, the comparison indicates that the Drewry spot rates capture the direction and timing of changes in shipping costs observed in aggregate trade data. While the lack of data availability on effective shipping costs across countries prevents us from comparing spot vs. effective rates across countries, the findings reported in this section suggest the spot rates used in our model reflect broader shipping cost trends, making them a suitable proxy for the purpose of this study.

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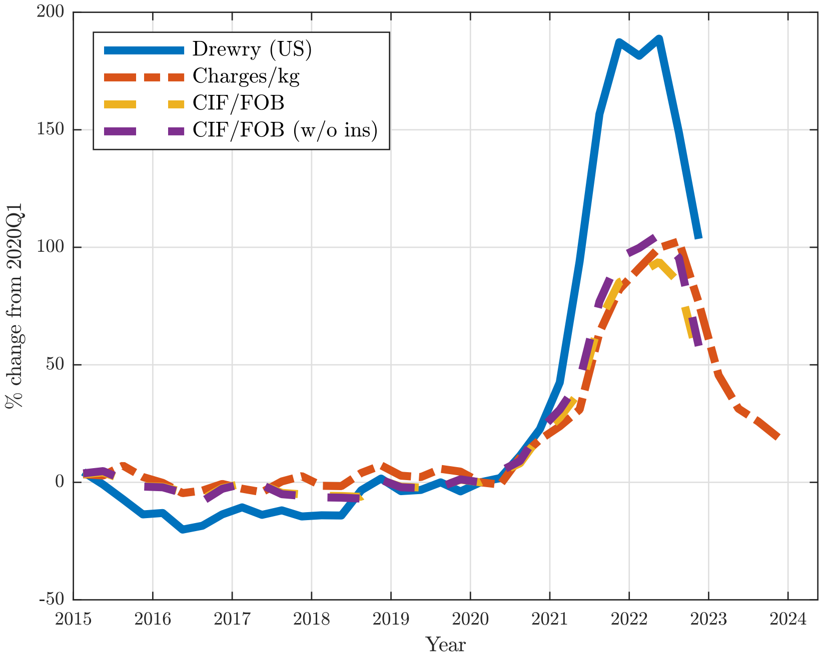
[5] To calculate the CIF/FOB rate without insurance, we remove 0.5% from the CIF before calculating percent changes. The 0.5% insurance estimate is taken from Freightos: `https://www.freightos.com/freight-resources/freight-insurance`.

Figure 2: Shipping costs, spot vs. effective rates



Note: Data from Drewry Supply Chain Advisors and US Trade Census.

3 Containers and global shipping

Understanding the role of container shipping in global trade is crucial to assessing the broader impact of shipping disruptions on economic fluctuations. While the paper focuses on container shipping, this section provides additional context by examining the value and volume of goods transported by different shipping modes, comparing industry dynamics across container and bulk shipping, and analyzing trade fluctuations following the COVID-19 pandemic. The evidence presented here highlights that container shipping accounts for a significant share of global trade value, exhibits dynamics similar to other important seaborne shipping markets, and experienced trade fluctuations comparable to bulk shipping during COVID-19.

3.1 Containers: Value and volume of goods shipped

To assess the significance of container shipping within global trade, it is useful to examine the breakdown of trade by different shipping modes. Tables 1 and 2 present the distribution of trade shares across sea, air, and land, both globally and for the United States. These tables highlight the dominant role of maritime shipping in international trade and the substantial contribution of containerships.

Table 1 shows that sea shipping accounts for a significant share of global trade, both in value and volume. Globally, around 42.6% of trade value is transported by sea, while in the U.S., sea shipping represents 41.3% of trade value. In terms of volume, sea shipping dominates air: relative to air shipping, more than 99% of the volume of goods transported in the U.S. and globally are moved by sea.[6] Air freight trade values are higher given the prevalence of high-value goods.

These patterns highlight the limited scope for mitigating COVID-19-related shipping disruptions through a reallocation from sea shipments to air or land transport. First, air shipping capacity is minimal compared to sea shipping capacity. Second, land-based reallocation is only feasible for shipments between geographically proximate and connected locations.

Table 2 provides a breakdown of sea transport by shipping type. Containerships account for a substantial portion of sea trade by value, representing 58.1% and 55.5% of U.S. and global sea trade value, respectively. In terms of volume, containerships represent about 13.9% of U.S. sea shipping volume and approximately 15% globally. The remainder of sea trade volume is primarily carried by bulk shipping.

These figures underscore that container shipping accounts for a significant portion of global trade value and plays a key role in maritime transport worldwide, making it central to understanding global shipping dynamics.

3.2 Industry dynamics: Containers vs. bulk

Given that container and bulk shipping together account for the majority of sea trade, it is useful to examine whether the dynamics observed in the containership sector extend to bulk shipping as well. Figure 3 shows these subsectors exhibit similar patterns across fleet growth, capacity utilization, new orders relative to

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[6] Data limitations prevent us from comparing trade volumes relative to land.

Table 1: Total trade shares

	Value share		Volume share	
Mode	**US**	**Global**	**US**	**Global**
Sea	41.3%	42.6%	99.4%	> 99%
Air	28.1%	15.4%	0.6%	< 1%
Land	30.6%	38.1%	-	-
Other	-	4.0%	-	-

Notes: Columns 1 and 3 are 2015 - 2023 averages from the US Trade Census for both exports and imports. Column 2 is the 2017 - 2023 average from a sample of 46 countries from Comtrade. Column 4 is a 2021 value reported in Boeing World Air Cargo Forecast 2022 - 2041. In columns where the "Land" and/or "Other" categories are omitted, it is because those categories are not included in that data.

Table 2: Sea trade shares

Mode	Value share		Volume share	
	US	**Global**	**US**	**Global**
Containerships	58.1%	55.5%	13.9%	15.0%
Dry Bulk	8.3%	10.3%	34.9%	52.5%
Other	33.6%	34.2%	51.2%	32.5%

Notes: Columns 1 and 3 correspond to those in Table 1. To classify the goods shipped between containerships and dry bulk, we consider the following HS commodities as containership goods: 7-9, 16, 19-22, 39-40, 50-63, 68-70, 73-74, 76, 78-79, 84-88, 90-91, 94-96. We consider the following commodities as dry bulk goods: 10, 12, 23, 25-26, 28, 31, 44, 47-48, 2701-2704, 2713. Column 4 is the 2015 - 2023 average from Clarkson's *Shipping Intelligence Network*. The dry bulk category here includes grain, iron ore, minor bulk, coal, and other dry bulk. The "Other" category includes crude oil, oil products, gas, and chemicals.

earnings, and the relationship between earnings and excess demand. The observed similarities suggest that the key economic forces driving shipping dynamics are common across shipping modes and not unique to containerships.

The top left panel of Figure 3 shows that fleet sizes for both container and bulk shipping have grown steadily over time, reflecting consistent investment in shipping capacity across both markets. The top right panel illustrates capacity utilization rates for these subsectors, which have remained high and stable, indicating a persistent balance between supply and demand in both the containership and bulk shipping markets.

The middle panels of Figure 3 show new orders and average earnings for both subsectors. In both cases, we observe a positive relationship between earnings and new orders, indicating that periods of higher earnings are also ones featuring increases in new ship orders. This similarity suggests that investment decisions are driven by comparable incentives across both subsectors.

The bottom panels of Figure 3 illustrate the relation between earnings and excess demand for both container and bulk shipping. The positive correlation observed in both markets further demonstrates that pricing and investment dynamics are driven by similar economic forces, regardless of subsector.

Lastly, Figure 4 shows that spot rates for containers (Drewry World Container Index) and dry bulk (Baltic Dry Index) have followed similar trends over the past 20 years. However, the Great Recession had a more pronounced impact on dry bulk rates, while the effects of COVID-19 were slightly more significant for containerships.

These similarities are particularly noteworthy given the differences in market structure between the two subsectors. The containership sector is dominated by a few large firms, with the top 10 companies controlling approximately 80% of the market. These firms often operate through strategic alliances to coordinate capacity and routes. In contrast, bulk shipping is much more fragmented and competitive, with a large number of smaller operators. The bulk shipping market, as studied by Kalouptsidi (2014) and Brancaccio et al. (2020), is generally considered a benchmark for competitive behavior in shipping markets.

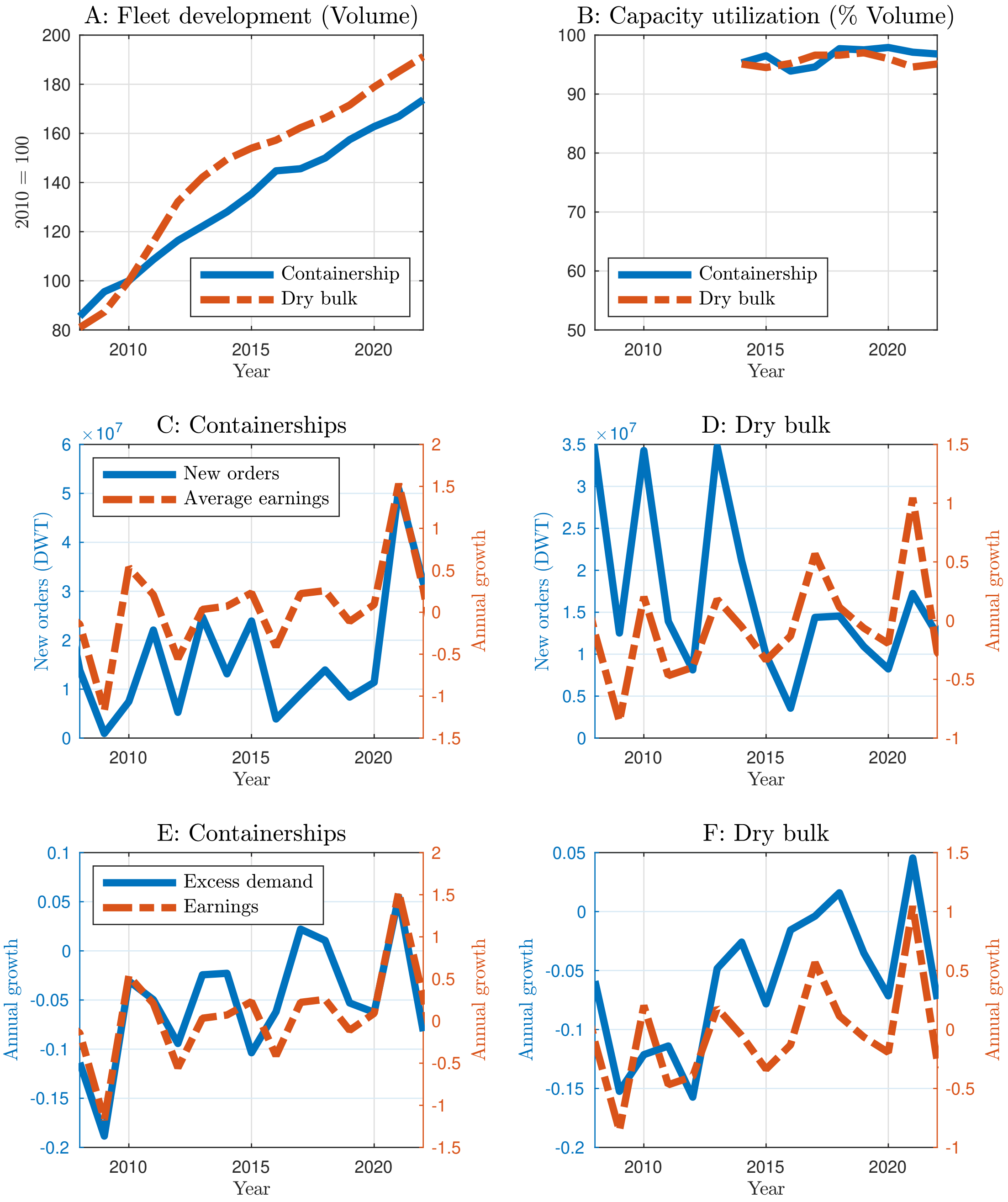
Despite these differences in market structure, the observed dynamics across both subsectors—such as fleet growth, capacity utilization, investment responses to earnings, and spot rates—are remarkably similar. This suggests that the shipping dynamics we observe are unlikely to be driven primarily by differences in market structure. Instead, they appear to reflect broader economic forces that are common across different types of sea shipping. The fact that containerships, despite their more concentrated market structure, exhibit similar investment and price patterns to bulk shipping supports the relevance of using container shipping as a representative case for modeling broader shipping dynamics.

3.3 Trade dynamics following COVID-19: Containers vs. bulk

The dynamics of global trade following the COVID-19 pandemic further support the relevance of our focus on container shipping. Figure 5 compares trade dynamics for containers and dry bulk shipping, showing the detrended world trade volume relative to 2020Q1 for both segments. We observe that both container and dry bulk shipping experienced a similar percentage decline in the aftermath of the pandemic.

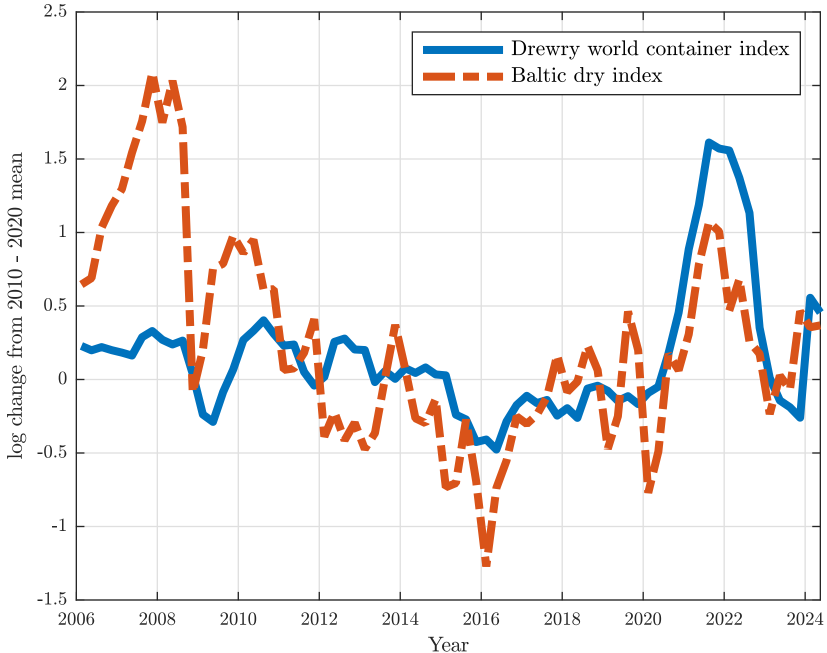
These above comparisons suggest that, although our analysis focuses on container shipping, many of the key dynamics in our model also apply to other forms of sea shipping. The similarities in trade and investment patterns between container and bulk shipping highlight the broader relevance of our findings to global shipping markets.

Figure 3: Shipping industry dynamics, containers vs. dry bulk



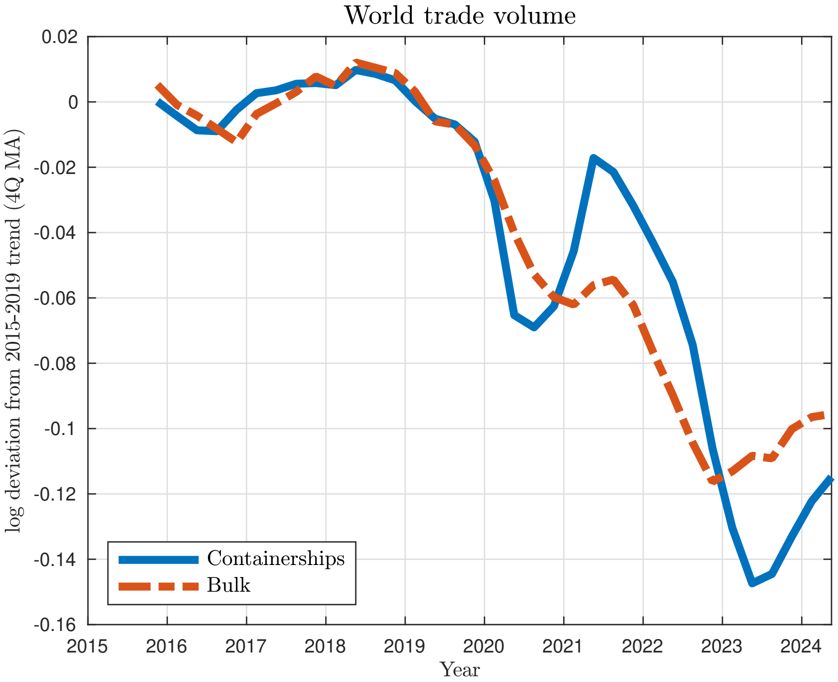
Note: Data from Clarkson's *Shipping Intelligence Network* and *OECDstat*.

Figure 4: Shipping prices, containers vs. dry bulk



Note: Data from Clarkson's *Shipping Intelligence Network* and Drewry Supply Chain Advisors.

Figure 5: Global trade dynamics following COVID-19



Note: Data from Clarkson's *Shipping Intelligence Network*.

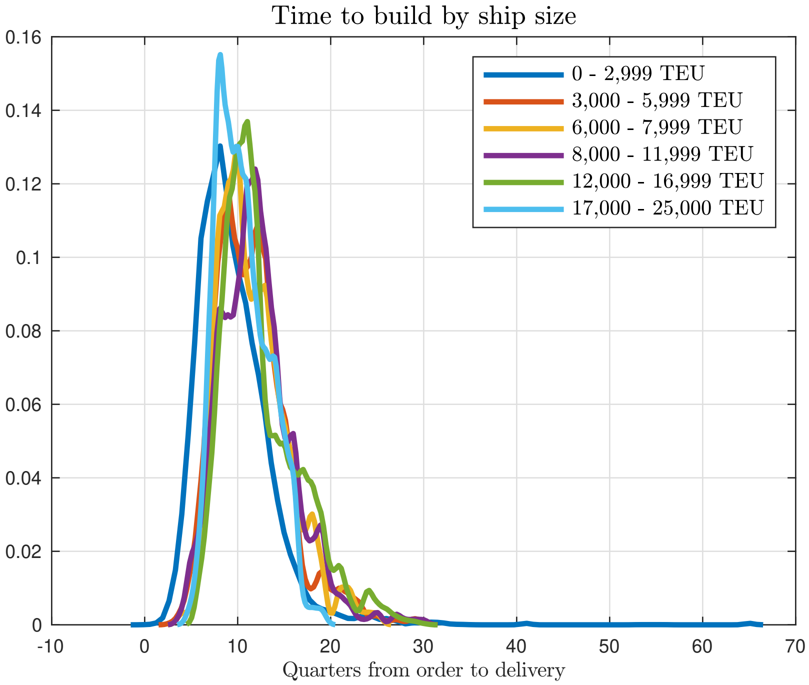
4 Containership time-to-build

Understanding the time it takes to build new containerships is essential for assessing the dynamics of shipping capacity. In this section, we examine how the time-to-build varies both by ship size and across different time periods. While our model abstracts from explicit time variation in production lags, the shipping adjustment cost can generate similar effects, particularly by limiting the speed of capacity expansion during periods of high ordering activity.

4.1 By ship size

Figure 6 presents the distribution of time-to-build by ship size, measured in quarters, using data from Clarkson's Shipping Intelligence Network. The figure shows that construction times remain relatively uniform across different ship sizes, suggesting that production lags are not significantly affected by vessel size. This indicates that shipyards can maintain similar timelines regardless of the ships' dimensions.

Figure 6: Containership time-to-build by ship size

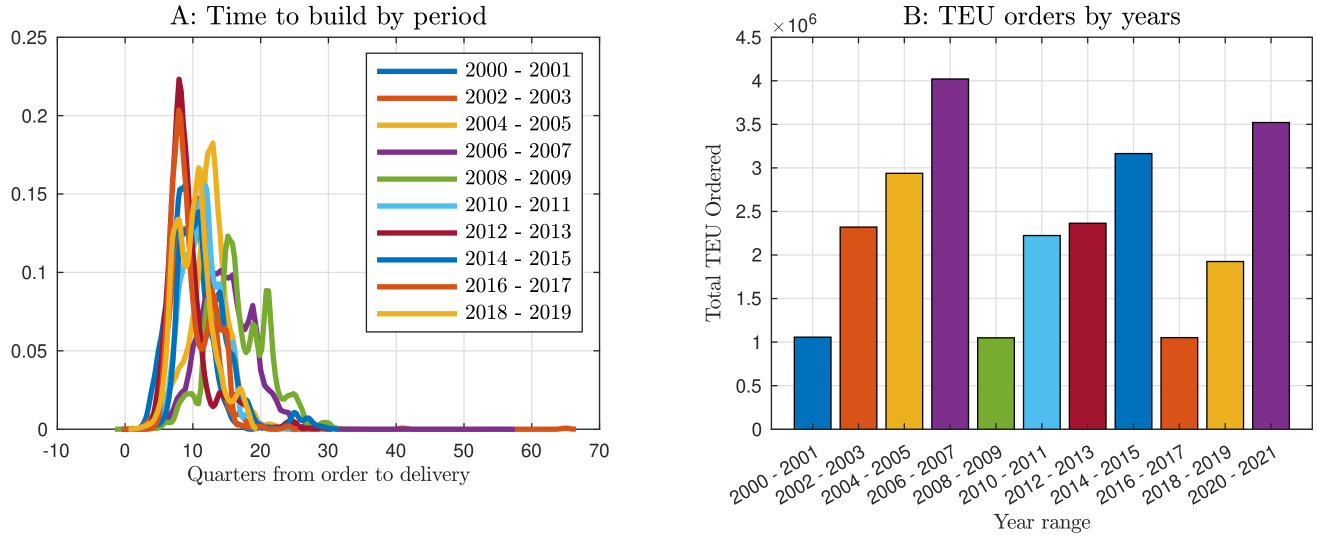


Note: Data from Clarkson's *Shipping Intelligence Network*.

4.2 By time period

Next, we examine how time-to-build varies over time, particularly between periods of high and low total demand for new ships. Figure 7 presents the distribution of time-to-build by time period, using data from Clarkson's *Shipping Intelligence Network*. The left panel shows how time-to-build fluctuates across different periods, while the right panel plots the volume of ship orders in twenty-foot equivalent units (TEUs) over time. The left panel indicates that time-to-build extends during periods of heightened ordering activity, consistent with the idea that increased demand strains shipyard capacity and leads to longer production timelines.

Figure 7: Containership time-to-build by time period



Note: Data from Clarkson's *Shipping Intelligence Network*.

Table 3 provides a summary of shipbuilding activity by time period. For each period, we report the total TEUs ordered, the number of ships ordered, and the mean and median time-to-build. The table confirms that both the mean and median time-to-build increase during periods of high ordering activity, suggesting that shipyard capacity constraints become more binding during shipping booms.

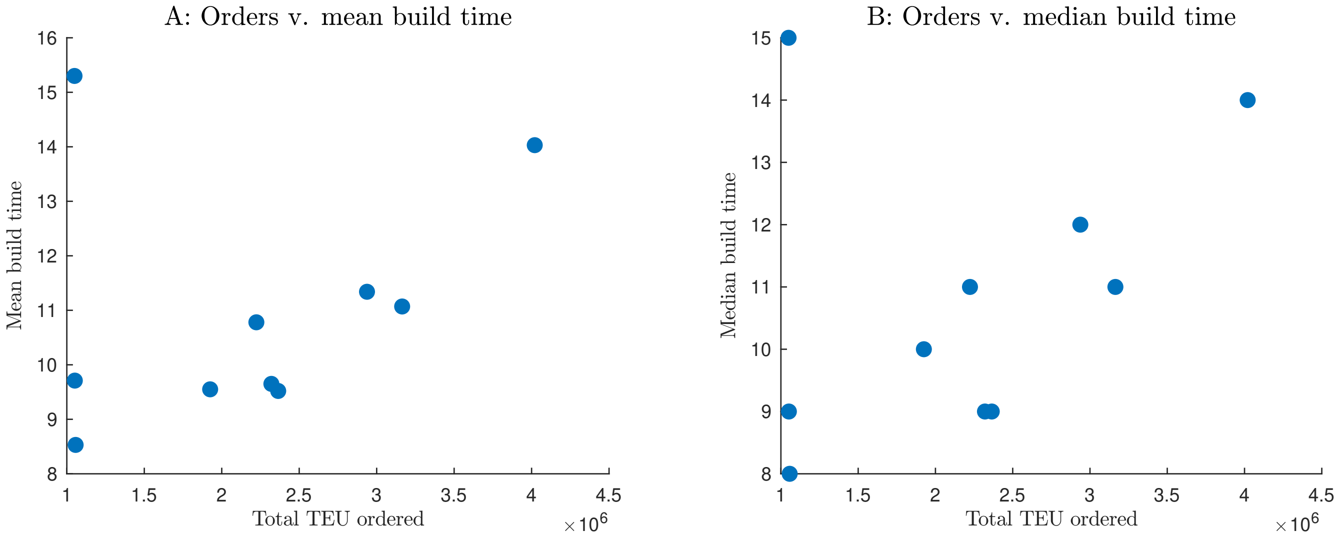
Table 3: Containership time-to-build by time period

Period	Orders (TEU)	Orders (Ships)	Mean time	Median time
2000 - 2001	1,056,841	332	8.53	8
2002 - 2003	2,320,349	535	9.65	9
2004 - 2005	2,937,581	790	11.34	12
2006 - 2007	4,020,397	706	14.03	14
2008 - 2009	1,049,622	169	15.30	15
2010 - 2011	2,223,460	302	10.78	11
2012 - 2013	2,364,439	304	9.52	9
2014 - 2015	3,164,462	323	11.07	11
2016 - 2017	1,051,611	188	9.71	9
2018 - 2019	1,925,130	284	9.55	10
2020 - 2021	3,520,884	501	8.76	9

Figure 8 further illustrates this relationship. The scatterplot shows the relationship between the size of ship orders (in TEUs) and the time-to-build. The left panel presents the mean time-to-build, while the right panel presents the median time-to-build, with each point representing a two-year period from 2000 to 2019. Both panels indicate a positive relationship between the volume of orders and the time-to-build, reinforcing the notion that production lags increase during periods of high demand.

The empirical evidence documented in this section shows that time-to-build varies across periods of high and low ship orders, reflecting shipyard capacity constraints. While our model assumes a fixed production lag, the shipping adjustment cost can partially capture these dynamics by limiting the speed at which new capacity enters the market. In periods of high demand, the adjustment cost slows capacity expansion, mirroring the observed lengthening of time-to-build when shipyard constraints become more binding. As a result, the model leads to a gradual adjustment of shipping capacity that echoes the delays observed during boom periods.

Figure 8: Containership time-to-build, amount ordered vs. build time



Note: Data from Clarkson's *Shipping Intelligence Network*. Each point represents a two year period from 2000 - 2019.

5 Prices following COVID-19: Tradables vs. non-tradables

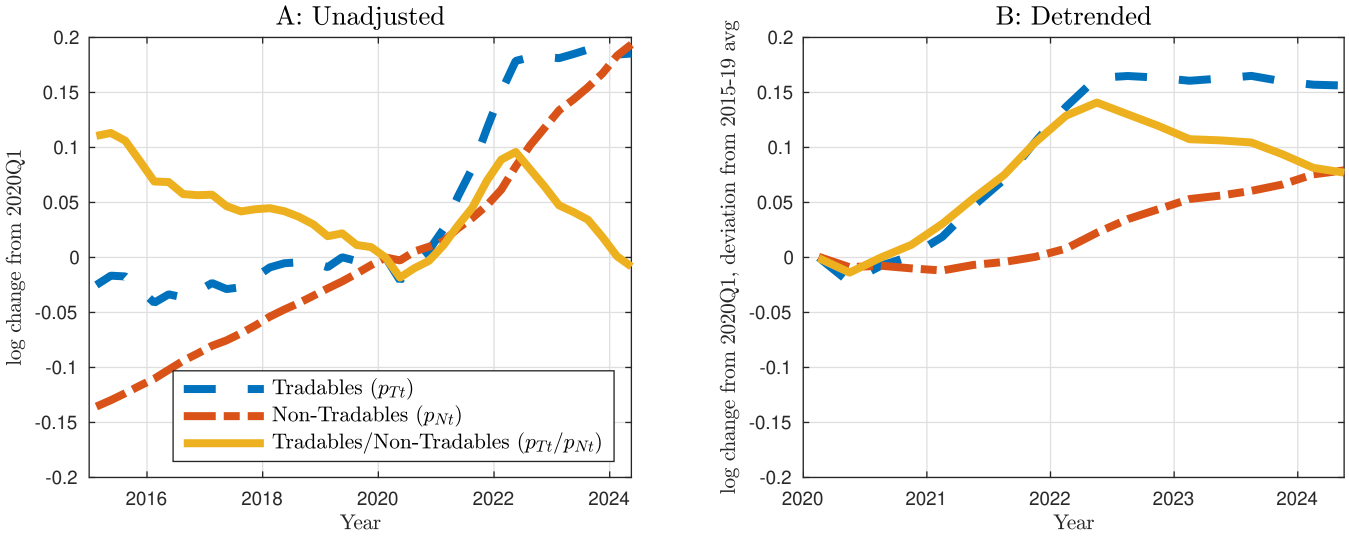
The model's implications for relative prices exhibit qualitative similarities with observed trends in U.S. data. To evaluate the extent to which this is the case, we obtained series for the prices of tradable goods (commodities) and non-tradable goods (services) from the Consumer Price Index for All Urban Consumers (CPI-U) produced by the U.S. Bureau of Labor Statistics. Figure 9 presents the log-changes in these prices relative to Q1 2020, as well as the relative price of tradables to non-tradables. The left panel (A) shows the raw data, while the right panel (B) presents the same data after removing a linear trend over 2015-2019.

The raw data in panel (A) show that prices for tradable goods rose considerably more than those for non-tradable goods following the onset of the COVID-19 pandemic. The relative price of tradables to non-tradables increased by about 10% by early to mid-2022, before gradually reverting as non-tradable prices began to catch up. Our model captures this pattern, as shown in the top right panel of Figure 5 of the paper, exhibiting an increase in the relative price of tradables by approximately 15% before gradually declining after peaking at around 20%. While the increase in the model is somewhat larger than in the raw data, the overall magnitude and both the timing and direction of the relative price movements align.

Panel (B) presents the detrended series, which isolate cyclical movements in relative prices by removing long-term trends. This adjustment provides a more appropriate comparison with the model, as the model does not feature secular long-term trends. Once detrended, the increase in the relative price of tradables to non-tradables is more pronounced, bringing it closer in magnitude to the response implied by the model.

These findings show that the model captures key features of the relative price movements, particularly the initial surge in tradable prices and their subsequent reversion. These results reinforce the model's ability to explain short-run price dynamics during the pandemic, driven by disruptions in global shipping and supply chains.

Figure 9: Prices following COVID-19, tradables vs. non-tradables



Note: Data from the *U.S. Bureau of Labor Statistics.*

Part II

Model and Quantitative Results

6 Equilibrium

A *competitive equilibrium of the world economy* described in Section 3 of the paper consists of prices, home allocations, foreign allocations, and global shipping allocations such that the following conditions hold in every period t:

- Home country:
    1. Given prices, allocations solve household problem
    2. Given prices, allocations solve problem of producers of tradable varieties
    3. Given prices, allocations solve problem of producers of non-tradable varieties
    4. Given prices, allocations solve problem of producers of intermediate goods
    5. Given prices, allocations solve problem of producers of final goods
    6. Profits from producers rebated to households: $\Pi_t = \pi_t + \pi_{Mt} + \pi_{Tt} + \pi_{Nt}$
    7. Labor market clears: $n_{Tt} + n_{Nt} = n_t$
    8. Capital market clears: $k_{Tt} = k_t$
    9. Tradable varieties clear: $y_{Tt} = q_{Tt}^h + \tau {q_{Tt}^h}^* + m_t^h + \tau m_t^{h*}$
    10. Non-tradable varieties clear: $y_{Nt} = q_{Nt}$
    11. Intermediate goods clear: $m_{Tt} = m_t$
    12. Final goods clear:

$$y_t = c_t + i_t + \psi i_{Gt} + \frac{\Phi_b}{2}\left(b_{t+1} - \bar{b}\right)^2 + \psi \frac{\Phi_G}{2}\left(\frac{i_{Gt}}{i_{Gt-1}} - 1\right)^2$$

- Foreign country:
    1. Given prices, allocations solve household problem
    2. Given prices, allocations solve problem of producers of tradable varieties
    3. Given prices, allocations solve problem of producers of non-tradable varieties
    4. Given prices, allocations solve problem of producers of intermediate goods
    5. Given prices, allocations solve problem of producers of final goods
    6. Profits from producers rebated to households: $\Pi_t^* = \pi_t^* + \pi_{Mt}^* + \pi_{Tt}^* + \pi_{Nt}^*$
    7. Labor market clears: $n_{Tt}^* + n_{Nt}^* = n_t^*$

8. Capital market clears: $k^*_{Tt} = k^*_t$
9. Tradable varieties clear: $y_{Tt}{}^* = \tau q^f_{Tt} + q^{f*}_{Tt} + \tau m^f_t + m^{f*}_t$
10. Non-tradable varieties clear: $y^*_{Nt} = q^*_{Nt}$
11. Intermediate goods clear: $m^*_{Tt} = m^*_t$
12. Final goods clear:

$$y^*_t = c^*_t + i^*_t + (1-\psi)i_{Gt} + \frac{\Phi_b}{2}\left(b^*_{t+1} - \overline{b}^*\right)^2 + (1-\psi)\frac{\Phi_G}{2}\left(\frac{i_{Gt}}{i_{Gt-1}} - 1\right)^2$$

- Global shipping:

  1. Given prices, allocations solve problem of global shipping firm
  2. Shipping services clear: $q^f_{Tt} + q^{h*}_{Tt} + m^f_t + m^{h*}_t = \upsilon_t \overline{g} g_t$

- Financial market clears: $b_{t+1} + b^*_{t+1} = 0$

7 Dynamics following COVID-19

7.1 Investment dynamics: Model vs. data

Figure 10 compares the model's implications for aggregate investment dynamics following COVID-19 with their empirical counterparts. This comparison allows us to assess how well the model captures key features of investment behavior, including its responsiveness to economic conditions. We find that the model broadly captures the observed investment dynamics.

7.2 Additional variables

Figure 11 reports the dynamics of additional variables of the model in the aftermath of COVID-19.

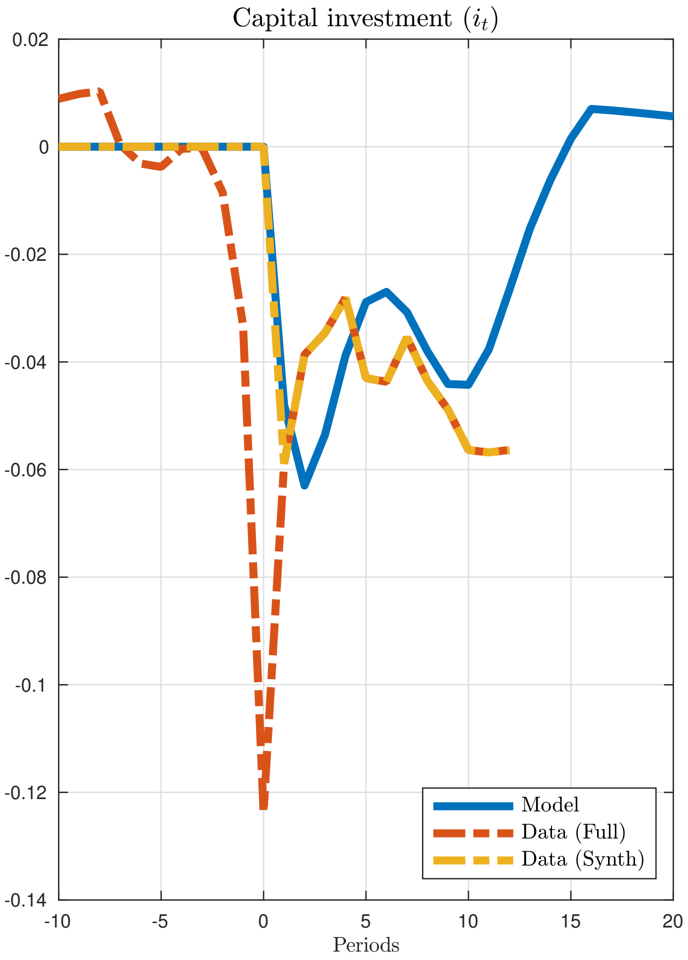
7.3 Key channels

In this section, we investigate the relative importance of alternative channels in accounting for the findings reported in Section 5 of the paper.

Shipping investment technology

First, in Figure 12, we examine the role of the shipping production lag (J), shipping investment adjustment costs (Φ_G), and the productivity of shipping investments (a_G). To do so, we start with the baseline and change one parameter (or set of parameters) while keeping all other parameters at their baseline values. We consider 4 alternative versions of the model: (i) lower shipping investment productivity $a_G = 0.15$, which implies a steady-state ratio of shipping costs to imports equal to 17.2% (vis-a-vis $a_G = 0.36$ in the baseline which implies a value of the ratio equal to 6.4%), (ii) lower shipping adjustment cost $\Phi_G = 0.001$

Figure 10: Capital investment dynamics



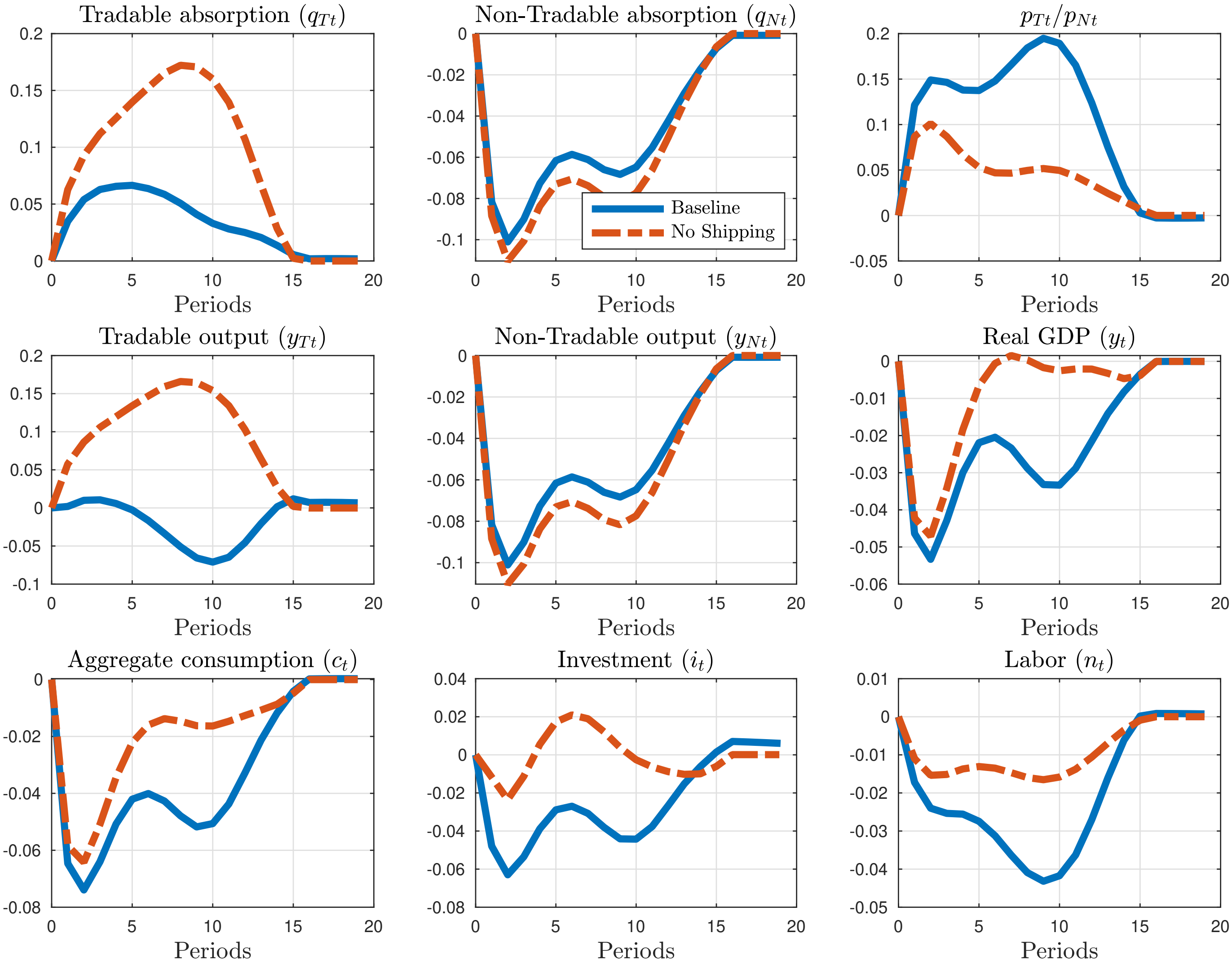
Note: Capital investment is expressed as the log-deviation from its respective steady-state value. The shipping investment and shipping utilization rates are expressed as a percentage point deviation from the steady-state value. "Data (Full)" reports the raw data while "Data (Synth)" excludes the sharp and transitory decline in 2020Q2 by setting its value to zero.

(vis-a-vis 0.35 in the baseline), (*iii*) a one-period shipping production lag ($J = 1$, vis-a-vis $J = 6$ in the baseline), and (*iv*) the combination of (*ii*) and (*iii*).

Input-output linkages and trade elasticity

Second, in Figure 13, we examine the role of input-output linkages and the degree of complementarity or substitutability between domestic and imported varieties in final goods (ρ) and intermediates (ν). To do so, we start with the baseline and fully re-estimate the model under alternative values of the relevant parameters. We consider 3 alternative versions of the model: (*i*) low intermediate inputs ($\varphi = 0.05$, vis-a-vis $\varphi = 0.63$ in the baseline), (*ii*) higher elasticity between tradable domestic and imported varieties in the production of final goods ($\rho = 2.50$, vis-a-vis $\rho = 1.50$ in the baseline), and (*iii*) higher elasticity between tradable domestic and imported varieties in the production of intermediates ($\nu = 4$, vis-a-vis $\nu = 1$ in the baseline).

Figure 11: Additional aggregate implications



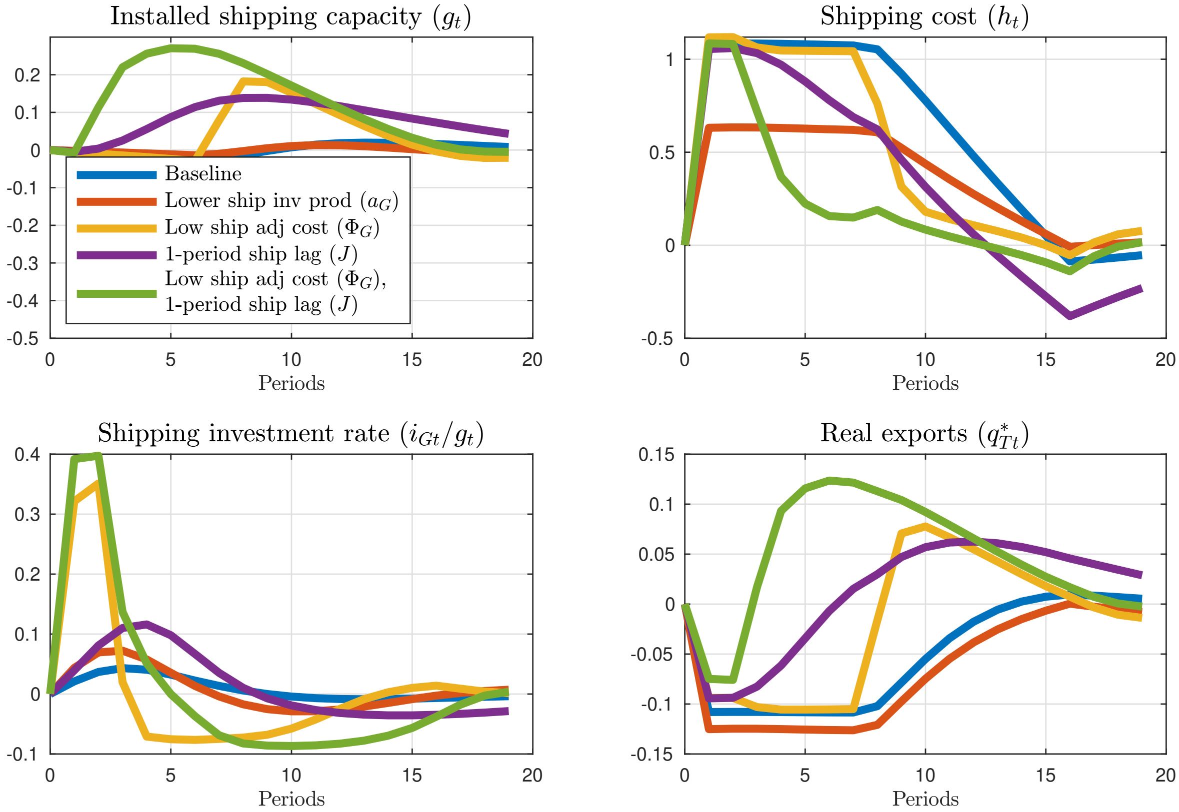
Note: All impulse-response functions (except investment) are expressed as log-deviations from their respective steady-state values. The investment IRFs are expressed as the percentage deviation from the steady-state. Baseline IRF's mirror those shown in Figure 7, while the "No Shipping" IRF's represent those in the counterfactual model with perfectly elastic shipping supply.

8 Business cycle dynamics

8.1 Local vs. global shocks

Given the global nature of international shipping, the extent to which shocks are local or global may play an important role in its aggregate implications. To evaluate this, we investigate the effect of global vs. local shocks on the volatility of shipping and aggregate variables. We do so by contrasting two economies. The first economy is our baseline, that is, an economy with no productivity spillovers across countries ($\rho_{zz} = 0$) — thus, all shocks are truly country-specific and we refer to it as an economy subject to "local shocks." The second economy is identical to our baseline but is subject to productivity shocks that are

Figure 12: Alternative shipping investment technologies



Note: All impulse-response functions are expressed as log-deviations from their respective steady-state values (except for the shipping investment rate, which is a percent deviation).

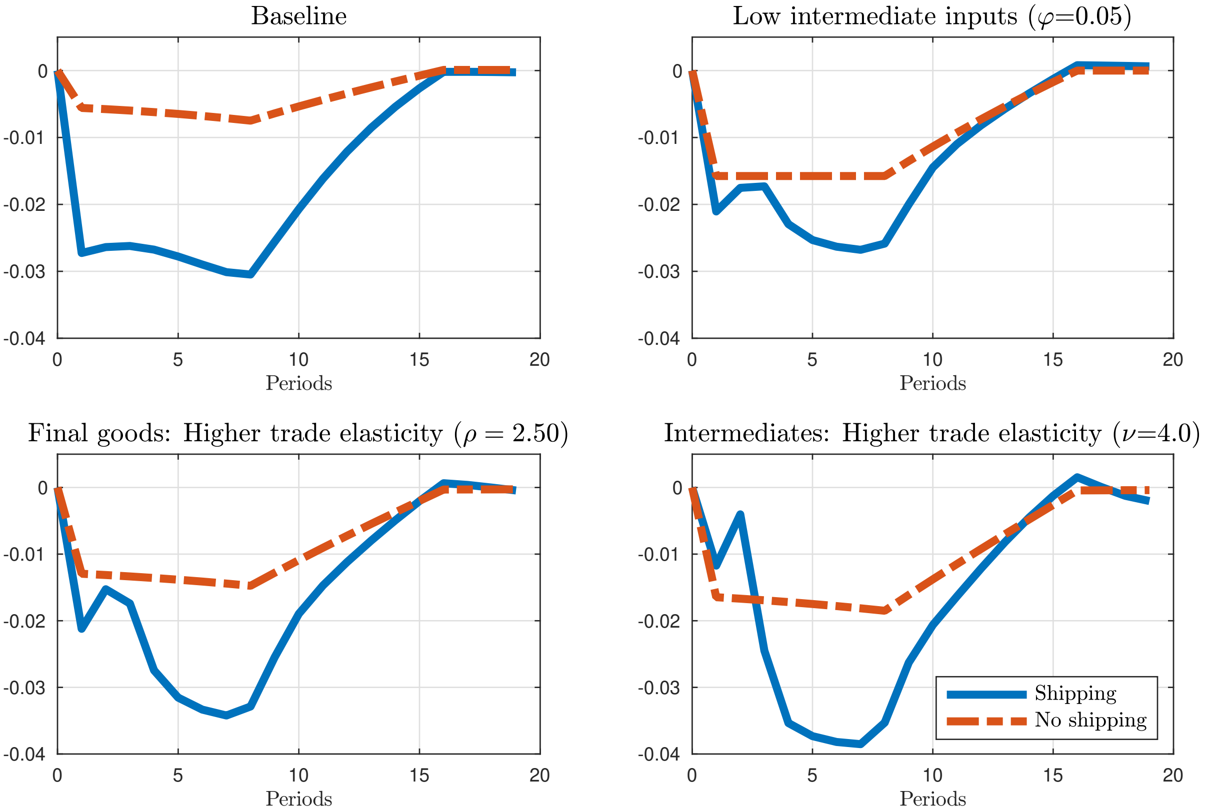
perfectly correlated across countries — thus, we refer to it as an economy subject to "global shocks." Table 4 reports the implications of these economies for the fluctuations of shipping costs and real GDP.

We find that the local vs. global nature of the productivity shocks is critical for shipping volatility and its aggregate implications. In particular, in a world where countries have uncorrelated shocks, productivity shocks are country-specific, so shipping capacity is rarely subject to extended periods of significant excess demand. In contrast, if productivity shocks are global, economic booms in the world economy are periods in which both countries have high demand for trade and shipping services, leading to substantial changes in shipping costs. Shipping costs are 47% more volatile in the economy with global shocks. As a result, we find that the aggregate implications of global shipping ridigities become much larger in such case. For instance, while real GDP is 14.1% more volatile without shipping rigidities when subject to local shocks, its volatility increases by 20.6% in the absence of shipping when subject to global shocks.

8.2 Shipping production lags and shipping cost volatility

Figure 12 shows that the dynamics of shipping costs are driven by several key factors, including the time required to expand shipping capacity and the costs associated with adjusting capacity. In this section, we investigate how these factors affect the volatility of shipping costs in our business cycle analysis. Specifically,

Figure 13: Real GDP under alternative model specifications



Note: All impulse-response functions are expressed as log-deviations from their respective steady-state values. "Baseline" denotes the dynamics implied by the model with endogenous shipping capacity, while "No shipping" denotes the dynamics implied by a model with perfectly elastic shipping supply.

we reduce the shipping production lag from six quarters (baseline) to one quarter and remove shipping adjustment costs. We compute the results in two ways: first, by re-estimating the model parameters to match the target moments under these constraints, and second, by keeping the parameters unchanged from their baseline values.

Table 5 presents the ratio of shipping cost volatility to GDP volatility across the different specifications. In the baseline model, this ratio is 7.08. When we reduce the shipping production lag and remove adjustment costs, the volatility of shipping costs decreases significantly. In both the re-estimated and fixed-parameter versions of the model, the volatility ratio falls to approximately 4.9, representing a reduction of around 30%. These results indicate that time-to-build and adjustment costs play a critical role in amplifying the volatility of shipping costs by limiting the ability of firms to adjust shipping capacity in response to demand shocks.

These results suggest that time-to-build and adjustment costs play a more significant role in amplifying shipping cost volatility than previously documented. In particular, while our findings are broadly consistent with the results in Kalouptsidi (2014), their analysis shows that reducing the shipping production lag to one period results in a shipping cost volatility that is 14% lower. While such analysis focuses on partial

Table 4: Local vs. global shocks

	Local	Global
Std. dev. shipping costs relative to real GDP		
Baseline	7.08	10.42
No shipping	—	—
Std. dev. real GDP		
Baseline	1.92	1.80
No shipping	2.19	2.17

Note: "Local" refers to the baseline economy without productivity spillovers across countries, while "Global" refers to the economy with perfectly correlated productivity shocks across countries.

Table 5: Shipping cost volatility relative to GDP volatility

	Std. dev. shipping costs	% Change from baseline
Baseline model	7.08	-
$J = 1$, No adjustment costs, re-estimated	4.91	-30.7%
$J = 1$, No adjustment costs, fixed parameters	4.88	-31.1%

Note: The standard deviation of shipping costs is expressed relative to the standard deviation of GDP.

equilibrium dynamics, our general equilibrium framework suggests that the interaction between shipping capacity adjustments and aggregate economic conditions can amplify shipping cost volatility further. The key differences are that, in a general equilibrium setting, shipping costs must adjust to clear the market, and changes in the shipping production technology can additionally alter the response of the demand for shipping services relative to what is estimated empirically.

References

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