On the Aggregate Effects of Global and Local Supply Chain Bottlenecks: Delays, Trade, and Inventories*

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1 Introduction

The reopening of the world economy post-COVID has been hampered by large, unprecedented, supply chain disruptions that have substantially increased both the costs and time involved in moving goods within and across borders. For example, through August of 2021, the costs of shipping goods from China to the United States by air have risen by about 50 percent while the costs of long-distance trucking in the United States have risen almost 12 percent since the start of the pandemic. Accompanying these cost increases has been a large increase in delivery delays. The ISM delivery times index shows that the average lead time for materials and inputs has risen by about 30 days in the United States and similarly in Europe. While a substantial focus has been on delays at ports, which are processing record trade volumes, these delays are also present in purely domestic transactions. The higher costs and longer lead times come at a time in which inventories are leaner than they've ever been in the United States, and these forces have contributed to lower economic activity and increasing inflation. Global auto production, for example, has fallen dramatically in 2021 as supply disruptions have risen, and recent forecasts have downgraded the production substantially through the beginning of 2023 and are predicting expanded production after 2023.[1]

While many of the supply disruptions from the past year are viewed as "transitory" and expected to dissipate over the next six months to a year, the recent and near-term aggregate implications are unknown. Moreover, there is the potential for the experience to cause a shift in the global organization of supply chains towards either more local, faster sourcing either through a re-evaluation of the risks at the firm-level or outright policy directives. The current U.S. administration, for example, has developed a task force to develop recommendations to alleviate current disruptions and prevent future disruptions. While

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[1]On September 16, IHS Markit reduced projections of 2022 global auto production by 6.2% in 2021, and by 9.3% in 2022, and 1.1% in 2023. For 2023, the reductions are front-loaded, as supply chains are expected to be normalized and pent-up demand and restocking will boost estimates for 2024 and 2025.

policy recommendations are scant, past supply disruptions have been met with the creation of stockpiles and subsidies for domestic investment and changes in trade policy.[2]

The sources of the current supply disruptions are varied. Macroeconomic factors are certainly at play. The COVID shutdowns in 2020 led to a substantial depletion of inventories that have not yet been rebuilt. The pent-up demand and stimulus associated with the re-opening of the economy have stretched infrastructure, which in some cases had been operating at reduced capacity owing to public health and travel restrictions. Some of these capacity constraints are quite severe owing to the very uneven demand for products from COVID. These macroeconomic factors have allowed seemingly microeconomic shocks to propagate. For instance, the Suez canal was blocked temporarily in April, and large ports in China and elsewhere have been shut down by COVID outbreaks.

A key challenge to the analysis of the current global conditions is that the unique features of the current environment—increased delivery times and depleted inventories—are not included in the standard macroeconomic and trade models used in policy analysis. Moreover, a purely empirical analysis is challenging given the unprecedented size and global nature of the shocks. Our aim in this project is to study the aggregate effects of the current supply chain disruptions, as well as possible policy responses, in the United States and the global economy in a quantitative general equilibrium model that is disciplined by microeconomic data on firm behavior in the face of supply risks and costs.

We extend the two country sS inventory model of Alessandria et al. (2010b) to include a rich input-output structure and sectoral heterogeneity in the use and consumption of domestic intermediates. This model has been shown to capture the cyclical behavior of trade, inventories, prices, and aggregate economic activity in the Great Recession and, more generally, over the cycle. A key feature of the approach is that it explicitly models the differential costs in time, resources, and risk for domestic and international transactions. These risks are reflected in the different inventory management approaches by type of transaction and can be disciplined by firm-level data on inventories and ordering behavior. We know, for example, that goods involved in international trade are held in inventory about twice as long as goods in domestic transactions(Alessandria et al., 2010a; Nadais, 2017; Khan and Khederlarian, 2020), and that inventory accumulation and depletion in international transactions are particularly sensitive to business cycles and policy shocks (Khan and Khederlarian, 2019; Alessandria et al., 2019).

The rest of this proposal is split into two sections. We first describe the current state of shipping delays and costs, inventories, and trade. A key takeaway is that the changes we observe today are unprecedented in the last 30 years. In section two, we describe the model and some preliminary results from shocks to the timeliness of domestic and international trade. To date, we have developed and calibrated a model that captures the salient features of the pattern of trade between the United States and the rest of the world that is disciplined by trade flows and heterogeneous inventory holdings across firms and across domestic and

[2]Following the Oil Embargo of 1973–74, the U.S. established the Strategic Petroleum Reserve in 1975. Discussions of petroleum reserves were active after previous supply disruptions in 1944, 1956, and 1970. The United States also imposed restrictions on oil exports and raised taxes on U.S. petroleum imports.

international transactions. We have used the model to study the impact of transitory increases in domestic and international delivery times that double delivery times but are expected to dissipate in a year. These delays can be quite contractionary. For instance, adding 45 days to international shipments will reduce employment by nearly 8 percent in the quarter of impact but boost employment by 1 percent three quarters hence. When we increase domestic lead times by 23 days, the impact nearly triples. Our model allows us to study how these effects are influenced by the timing of the shock and the current level of inventories.

2 Data

We briefly summarize some important features of the the current state of the U.S. economy (as of August/September 2021) as related to depleted inventories and increases in shipping times and shipping costs. A key feature for all of these variables is that there are some unprecedented changes of late.

The current distribution of inventories across sectors is quite unusual with retail stocks at record lows. Figure 1 plots a time series of U.S. inventory-sales ratios by three major sectors: manufacturing, wholesale and retail. Two things are apparent. First, inventory-sales ratios have fallen in all sectors since the start of the crisis, but the decline has been spectacular in the retail sector, as retailers have moved from about 1.5 months of inventory to about 1.1 months. Second, the traditional structure of inventory holdings across sectors has been upended with retail, normally the most inventory-intensive industry, becoming the least inventory-intensive. As an example, Figure 2 shows that the inventory-sales ratio of autos has reached a record low. There are important challenges to rebuilding these stocks of autos in the near future.

There is robust anecdotal evidence that it is taking longer to get inputs for production and that these delays vary across industries. For more concrete evidence, we plot the ISM delivery times index which is a survey of purchasing manager times from order to delivery for important inputs. A nice feature of this series is that it yields a time series of the delays in a way that we can discipline the model. Figure 3 shows that delivery times were stable in the 2000s at about 45-50 days, drifted up to about 60 days following the Great Recession, and have risen to nearly 90 days since the start of 2021. Looking forward, it is useful to note that the previous increase following the Great Recession was quite persistent. A complementary, and longer measure of delivery times comes from the long-running Philadelphia Fed Business Outlook survey. This is a diffusion index that shows the difference between firms that are experiencing longer and shorter delivery times. This series also shows a substantial increase to the highest levels ever.

Shipping costs, domestic and international, have risen spectacularly in the last year. We take a conservative approach to measuring these shipping costs by focusing on U.S. price indices rather than route-specific measures. Figure 4 plots the percentage change in shipping costs since the start of COVID for international and domestic transactions. Air freight prices have risen by about 50 percent for products from Asia and about half that for products from Europe. These costs spiked with the onset of COVID and have not moderated. Part of this increase certainly reflects the reduced capacity from reductions in air travel but another

part reflects increasing demand for faster transport to compensate for the delays in other modes of transport. Domestic transportation costs have also grown sharply as the economy has reopened. Based on the PPI for long-distance trucking, domestic trade costs have risen about 12 percent since the onset of COVID after being largely stagnant in the lead up to COVID.

3 Model

In this section, we introduce a two-country dynamic general equilibrium model that embeds an sS inventory model that we will use to study the aggregate effects of global and domestic shipping disruptions. The basic model framework is the inventory adjustment model of Alessandria et al. (2010b), but is extended to include multiple sectors and roundabout production linkages. The key agents in the model are retailers (which we call final goods producers). These firms order domestic and imported inputs to sell in the domestic economy subject to source-specific delays, fixed and variable costs. Unsold goods can be saved by the firm as inventories and sold in future periods, but depreciate with time. Thus, firms are wary of holding too many goods in inventory. At the same time, each time the firm orders new goods, they incur a fixed ordering cost, which gives firms an incentive to order infrequently and hold more goods in inventories. Firms face idiosyncratic demand shocks for their varieties from goods consumers, so their sales in each period are uncertain. Furthermore, new orders do not always arrive in the current period. These two sources of uncertainty affect firm decisions on the timing of orders and the price they set on goods. In general, firms want to avoid stocking out of their products to maximize profits.

3.1 Shipping delays in the model

Firms order goods after observing an idiosyncratic demand shock but before setting prices. Goods ordered at the beginning of the period arrive within the same period with probability μ. With probability $1-\mu$, the goods are delayed and arrive in the next period. We explore the effect of changes in shipping delays by assuming that μ follows an AR1 stochastic process defined by

$$\mu_t = \rho_\mu \mu_{t-1} + (1-\rho_\mu)\bar{\mu} + \varepsilon_{\mu t} \tag{1}$$

where ρ_μ is the persistence of the shock and $\bar{\mu}$ is the steady state probability of goods arriving within the period. Thus, an increase in shipping delays in our model represents a negative value of the shock ε_μ.

3.2 Consumers

We model two symmetric countries populated by representative consumers. Consumers in the Home and Foreign countries make consumption and labor supply decisions every period. They also trade a state-contingent bond for each state η_t, where a history is given by $\eta^t = (\eta_0, \eta_1, ..., \eta_t)$. Consumers form a constant

elasticity of substitution (CES) consumption bundle using domestic (D) and imported (I) varieties. Foreign country variables are denoted with an asterisk. Consumers maximize

$$\sum_t \sum_{\eta^t} \beta^t \pi(\eta^t) \left[\ln C(\eta^t) + \psi \ln(1 - L(\eta^t)) \right] \tag{2}$$

$$\begin{aligned} C(\eta^t) = \Bigg[& \left(\int_0^1 \nu_D(j,\eta^t)^{\frac{1}{\theta}} c_D^c(j,\eta^t)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \\ & + \tau_c^{\frac{1}{\gamma}} \left(\int_0^1 \nu_I(j,\eta^t)^{\frac{1}{\theta}} c_I^c(j,\eta^t)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \Bigg]^{\frac{\gamma}{\gamma-1}} \end{aligned} \tag{3}$$

where $\nu_X(j,\eta^t)$ denotes the demand shock to variety j from source $X \in \{D, I\}$ and c^c denotes the corresponding quantity demanded by the consumer. Home bias in the consumption bundle is governed by τ_c. The elasticity parameters θ and γ denote the degree of substitutability within and across domestic and foreign goods, respectively.

The representative consumer maximizes (2) subject to

$$P_c(\eta^t)C(\eta^t) + \sum_{\eta^{t+1}} Q(\eta^{t+1}|\eta^t)B(\eta^{t+1}) = B(\eta^t) + W(\eta^t)L(\eta^t) + \Pi(\eta^t),$$

where $B(\eta^{t+1})$ denotes the quantity of bonds that pay one unit next period in state η^{t+1} (and zero otherwise) and are priced at $Q(\eta^{t+1})$. The price index of the consumption bundle and wage level are denoted by P_c and W, respectively. Final-goods firms are owned by the consumer and their aggregate profits are denoted by Π.

The consumers problem delivers demand functions for domestic and imported consumption goods of each variety:

$$c_D^c(j,\eta^t) = \left(\frac{p_D(j,\eta^t)}{P_D(\eta^t)} \right)^{-\theta} \left(\frac{P_D(\eta^t)}{P_C(\eta^t)} \right)^{-\gamma} \nu_D(j,\eta^t) C \tag{4}$$

and

$$c_I^c(j,\eta^t) = \left(\frac{p_I(j,\eta^t)}{P_I(\eta^t)} \right)^{-\theta} \left(\frac{P_I(\eta^t)}{P_C(\eta^t)} \right)^{-\gamma} \nu_I(j,\eta^t) \tau_C C, \tag{5}$$

where $P_D(\eta^t)$ is the CES price index of the bundle of domestic goods and $P_I(\eta^t)$ is the CES price index of the bundles of imported goods, defined by

$$P_D(\eta^t)^{1-\theta} = \int_0^1 \nu_D(j,\eta^t) p_D(j,\eta^t)^{1-\theta} dj \qquad \text{and} \qquad P_I(\eta^t)^{1-\theta} = \int_0^1 \nu_I(j,\eta^t) p_I(j,\eta^t)^{1-\theta} dj. \tag{6}$$

The aggregate price $P_c(\eta^t)$ is also a CES price index which includes the price of the domestic and imported bundles:

$$P_C(\eta^t)^{1-\gamma} = P_D(\eta^t)^{1-\gamma} + \tau_C P_I(\eta^t)^{1-\gamma}. \tag{7}$$

3.3 Intermediate-goods Producers

Each economy has a representative intermediate goods sector. Intermediate goods producers operate in a perfectly competitive market and combine labor and a final goods bundle in a roundabout fashion,

$$M(\eta^t) = L_p(\eta^t)^{1-\alpha} Y_m(\eta^t)^{\alpha}, \tag{8}$$

where M and L_p represent the quantity of intermediate goods produced and labor used used in their production. The bundle of final goods used in intermediate-good production is denoted by Y_m,

$$\begin{aligned} Y_m(\eta^t) = \Bigg[& \left(\int_0^1 \nu_D(j,\eta^t)^{\frac{1}{\theta}} c_D^m(j,\eta^t)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \\ & + \tau_m^{\frac{1}{\gamma}} \left(\int_0^1 \nu_I(j,\eta^t)^{\frac{1}{\theta}} c_I^m(j,\eta^t)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}\frac{\gamma-1}{\gamma}} \Bigg]^{\frac{\gamma}{\gamma-1}}, \end{aligned} \tag{9}$$

where ν represents the producer-specific demand shock as in (3). The quantity of varietie j used for materials is denoted by $c^m(j)$. The home bias in materials is captured by τ_m. The differential home bias in consumption and materials allows us to make trade less intensive in consumption goods as observed in the data (Boileau, 1999; Miroudot et al., 2009).

Intermediate-good producers take the wage (W) and final-good price for materials (P_M) as given. The intermediate-good producer's problem delivers demand functions for each variety of final good,

$$c_D^m(j,\eta^t) = \left(\frac{p_D(j,\eta^t)}{P_D(\eta^t)} \right)^{-\theta} \left(\frac{P_D(\eta^t)}{P_M(\eta^t)} \right)^{-\gamma} \nu_D(j,\eta^t) Y_m \tag{10}$$

and

$$c_I^m(j,\eta^t) = \left(\frac{p_I(j,\eta^t)}{P_I(\eta^t)} \right)^{-\theta} \left(\frac{P_I(\eta^t)}{P_M(\eta^t)} \right)^{-\gamma} \nu_I(j,\eta^t) \tau_M Y_m. \tag{11}$$

The CES price index for the aggregate price of material goods is

$$P_M(\eta^t)^{1-\gamma} = P_D(\eta^t)^{1-\gamma} + \tau_M P_I(\eta^t)^{1-\gamma}. \tag{12}$$

3.4 Final-goods Producers

Each country has two final goods sectors for domestic and imported goods. Each sector consists of a unit mass of firms that sell differentiated product and that are heterogeneous in their demand (ν) and inventory holdings (s). In each period, firms decide how much input, z, to order and what price, p, to charge for their differentiated variety.

The lag between order and delivery is modeled as a stochastic process where, with probability $1-\mu$ the order arrives in the current period. If an order does not arrive in the current period, it will arrive with certainty in the next period. The timing is as follows: firms place their input order, they observe whether the

inputs arrive in the same period or not, and finally, they set prices to meet demand. Firms pay a fixed cost ϕ_D or ϕ_I if they order a positive quantity of inputs. Thus, firms have an incentive to order less frequently and save inputs in inventories to meet demand intertemporally. Inventories of domestic firms $s_D(j,\eta^t)$ (and for import firms, $s_I(j,\eta^t)$) depreciate at rate δ. Goods that were ordered but not delivered in the current period also depreciate at the same rate—they depreciate in transit.

A firm cannot sell more goods than it has on hand, so total sales are restricted to sales of inventories and any goods that arrive in the current period. If demand exceeds this value, the firm sells all of its goods on hand and carries zero inventories into the next period. In general, the ending period inventories are carried over to the next period after incurring the depreciation cost.

In the following, we present the problem of the home country's domestic good producer. To highlight the within-period decision, we separate the delivery from the overall state i.e. $\eta^t = (\tilde{\eta}^t, \xi_t)$. Here, ξ_t is an indicator variable which is one if the the input order arrives immediately and zero otherwise. Taking intermediate goods price, ω, and wage level, W, as given, the producers solve,

$$\max_{p_D(j,\eta^t), z_D(j,\tilde{\eta}^t,\xi^{t-1})} \sum_t \sum_{\eta^t} Q(\eta^t) \left[\mu_D p_D(j,\tilde{\eta}^t,0) q_D(j,\tilde{\eta}^t,0) + (1-\mu_D) p_D(j,\tilde{\eta}^t,1) q_D(j,\tilde{\eta}^t,1)\right] \tag{13}$$
$$- \omega(\eta^t) z_D(j,\tilde{\eta}^t,\xi^{t-1}) - W(\eta^t)\phi_D \mathbf{1}_{\{z_D>0\}}$$

$$\text{s.t.} \quad q_D(j,\eta^t) = \min\left[y_D(j,\eta^t), s_D(j,\eta^t) + \xi_t z_D(j,\tilde{\eta}^t,\xi^{t-1})\right]$$

$$s_D(j,\eta^{t+1}) = (1-\delta)(s_D(j,\eta^t) - q_D(j,\eta^t) + z_D(j,\tilde{\eta}^t,\xi^{t-1}))$$

$$y_D(j,\eta^t) = \nu_D(j,\eta^t) \sum_{X\in\{C,M\}} \tau_X \left(\frac{p_D(j,\eta^t)}{P_D(\eta^t)}\right)^{-\theta} \left(\frac{P_D(j,\eta^t)}{P_X(\eta^t)}\right)^{-\gamma} Y_X(\eta^t).$$

3.5 Equilibrium

An equilibrium is as (i) an allocation of aggregate quantities $\{C(\eta^t), B(\eta^t),\ L(\eta^t), M(\eta^t), \pi(\eta^t)\}_{t=0}^{\infty}$, variety-specific factor allocations $\{L_p(j,\eta^t), c_D^m(j,\eta^t), c_I^m(j,\eta^t)\}_{t=0}^{\infty}$ and variety-specific consumption allocations $\{c_D^c(j,\eta^t), c_I^c(j,\eta^t)\}_{t=0}^{\infty}$ as well as variety-specific inventory and ordering allocations $\{\{s_i(j,\eta^t), q_i(j,\eta^t) z_i(j,\tilde{\eta}^t,\varepsilon^{t-1}\}_{i=D,I}$ for both Home and Foreign; (ii) prices of goods and factors $\{\{p_i(j,\eta^t)\}_{i=D,I}, \omega(\eta^t), W(\eta^t)\}_{t=0}^{\infty}$ for both Home and Foreign; and security prices $\{Q(\eta^{t+1}|\eta^t)\}_{t=0}^{\infty}$ such that:

1. Given prices, allocations satisfy the consumers' and intermediate-good and final- good producers' optimization problem in both Home and Foreign.

2. The intermediate-good, final-good, and labor markets clear in each country and the security markets clear.

The market clearing condition for bonds requires zero net supply of bonds, i.e. $B(\eta^t) + B^*(\eta^t) = 0$. The

market clearing of the Home and Foreign intermediate goods requires production to equal orders

$$M(\eta^t) = \int_0^1 z_D(j, \eta^t)dj + \int_0^1 z_I^*(j, \eta^t)dj$$
$$M^*(\eta^t) = \int_0^1 z_D^*(j, \eta^t)dj + \int_0^1 z_I(j, \eta^t)dj.$$

Recall that intermediate good producers sell to both Home and Foreign final good producers. Finally, the labor market clearing condition includes labor used for production and ordering costs

$$L(\eta^t) = L_p(\eta^t) + \int_j \phi_D \mathbf{1}_{z_D(j,\eta^t)}dj + \int_j \phi_I \mathbf{1}_{z_I(j,\eta^t)}dj.$$

4 Aggregate Effects of Shipping Disruptions

In this section, we present some preliminary results from our model on the aggregate effects of an exogenous increase in shipping delays.

4.1 Calibration

The parameter values used in the simulations below are described in Table 1. Some of the parameters are relatively standard in the business cycle literature and hence we assign conventional values. The macro elasticity across Home and Foreign goods (γ) is 2 and the micro elasticity (θ) is 4 (Ruhl, 2008). We set the weight on leisure (ϕ) to match a labor supply of one third in the steady state. We assign the material share in the production of the intermediate good (α) to be 60 percent, a typical value in the literature.

Other parameter values are calibrated to match empirical facts. The home biases of consumption (τ_c) and material production (τ_m) are set to match a trade-to-GDP ratio of 15 percent and a material share of imports of 80%. The fixed cost of ordering the domestic good relative to the imported good is critical in determining the inventory premium of importing. We assign values such that the steady state aggregate inventory-purchase ratio of imported goods is around 2.5 times that of domestic goods (Alessandria et al., 2010b; Nadais, 2017; Khan and Khederlarian, 2020). The aggregate inventory-purchase ratios and ordering frequencies are jointly determined by the the variance of demand, the ordering cost, the depreciation rate and the delivery lags. We follow Alessandria et al. (2010b) in setting the variance of the demand shocks to be 1.5. The depreciation rate is set to 20 percent for the United States (Richardson, 1995). A model period is one quarter, so the discount factor is $0.96^{1/4}$. This implies that the probability of receiving the domestic good in the next quarter yields an average domestic delay of 23 days. International sourcing delivery times are twice as large, 45 days. These parameter values yield an aggregate quarterly inventory-purchase ratio of 1.32, well within the range of observed values for the United States in the past decades and result in a firm level ordering frequency of 0.2 and 0.4 per quarter of the foreign and domestic good, respectively.

4.2 Model Results

Our baseline analysis considers a shock ε_{μ_I} that lowers the probability of within-period delivery of imported goods μ_I to zero from its calibrated value of 0.5 for both countries, which effectively doubles the import delay from 45 days to 90 days on impact. Figures 5 and 6 show the aggregate implications of this shock relative to the steady state (blue lines). In the stationary equilibrium, 50 percent of firms that order inputs get those inputs in the same period, but with the shock, all firms' import orders are delayed. Thus, more firms now face the possibility of a stock out in the period, and they raise the price of the imported goods sold to consumers and intermediate-good producers. In Figure 6, we see that the foreign good price index increases by about 20 percent on impact. The price increase in foreign goods feeds through to inflation in consumer and material prices. Consumer prices grow by more than 5 percent, and the material price, because it is more intensive in imported goods, increases by nearly 10 percent. Finally, the increase in the material prices also feeds through to inflation in intermediate input prices, which grow by 5 percent on impact, so that imported inputs are now more expensive both in terms of time and money.

Widespread inflation has a strong effect on aggregate quantities. Because material prices increase, intermediate-good production falls by more than 10 percent on impact. Inflation in consumer prices leads to a one percent reduction in consumption on impact and a further decrease the next period. Because imports become relatively more expensive than domestic goods, the import share decreases by 20 percent. Finally, total labor decreases on impact both because production is low and because firms delay further orders until the shock begins to subside. The shock we have considered is fairly transitory ($\rho_\mu = 0.5$), and the inflationary and recessionary effects of the shock resolve fairly quickly. Inventories, however, take longer to build back up to their initial values.

As discussed in the introduction, the shipping delays that we observe in the economy today are not restricted to imported goods; Domestic shipping has also been subject to delays. Labor shortages in the trucking industry have decreased capacity and railways are overtaxed with extra cargo. We consider how additional delays in the deliveries of domestic goods affect the aggregate economy in our model. The red dotted lines in Figures 5 and 6 give the aggregate effects when we double the days for delivery for both domestic and imported goods.

Qualitatively, the results are similar to the baseline case with delays in imported goods only. The quantitative effect, however, is much stronger. Final-good producers of both domestic and imported goods now face higher possibilities of stocking out and raise prices on both types of goods, leading to strong inflationary effects throughout the economy. On impact, consumer and material prices rise by 30 percent while intermediate input prices rise by more than 15 percent. Production, consumption, and total labor all decrease between 2.5 to 10 times as much as they did in the model with import delays only.

Finally, we also consider how the effects of the delay to import shocks differs when the economy has lower inventories. Figures 7 and 8 show that inflationary and recessionary pressures on the economy are stronger when the economy starts out with lower inventories. This result is intuitive, as lower inventories

bring firms closer to stocking out, even without any delay in deliveries. Adding the delay will thus result in higher inflation to avoid stocking out.

4.3 Other considerations

One caveat to applying our quantitative results to the current economy is that shipping delays need not arise solely from exogenous factors, as they have in our model. The shipping delays faced by the economy today likely have both endogenous and exogenous forces to blame. The shut down of many services in the U.S. economy during the pandemic led to unprecedented import and shipment volumes as consumers shifted their consumption away from services towards goods. These elevated shipment volumes would have exceeded port, rail, and truck capacity even in the best of times, leading to shipping delays. However, far from being the best of times, ports and trucking companies have struggled with exogenous shocks to their work force due to the spread of COVID-19. Thus far, we have looked only at the effects of exogenous delay shocks, but we plan to study the effects of shipping delays that arise from endogenous demand shocks as well.

5 Final Thoughts

We propose building on our quantitative framework to study the short-run and long-run implications of changes in the timeliness and costs of domestic and international trade. The framework we are developing will be useful to study the effects in the United States and the rest of the world and the impact of policies aimed at avoiding the types of supply disruptions that the world is experiencing.

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6 Figures and Tables

Table 1: Parameter Values and Moments

Parameters		
Macro Elasticity	γ	2
Micro Elasticity	θ	4
Material Prod Share	α	60%
Depreciation Rate (annual)	δ	20%
Delay shock persistence	ρ_μ	0.5
Fixed cost/Rev (dom)	ϕ_D	6%
Fixed cost/Rev (imp)	ϕ_I	35%
Domestic delays (days)	μ_D	23
Import delays (days)	μ_I	45
Moments		
Trade-GDP Ratio		15%
Material share of imp		80%
I-Prod Ratio (dom)		1.09
I-Prod Ratio (imp)		2.63
I-Prod Ratio (agg)		1.32
Order freq (dom)		40%
Order freq (imp)		20%

Figure 1: U.S. Inventories by Sector

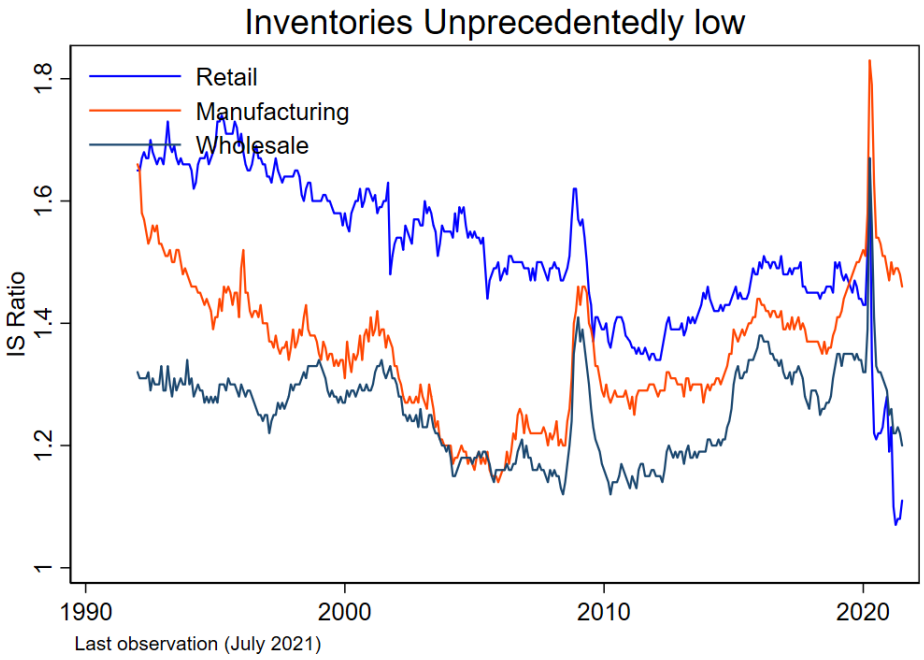


Figure 2: U.S. Auto Inventories

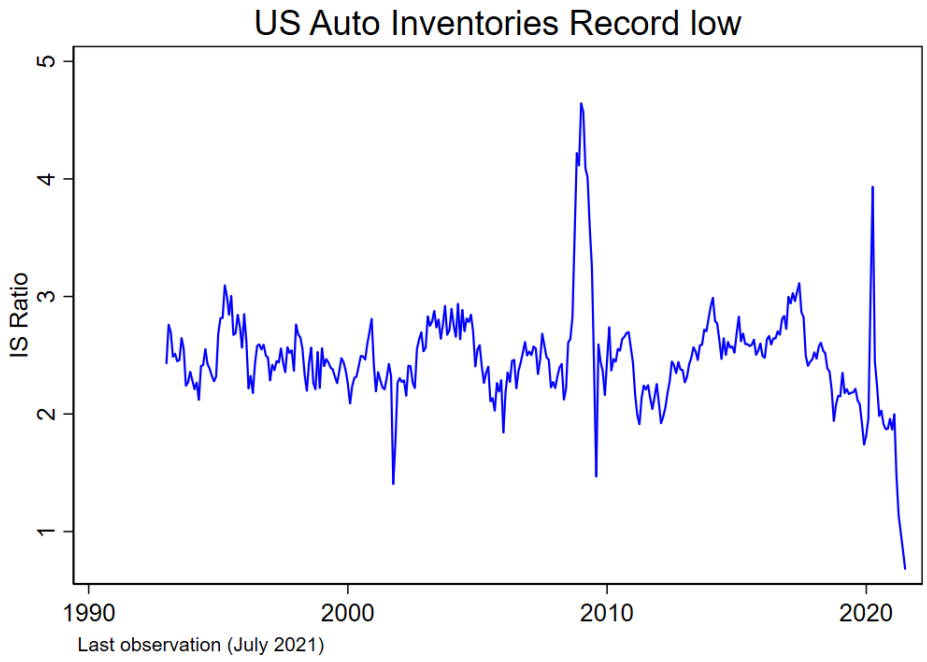


Figure 3: Delivery Delays

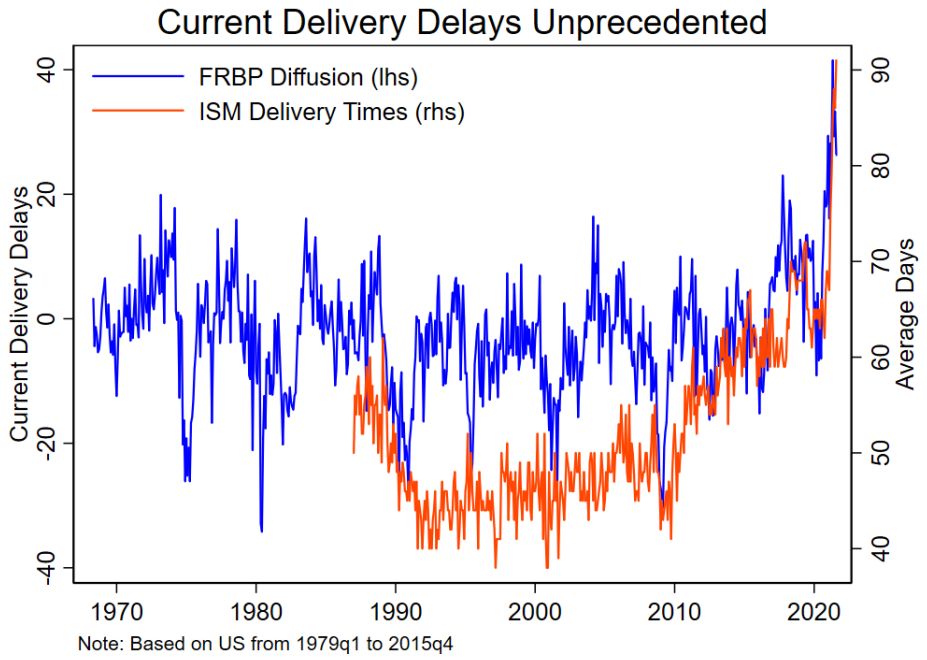


Figure 4: Domestic and International Shipping Costs (percent change over average in 2019

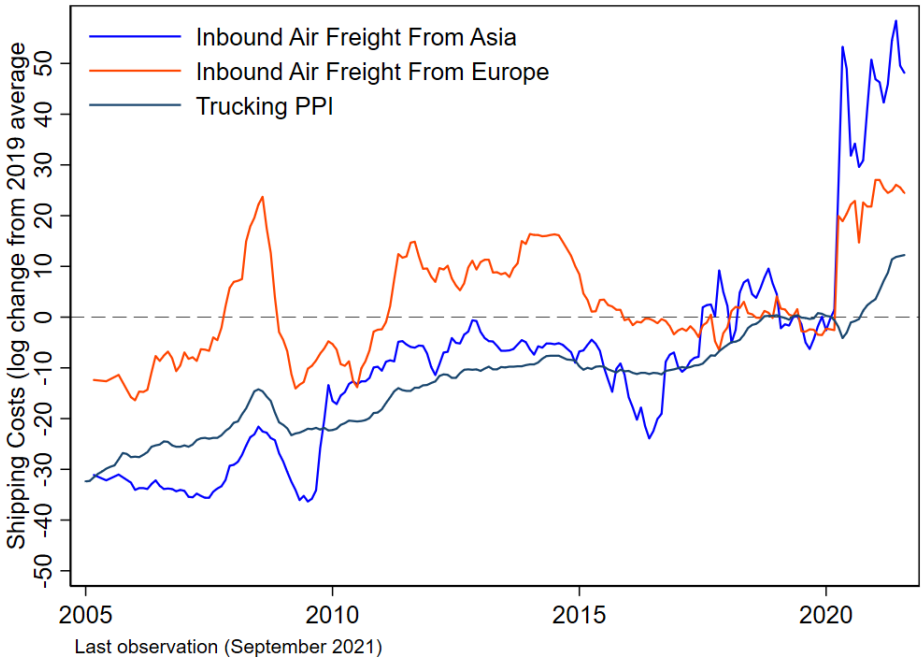


Figure 5: Delivery Lag shock effect

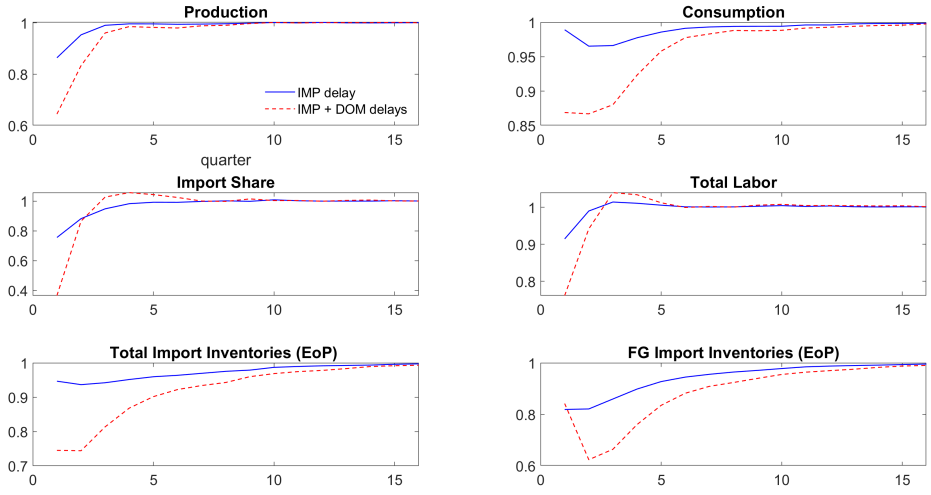


Figure 6: Delivery Lag shock effect

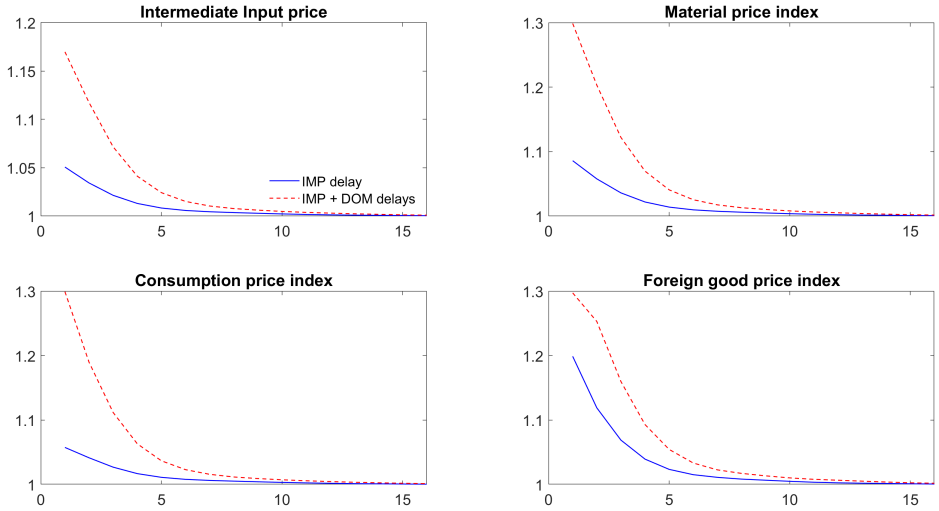


Figure 7: Delivery Lag shock effect: w/ Low initial inventories

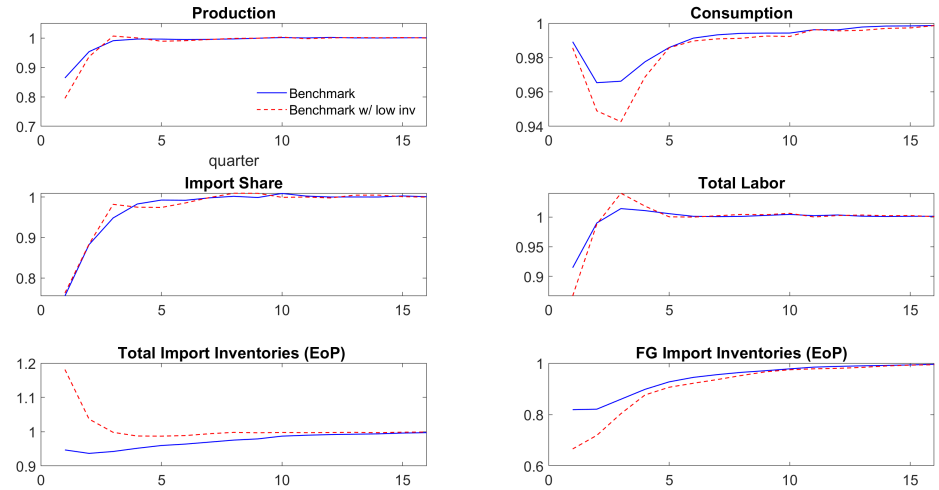


Figure 8: Delivery Lag shock effect: w/ Low initial inventories

