Batten Down the Hatches:

The macroeconomic effects of maritime shocks:

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Abstract

From the Suez Canal blockage to the Covid-19 lockdowns, recent events showed that turmoil in maritime transportation can turn into macroeconomic disruptions. Some argue that since these supply chain shocks will eventually dissipate, the effects on aggregate variables is transitory. Is this the case for small open economies? This paper investigates the macroeconomic effects of maritime transportation shocks in the case of Chile. Leveraging high-frequency customs data and port-level statistics, I identify these shocks using a strategy based on the inelastic short-term supply of vessels embeded in a SVAR framework. I then use local projections to estimate the dynamic impact of shipping disruptions on trade flows, industrial production, employment, and prices. The results reveal that maritime shocks significantly affect both port operations and broader macroeconomic aggregates, with notable implications for trade patterns, producer prices, and sectoral output.

Keywords: Shipping, International Trade, Supply Chains

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1 Introduction

How can port infrastructure mitigate the propagation of shipping shocks through the economy? Recent disruptions, such as the COVID-19 pandemic and the Red Sea crisis, have highlighted the vulnerabilities created by the reliance of maritime transportation on critical nodes. These events triggered widespread delays in container movements, leading to congested ports overwhelmed by increased inflows of ships. One of the most effective tools for mitigating the impact and amplification of such shocks is port infrastructure, as efficient operations can process arriving ships more rapidly under rising congestion. However, despite growing attention to global supply chain disruptions, relatively little is known about how port-specific factors—such as operational efficiency and infrastructure capacity—interact with these shocks to influence trade, prices, and production.

This paper addresses this gap by analyzing the dynamic effects of maritime transportation shocks in a small open economy, with Chile as a case study. First, I identify shocks to the number of ships arriving at every port, using a unique dataset of high-frequency customs data. I do this by using a structural vector-autoregression (SVAR) to model the shipping market. Then, I examines how these shocks propagate through the economy by estimating a series of local projections on key variables, including port operations, international trade, inflation, and other aggregate macroeconomic indicators.

To identify shipping arrival shocks, I estimate an SVAR model of the transportation market with timing restrictions. This framework accounts for the dynamic relationships between the number of ships and the average freight rates for both arrivals and departures. Since higher freight rates can increase the inflow of ships, reduced-form estimates may suffer from potential simultaneity bias. The identification strategy addresses this by assuming a short-term inelastic supply of vessels: within a one-week timespan, the number of ships arriving at Chilean ports is not influenced by other market variables, such as freight rates. Structural decomposition of the variance-covariance matrix, following the methodology in Kilian (2009), allows me to isolate innovations to the number of arrivals that are driven solely by exogenous shocks to the supply of ships available for international trade, such as favorable weather conditions or strikes at foreign ports. Positive shocks are interpreted as increasing congestion, while negative shocks reflect delays.

I trace the dynamic effects of shipping arrival shocks, I estimate local projections that capture the response of key economic variables over time. This approach allows me to map the propagation of these shocks throughout the economy, from their initial impact on port operations to broader macroeconomic outcomes. The analysis begins with port operations, examining variables such as vessel delays and shifts in port worker activity. Next, it captures the effects on international trade, differentiating between key sectors such as mining, manufacturing, and agriculture. These trade disruptions then feed into producer prices, reflecting sector-specific supply constraints, and ultimately affect aggregate macroeconomic indicators, including inflation, unemployment, and industrial production. By systematically tracing these steps, local projections provide a detailed understanding of how maritime shocks influence the economy over time.

I find that a positive shock to ship arrivals has effects on ports, goods trade and macroeconomic aggregates. Port operations exhibit limited immediate responses to these shocks, with no significant change in the number of days ships spend at ports. However, after 15 months, the number of port workers begins to decline, dropping by 4%. In terms of international trade, congestion shocks lead to a long-run increase in imports of 5%, driven primarily by a rise in capital goods imports, which rise by 10%, and intermediate goods imports, which do so by 5%. Exports also increase by 5%, largely attributed to the mining sector. On the macroeconomic level, industrial production experiences a short-term decline over the first 5 months but subsequently recovers to its initial level, while the unemployment rate remains relatively stable throughout. Finally, we observe a small but steady decline in consumer prices (CPI) beginning 10 months after the shock. These results highlight the nuanced ways in which maritime shocks propagate through different economic channels, offering valuable insights into their broader economic implications.

Related literature This paper contributes to recent studies that study the macroeconomic implications of supply chain disruptions. Boehm, Flaaen and Pandalai-Nayar (2019) examine the 2011 Tōhoku earthquake in Japan to show how upstream shocks propagate through input linkages to reduce output, profitability, and employment in more downstream producers. They also highlights the role of geographic and sectoral diversification in mitigating these impacts. The study in Martincus and Blyde (2013) also examines the impact of a natural disaster, a major earthquake in Peru, on transportation networks and how roads significantly reduced export volumes, particularly for time-sensitive and high-value goods. Further research has also explored the effects of supply chain disruptions on financial markets, as in Smirnyagin and Tsyvinski (2022), who show that firms with greater exposure to disrupted supply chains experience significant declines in market valuation.

In the case of maritime transportation, high-frequency shipping data has facilitated real-time monitoring of seaborne trade, as demonstrated by Cerdeiro et al. (2020), and congestion patterns, as explored in Bai et al. (2024). The latter use AIS data on global shipping traffic to construct a measure of supply chain disruptions, and estimate their impact on inflation and output using a Bayesian structural vector autoregression (SVAR) model. Their findings focus on the role of monetary policy, instead of port infrastructure, in mitigating the adverse effects of shipping shocks. González, Luttini and Rojas (2023) study exogenous increases in freight rates and their effect on domestic prices across several sectors, showing that tradable goods, especially food and manufactured products, experienced the highest price increases. The analysis Nomikos and Tsouknidis (2023) focuses on shipping investments and shows that demand shocks primarily drive short-term volatility in freight rates, while supply shocks have a more persistent influence on market dynamics and investment decisions.

Recent studies specifically analyze the role of infrastructure investments. Brancaccio, Kalouptsidi and Papageorgiou (2024) use queueing theory to model port operations and find that increasing port capacity by 1% can increase trade by 1.3% in the case of the US. They also find these investments can have significant spillovers as they lower the usage of other ports, therefore reducing congestion all across the economy. This is consistent with the fact that maritime trade exhibits a hub-and-spoke network, as shown in Ganapati, Wong and Ziv (2024), where a small number of entrepôts manage over 90% of indirect trade. Efficiency improvements or disruptions at these locations can therefore lead to repercussions across the entire network.

2 Econometric Model

2.1 Vessel Arrival Shocks

To estimate how a small open economy responds to unexpected shocks in the number of ships arriving at its ports, this paper begins by identifying these shocks. As a small open economy without a shipbuilding industry, Chile relies on arrivals as the main source of supply for maritime transportation services. Therefore, for any given week w, the number of arrivals $vess_w^{arriv}$ will directly impact the number of departing vessels $vess_w^{depart}$. In addition, departures capture export capacity and the ability of ports to handle outgoing goods, providing a measure of throughput efficiency. Consequently, current departures will affect future arrivals as ports are more or less congested. The supply and demand of shipping services, as measured by these variables, will determine the price in this market: freight rates for imports and exports, $rate_w^{arriv}$ and $rate_w^{depart}$ respectively. Furthermore, these prices can influence the number of vessels passing through Chilean ports in future weeks, as shipping companies are drawn to routes offering higher rates.

I model the shipping market using a structural VAR structure that captures the dynamics described above. Define a vector $\boldsymbol{X}_w$ comprising the four variables discussed earlier – the number of vessels and the freight rates for arrivals and departures – and assume it follows a linear process:

$$\boldsymbol{A}_0 \boldsymbol{X}_w = \boldsymbol{\alpha}_0 + \sum_{l=1}^{p} \boldsymbol{\alpha}_l \cdot \boldsymbol{X}_{w-l} + \boldsymbol{\varepsilon}_w \tag{1}$$

where $\boldsymbol{A}_0$ is a non-singular matrix and $\boldsymbol{\alpha}_l$ is a $4 \times 4p$ matrix which, along with $\boldsymbol{A}_p$, describes the relation between present and past values $\boldsymbol{X}_w$. Furthermore, $\boldsymbol{\varepsilon}_w$ is a vector of structural innovations uncorrelated across time, with $E[\boldsymbol{\varepsilon}_w] = 0$ and $E[\boldsymbol{\varepsilon}'_w \boldsymbol{\varepsilon}_w] = I$. The reduced form of the model above is given by:

$$\boldsymbol{X}_w = \sum_{l=1}^{p} \boldsymbol{\delta}_l \cdot \boldsymbol{X}_{w-l} + \boldsymbol{B}\boldsymbol{\varepsilon}_w \tag{2}$$

where $\boldsymbol{B} = \boldsymbol{A}_0^{-1}$ and $\boldsymbol{\delta}_l = \boldsymbol{A}_0^{-1}\boldsymbol{\alpha}_l$.

Let $\boldsymbol{u}_w$ be the reduced-form residuals. After estimating equation 2 we need to identify $\boldsymbol{B}$ to obtain the structural shock to vessel arrivals $\varepsilon_w^{vess,arriv}$. To achieve this, I assume this matrix has a recursive structure so that the residuals can be written as:

$$\underbrace{\begin{bmatrix} u_w^{vess,arriv} \\ u_w^{rate,arriv} \\ u_w^{vess,depart} \\ u_w^{rate,depart} \end{bmatrix}}_{\boldsymbol{u}_w} = \underbrace{\begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}}_{\boldsymbol{B}} \cdot \underbrace{\begin{bmatrix} \varepsilon_w^{vess,arriv} \\ \varepsilon_w^{rate,arriv} \\ \varepsilon_w^{vess,depart} \\ \varepsilon_w^{rate,depart} \end{bmatrix}}_{\boldsymbol{\varepsilon}_w} \tag{3}$$

The main identifying assumption is that the supply of ships, as measured by the number of vessels arriving at Chilean ports, is highly inelastic in the span of a week. In other words, arrivals will only depend on structural shocks $\varepsilon_w^{vess,arriv}$, such as weather changes en-route, and are not affected by other factors in the shipping market, such as prices.

I also assume that innovations to importing freight rates are independent of factors influencing shipping services for exports. For these services, I assume that the residual in the number of departing vessels depends on shocks to arriving ships $\varepsilon_w^{vess,arriv}$ as well as their freight rates $\varepsilon_w^{rate,arriv}$. However, similar to arrivals, I assume that changes in export freight rates driven by unexpected shocks $\varepsilon_w^{rate,depart}$ do not affect departures within the same week, as these schedules are typically planned in advance. Finally, innovations to the rate paid by exporters are assumed to depend on all four unexpected shocks within the same week.

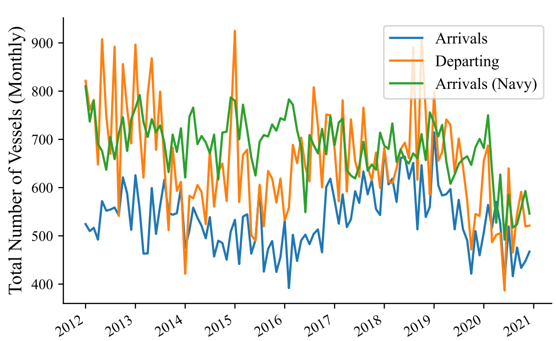
Once I estimate the weekly shocks to ship arrivals, I obtain the monthly average $\varepsilon_t^{vess,arriv}$ to aggregate them at the same frequency of other variables of interest. Thus, to estimate the dynamic response of y_t to these shocks, I estimate the following local-projection:

$$\Delta y_{t+h,t-1} = \beta_0^{(h)} + \beta_1^{(h)} \cdot \varepsilon_t^{vess,arriv} + \sum_{l=1}^{L} \gamma_l^{(h)} \cdot \Delta y_{t-l} + e_t \tag{4}$$

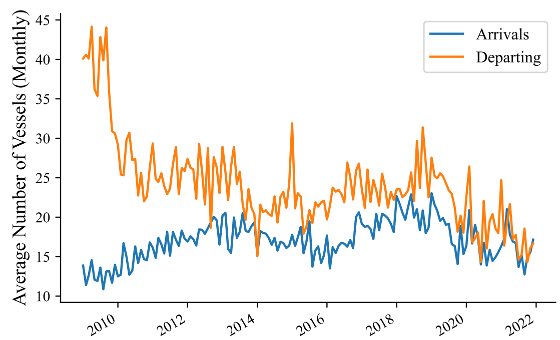
where h is the number of months after the shock and $\Delta y_{t+h,t-1} = y_{t+h} - y_{t-1}$. "Using this framework, I analyze how the shock propagates throughout the economy by examining a set of dependent variables. Specifically, I study the response of port operations, focusing on factors such as the number of workers and the duration of ship stays at ports. I then assess the impact on imports and exports, exploring whether the response differs across various types of goods. Finally, I estimate the effect of these shocks on aggregate economic variables, including industrial production and unemployment.

2.2 Data

The primary data source is customs documentation, specifically the *Document Unico de Salida* (DUS) and *Declaracion de Ingreso* (DIN) forms that exporters and importers are required to complete for outbound and inbound merchandise respectively. These forms provide detailed information at the shipment level, including the firm's unique identification number and location, the items traded (captured through 8-digit HS codes), and the corresponding free-on-board (FOB) values, weights, and currencies. This granularity allows for precise tracking of trade flows, enabling the identification of patterns and anomalies in import and export activity over time. To complement the customs data, monthly statistics published by the Chilean Navy provide aggregate measures of port activity. These include the number of arriving vessels, the number of workers employed at ports, and the total hours ships remain in port. These variables are crucial for understanding the operational capacity and congestion levels at ports, which influence the broader dynamics of trade and shipping services.



(A) Total Monthly Vessels



(B) Average Daily Vessels

Figure 1. Number of Ships

To identify arrival shocks, I first determine each vessel arriving at Chilean ports. The shipment-level dataset provides comprehensive trip-level information, including the type of goods transported, loading and unloading dates, transportation company, and ports of origin and destination. However, since there is no unique ship identifier, I define each *transportation company-manifest ID-port* combination as a vessel, based on either the port of arrival or departure. For arriving vessels, I use the earliest unloading date as the arrival date, while for departing ships, I use the last loading date. This approach enables the reconstruction of shipping routes and timelines, offering insights into the efficiency and patterns of maritime logistics. The left panel of Figure 1 illustrates the total number of

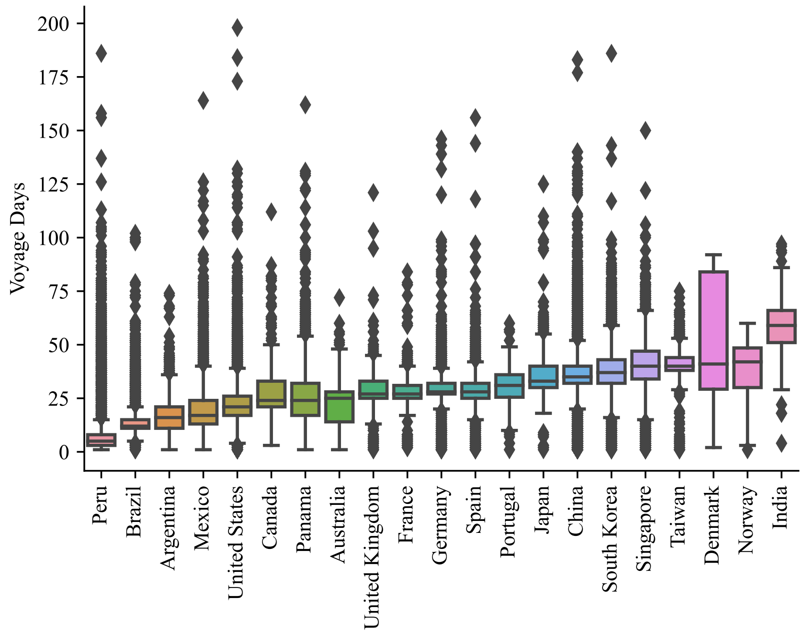


Figure 2. Last Trip Duration

arrivals and departures each month, alongside the counts extracted from Navy reports. The right panel shows that the average daily number of arrivals each month closely matches the number of departures.

Using dates, we can gain several insights into the duration of shipping to Chile. In addition to unloading dates, the import shipment forms provide the loading date along with the port of departure. Figure 2 illustrates the impact of geographic proximity, with nearby Latin American countries like Peru and Brazil showing shorter and more consistent voyage times, reflecting simpler logistics and shorter distances. The figure also highlights greater variability in shipping durations for distant countries like China and the United States, where longer routes and factors such as port congestion and weather conditions contribute to fluctuations. Finally, the presence of outliers in some countries' voyage durations underscores the potential for occasional disruptions or inefficiencies, independent of distance, such as delays at the port of origin or en route.

The table in Table 1 compares the significance of ports visited by ships en route to Chile, analyzing both all intermediate stops and the final port before arrival. One notable trend is that freight costs per kilogram increase with distance; shipments originating from ports in the Americas tend to have lower transportation costs compared to those from Asia, reflecting shorter and less complex routes. The table also reveals the shifting importance of ports depending on the perspective taken. When considering all ports that ships visit, Shanghai emerges as the most significant, with over 16,000 ships passing through. However, when focusing solely on the last port visited before arrival in Chile, Callao takes the lead

	Intermediate and Last Ports			Last Port Only		
	Imports (FOB)	Freight Cost (USD/kg)	Ships	Imports (FOB)	Freight Cost (USD/kg)	Ships
HOUSTON (USA)	4,331.99	0.05	3,019	4,125.42	0.04	2,113
SHANGAI (China)	3,065.51	0.23	16,282	1,003.18	0.24	7,340
CALLAO (Peru)	2,519.09	0.03	13,280	2,187.60	0.03	11,414
MANZANILLO (Mexico)	1,709.76	0.08	9,380	756.37	0.07	5,003
BUSAN (S. Korea)	1,627.36	0.18	10,894	381.71	0.16	4,123
HAMBURG (Germany)	1,319.22	0.13	5,548	254.11	0.11	1,796
HONG KONG (SAR)	1,198.53	0.21	8,586	259.43	0.15	2,350
GUAYAQUIL (Ecuador)	516.66	0.06	5,568	408.74	0.06	4,413

Source: DUS and DIN forms. FOB value in million USD. Sample: 2009-2021.

Table 1 Caption

with 11,414 ships, underscoring its role as a key final departure point. Additionally, the data highlight significant inequality in the economic importance of ports. For instance, ships passing through Houston account for import values eight times greater than those passing through Guayaquil, demonstrating the concentration of trade flows in a few highly significant ports.

3 Empirical Results

The analysis reveals that maritime shocks had nuanced impacts on port operations and trade. As Figure 3 shows, the number of days ships spent in ports experienced a minor increase of 0.05% after 20 months, indicating slight delays in port efficiency. Interestingly, the number of workers at ports saw no immediate effect but later declined by 0.04% starting the decrease one year after the shock. This decline, despite increased ship arrivals, may reflect operational bottlenecks caused by longer port stays, which reduce the throughput of ships and necessitate fewer workers per shift. Additionally, ports may have stretched their workforce over extended periods, shifted workers to address delays, or employed cost-saving measures due to higher operational expenses. The interplay between increased delays and declining labor suggests an adaptation to shocks through changes in workforce deployment and operational strategies.

After a shipping arrival shock, trade flows in certain sectors respond more than others. Total imports increased by 0.05% after 10 months and remained elevated, driven primarily by a sustained rise in capital goods imports, which grew by 0.10% as Figure 4 shows. Intermediate goods also saw a delayed but steady increase of 0.05%, reflecting ongoing industrial and manufacturing demands. However, consumption goods imports showed no significant change, possibly due to reduced consumer spending or stabilized inventories in this sector. The increase in imports of capital and intermediate goods may also indicate heightened inventory demand as firms mitigate future supply chain uncertainties by stockpiling essential materials and equipment.

Tradable sectors have the capacity to adapt and thrive despite shipping disruptions as

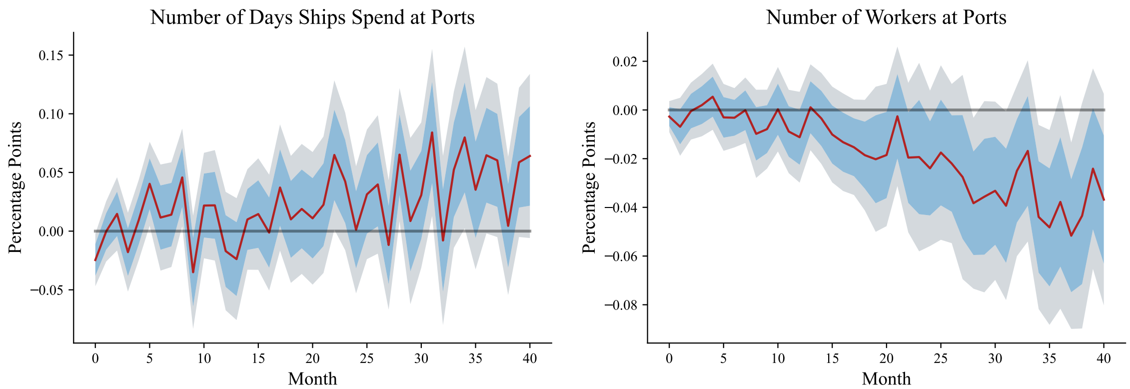


Figure 3. Port Operations

Figure 4 shows. After a shipping arrival shock, exports rise by 0.05% after 15 months, led by an increase of mining (0.05%) and manufacturing (0.06%). This export growth may reflect strategic prioritization of high-value goods during periods of congestion, as well as exporters in the main tradable sector leveraging the sudden increase in ship availability to clear backlogs and intensify shipments. The resilience and importance of sectors like mining, combined with potential price increases for tradable goods in global markets, may incentivize producers to maximize export volumes to capitalize on higher margins.

Maritime shocks had notable but varied effects on macroeconomic indicators, reflecting the capacity of small open economies to absorb shipping disruptions. For example, in Figure 5 industrial production experienced an initial drop of 0.01% after five months, likely reflecting disruptions in supply chains and reduced manufacturing activity. However, this decline was eventually reversed as firms adapted to the changing conditions, indicating resilience in industrial output. Unemployment, in contrast, showed no measurable reaction, suggesting limited spillover effects from maritime shocks to the broader labor market.

The arrival shock also affects prices across sectors, though the effects are modest. I find that overall producer prices did not exhibit a large response, but the mining Producer Price Index (PPI) dropped by 0.05% after two years, and the agriculture PPI declined by 0.04%, as shown in Figure 6. These declines reflect reduced input costs in these export-oriented sectors due to increased availability of imported machinery, equipment, and fertilizers, as we saw with the increase of imports. Additionally, the easing of delays in receiving imported goods and faster turnaround times could have lowered associated costs, such as storage and demurrage fees. Producers may also have substituted higher-cost domestic inputs with more affordable imported alternatives, further reducing production costs. However, consumer prices (CPI) showed a slight decrease but did not exhibit an economically significant response, suggesting limited transmission of maritime shocks to consumer markets. These findings emphasize the differentiated transmission of shipping disruptions, with input cost reductions playing a significant role in key export sectors, while consumer prices remained

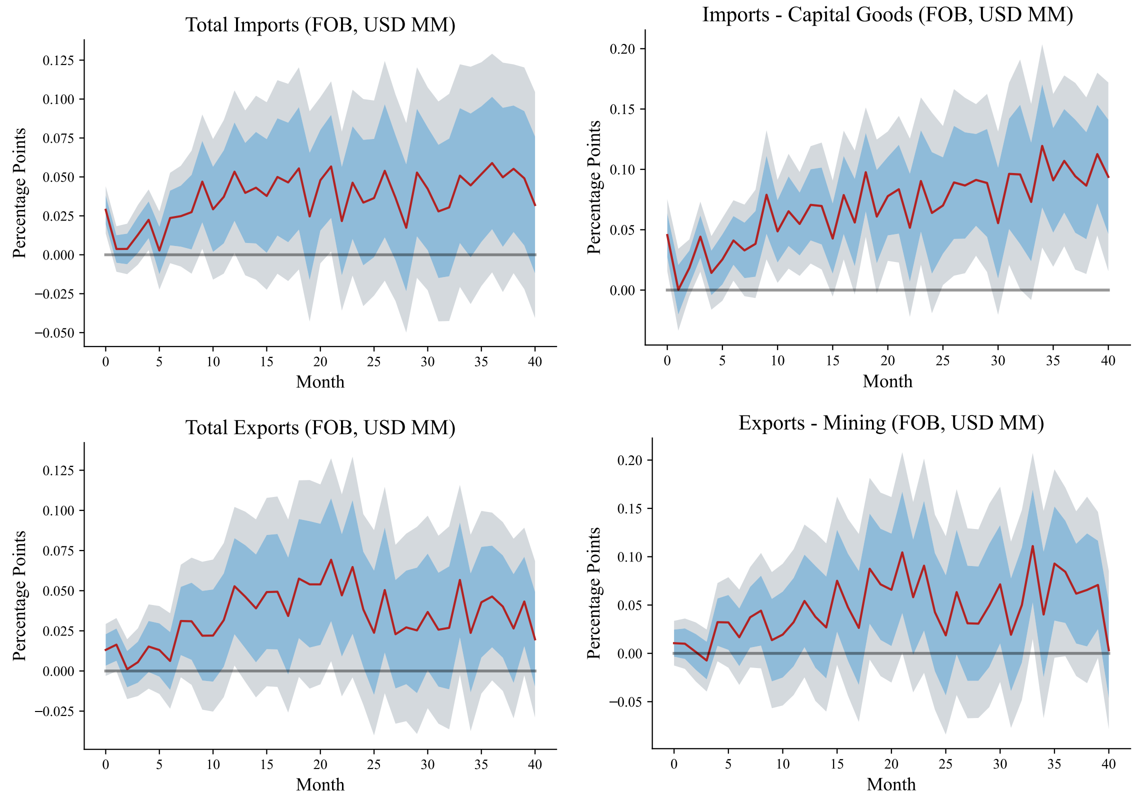


FIGURE 4. INTERNATIONAL TRADE

relatively stable.

4 Conclusion

This paper highlights the significant and lasting impacts of maritime transportation shocks on the macroeconomy, particularly within small open economies like Chile. By leveraging detailed daily customs data and employing timing restrictions to identify shipping supply shocks, I establish a robust connection between port operations and broader economic indicators, including industrial production, trade flows, and inflation. These findings emphasize the critical role of maritime infrastructure in economic resilience and policy formulation, especially amidst global supply chain disruptions. Future work aims to refine the methodology further by incorporating demand controls and developing innovative instruments to distinguish between supply constraints and logistical delays, thus deepening our understanding of these pivotal economic forces.

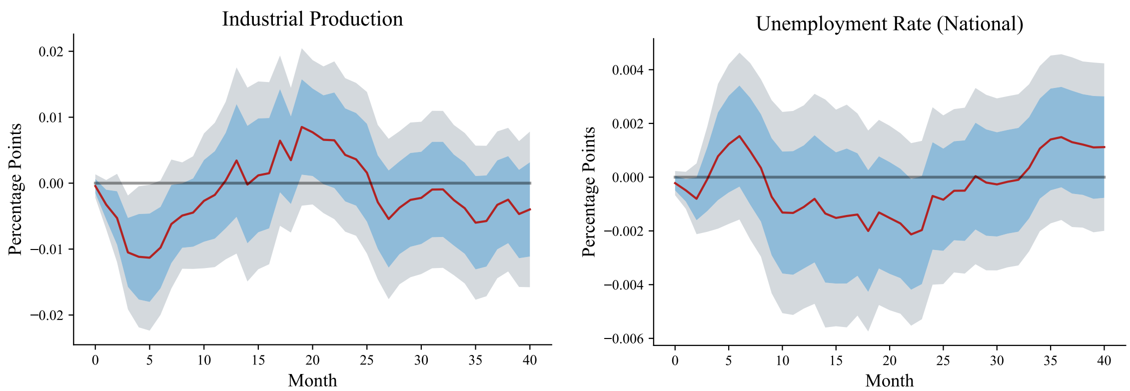


FIGURE 5. PRODUCTION AND UNEMPLOYMENT

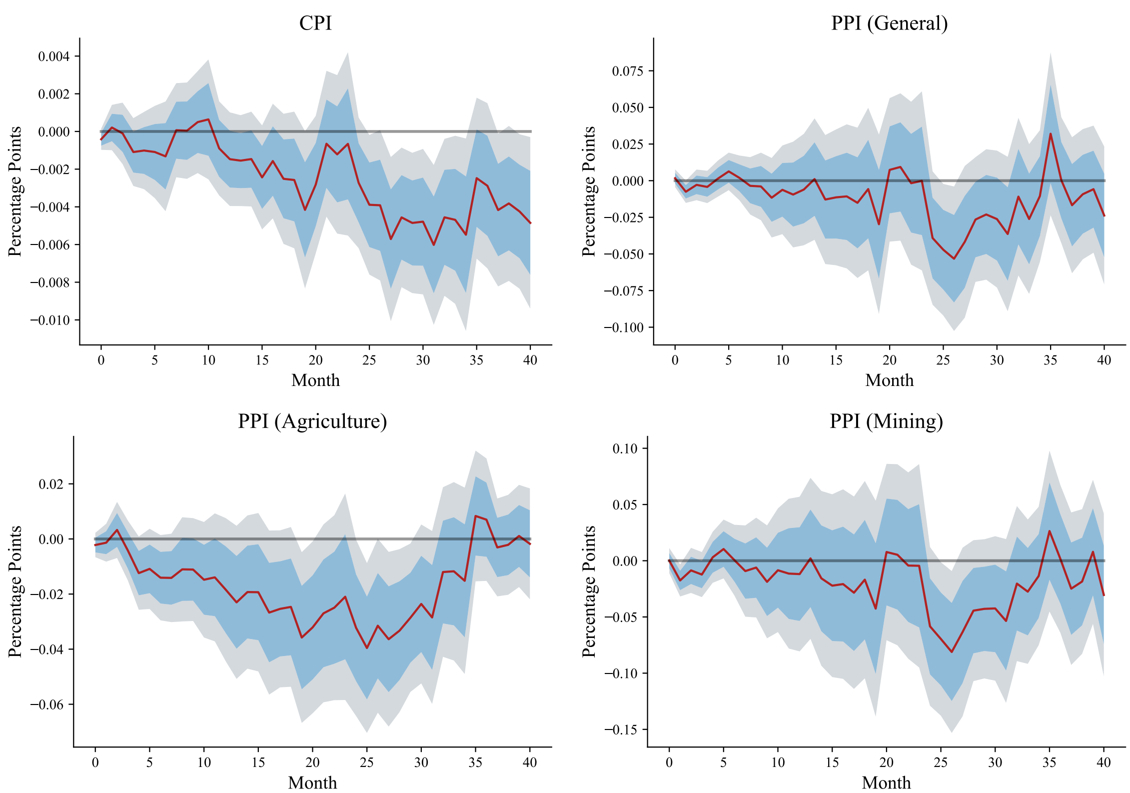


FIGURE 6. PRICES

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