Mitigating international supply-chain risk with inventories and fast transport

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Inventories and multimodal shipments

- Rise of global supply chains
  - Greater opportunity for diversification of supply
  - Lower per-unit costs on inputs and finished goods
  - Longer lead times and higher fixed order costs
  - Greater opportunity for disruption (choke points, policy)
- Managing risk
  - Firms hold inventories to economize on transaction costs and as risk-buffer
  - Firms can use air shipment to pull deliveries from the future
    - Only possible for goods that can go by air
    - Provides short-run boost to available resources, not available domestically
    - Return to normal depends on whether shock is idiosyncratic or aggregate

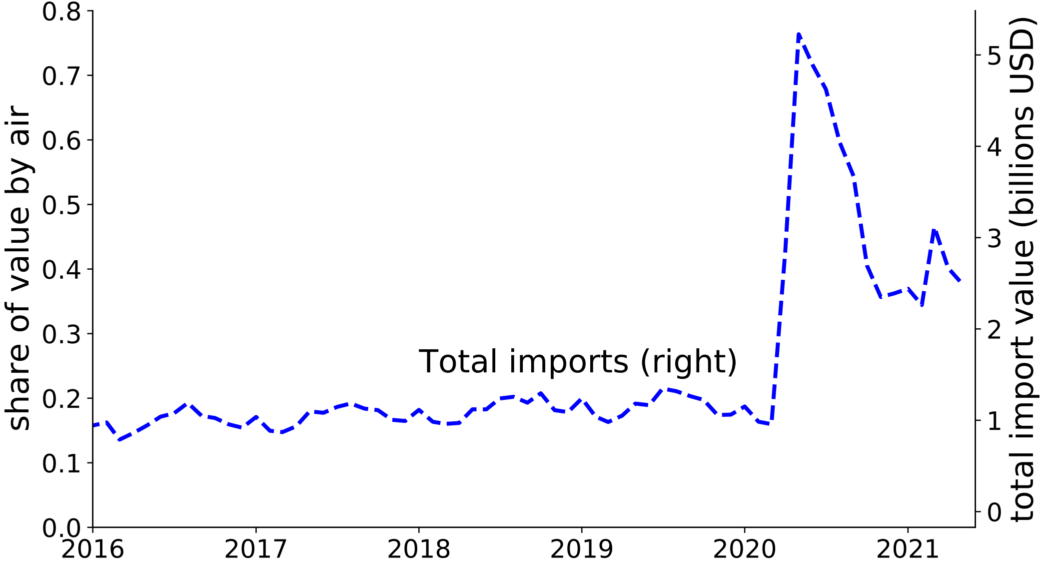
Goal 1: Understand how firm's use inventories and delivery-mode substitution to manage risks and reduce costs of trade.

Goal 2: Develop framework for analysis of changes in environment (risks, policies).

Outline

- Evidence from aggregate shocks
  - Unanticipated shocks – mode substitution
  - Anticipated shocks – precautionary stockpiling
- Evidence on inventory management and trade
  - Simple model to set ideas
  - Study U.S. trade data and show
    - Frequency, size of shipments depend on source & delivery mode
    - Substantial differences in inventory holdings by mode
  - Industry data: Trade involves substantial inventory stockpiles
- Structural Model
  - Industry model of firms facing stochastic demand & inventory management frictions
  - Study response to shocks with & without mode substitution choice
  - Recover trade frictions & risk by industry

PPE during the early covid pandemic



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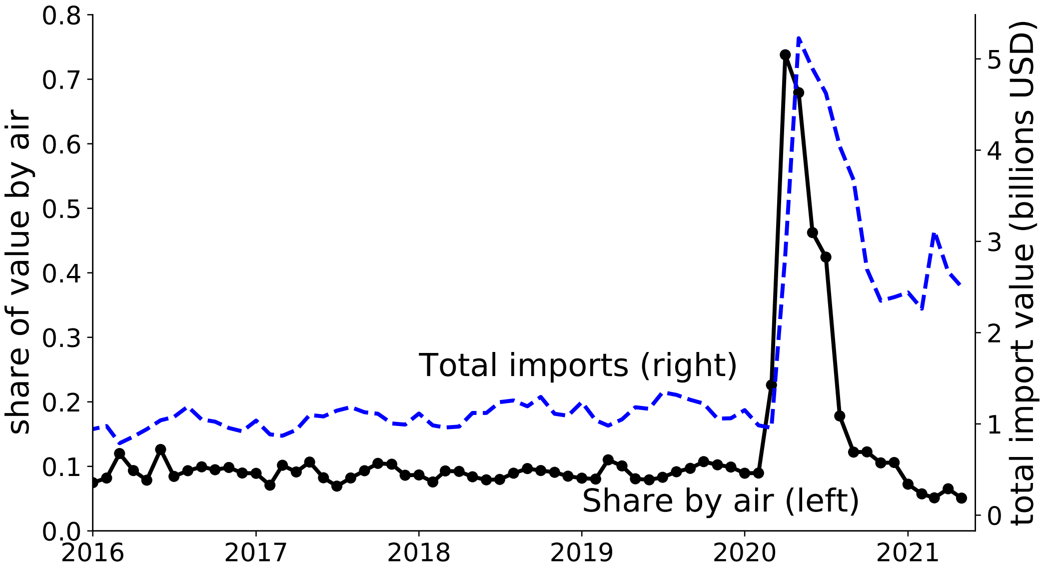
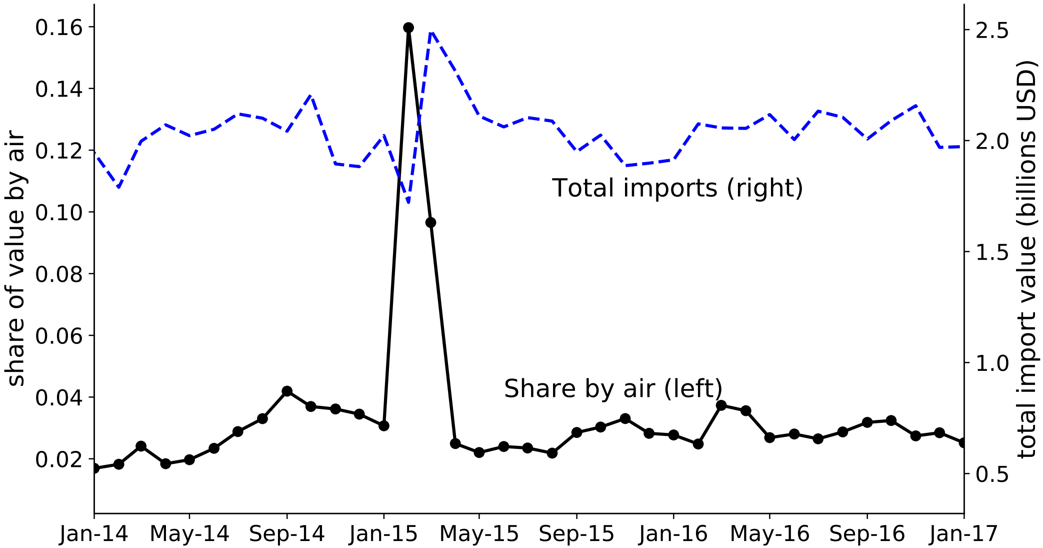


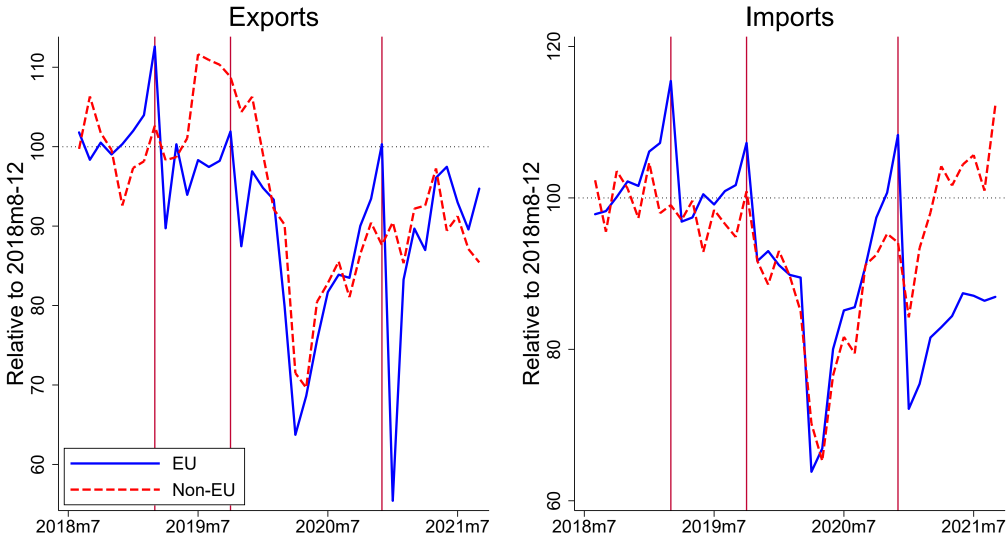
West Coast ports labor relations (Motor vehicle parts from Asia)



Stockpiling in advance of disruptions/cost shocks

- Firms also can use inventories to adjust to changes in trade policy.
- In advance of tariff cuts from NAFTA, firms reduce imports and run down stocks (Khan and Khederlarian, 2019)
- In advance of possible tariff increases, firms increase imports and build up stocks (Alessandria et al., 2019)
- Evident in the case of Brexit around two proposed dates & actual date.
  - Booms and busts in EU/UK trade in UK/non-EU trade

Stockpiling in advance of disruptions/cost shocks



The Economic Order Quantity Model

- i = product, j = source country
- Firm faces **certain** yearly demand of D_{ij}^m
- Holds inventories at cost h_{ij}
- τ_{ij} is marginal cost including shipping; f_{ij}^m is fixed order costs
- Decides how much to order (Q) and how many orders (D/Q)

$$\min_{Q_{ij}^m} \quad \tau_{ij}^m D_{ij}^m + f_{ij}^m \frac{D_{ij}^m}{Q_{ij}^m} + h_{ij} \frac{Q_{ij}^m}{2},$$

- Key tradeoff
  - Ordering costs $\rightarrow$ fewer, larger orders; more inventory
  - Inventory cost $\rightarrow$ more, smaller orders; less inventory

Model solutions

- Frequency of orders depends on sales ($+$), depreciation (+), order costs ($-$)

$$N_{ij}^m = \frac{D_{ij}^m}{Q_{ij}^m} = \sqrt{\frac{h_{ij}}{2f_{ij}^m} D_{ij}^m}$$

- Inventory level depends on sales ($-$), depreciation ($-$), order costs ($+$)

$$\frac{I_{ij}^m}{\text{sales}_{ij}^m} = \frac{Q_{ij}^m}{2D_{ij}^m} = \sqrt{\frac{f_{ij}^m}{2h_{ij}D_{ij}^m}}$$

Order frequency in the data

- Frequency of orders depends on sales (+), depreciation (+), order costs (−)

$$N_{ij}^m = \frac{D_{ij}^m}{Q_{ij}^m} = \sqrt{\frac{h_{ij}}{2f_{ij}^m} D_{ij}^m}$$

- Consider three shipping methods: land, air, sea

$$\log(N_{ijt}) = \beta_0 \log(V_{ijt}) + \beta_2 \text{air}_{ijt} + \beta_3 \text{land}_{ijt} + \beta_1 \log(w_{jt}) + c_{it} + c_{jt} + \epsilon_{ijt},$$

- Data: Monthly U.S. imports (HS 10 level); consider a product-source pair
- Single year, 2005, but robust to including more
  - Data on product depreciation rates (h) from insurance adjusters at HS6 level

Frequency of transactions, shipping mode, and depreciation

	log(N)					
log(V)	0.611***	0.610***	0.647***	0.652***	0.657***	0.654***
	(0.016)	(0.016)	(0.017)	(0.017)	(0.001)	(0.002)
log(w)	-0.0638***	-0.0640***	-0.0567***	-0.0602***		
	(0.005)	(0.005)	(0.008)	(0.008)		
land	0.763***	0.613***	0.273*	0.345**	0.372***	
	(0.139)	(0.139)	(0.116)	(0.104)	(0.013)	
airshare	0.523***	0.512***	0.603***	0.583***	0.490***	0.500***
	(0.037)	(0.038)	(0.045)	(0.042)	(0.007)	(0.007)
Canada		0.277**	0.385***	0.345***		
		(0.094)	(0.068)	(0.057)		
Mexico		0.157	0.246***	0.196***		
		(0.082)	(0.061)	(0.052)		
dep rate				0.00558***		
				(0.000)		
Adj. R-squared	0.753	0.753	0.814	0.819	0.870	0.860
HS FE	No	No	No	Yes	Yes	Yes
Country FE	No	No	Yes	Yes	Yes	Yes
NAFTA	Yes	Yes	Yes	No	Yes	Yes

t statistics in parentheses

Data takeaways I

- Shipments grow with trade, albeit at slightly stronger pace than predicted by theory
- Shipments fall with weight.
- Faster modes (land, air) have more transactions holding volume constant
  - Less storable goods are shipped more often
- Theory holds better (i.e., coefficent on $log(V)$ closer to 0.5) if we focus:
  - on single mode shipments (Table A1)
  - control for concentration of shipments within the year
    or across ports of entry (Table A2)
- These estimates imply that inventories are lower when sourced from nearby and shipped by air, more so if goods are less storable.

Trade, Inventories Across Industries

- Show that industry-level inventory holdings in manufacturing are related to trade integration.
- Unlike Alessandria et al. (2010a), Alessandria et al. (2010b), and Nadais (2017), focus on how the composition of industry exports influence industry-level inventories.
- Industries that export more hold more inventory, but that inventory levels are lower for trade with Canada and Mexico and higher for products that are likely to be shipped by air.
- Implies logistic savings by customers from import data may be offset by higher supplier logistic costs.

Trade, Inventories Across Industries

- Estimate, for 334 industries (j) in 2016

$$\log(I_{jt}) = \beta_0 \log(V_{jt}) + \beta_1 \log(exs_{jt}) + \beta_2 \text{air}_{jt} + \beta_3 \text{nafta}_{jt} + \alpha_{jt} X_{jt} + \epsilon_{ijt}.$$

  - *exs* = exports-shipment ratio
  - *air* = share of exports by air
  - *nafta* = share of exports to Mexico/Canada
  - X_{jt} = other controls, including number of establishments

- Data sources
  - U.S. exports (Census)
  - County Business Patterns (Census)
  - NBER-CES database (NBER)
  - Annual Survey of Manufactures (Census)

Inventories and export shipments

	Inventory (EOY)				
Total shipments	0.841***	0.820***	0.837***	0.832***	0.820***
	(0.024)	(0.026)	(0.033)	(0.032)	(0.031)
No. of establishments		0.0534**	0.0686**	0.0492*	0.0614**
		(0.026)	(0.028)	(0.028)	(0.028)
Export-shipment ratio			0.954***	0.495***	0.517***
			(0.157)	(0.176)	(0.170)
NAFTA share				-0.489***	-0.218*
				(0.109)	(0.111)
Airshare of exports				0.306***	0.189*
				(0.099)	(0.100)
Materials					-1.663***
					(0.229)
Finished					-0.705***
					(0.200)
N	334	334	333	333	319
Adj. R-squared	0.783	0.786	0.807	0.825	0.847

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A stochastic model of inventory management

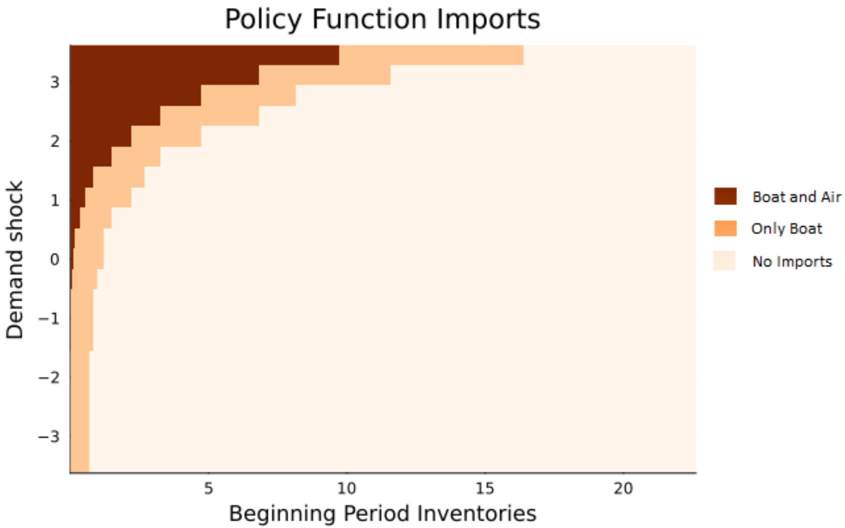
- Firms
  - Buy inputs from abroad
  - Use inputs to create a good to sell to consumers
  - Idiosyncratic demand shocks
  - Set prices, manage inputs to maximize discounted profits
- Imported inputs take time to ship
  - Shipping by sea takes longer than shipping by air
  - Shipping by sea is cheaper than shipping by air
- Stochastic demand + time to ship $\rightarrow$ firms hold inventories
  - Inventories are costly (depreciation/spoilage, interest costs)
  - Inventories allow firms to meet high demand rather than stockout and miss sales (Precautionary).

[jump to model details]

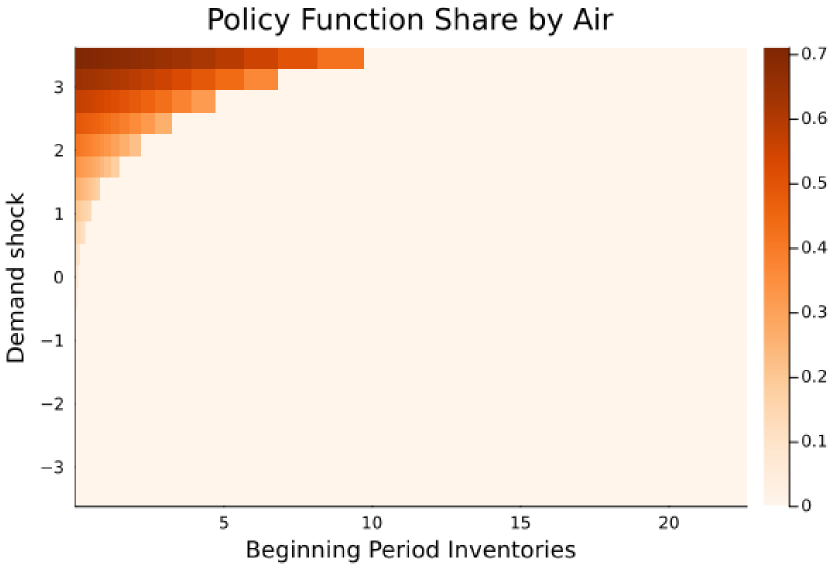
Calibration

- Follow AKM (2010), but allow two modes, target
  - Inventory-levels (4 months)
  - Trade lumpiness within year (2.5 transactions)
  - Most trade by boat (5 % air)

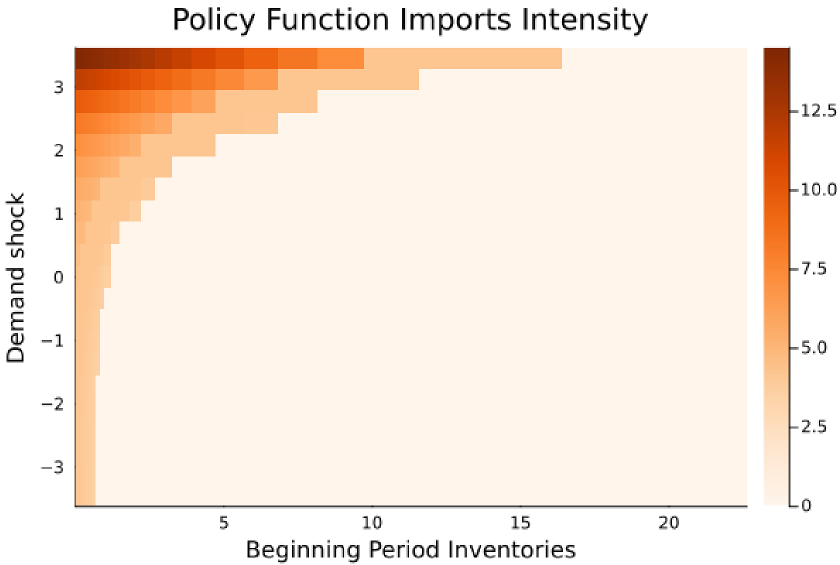
Policy Functions: Technology Choice and Imports



Policy Functions: Share by Air (Shipment)



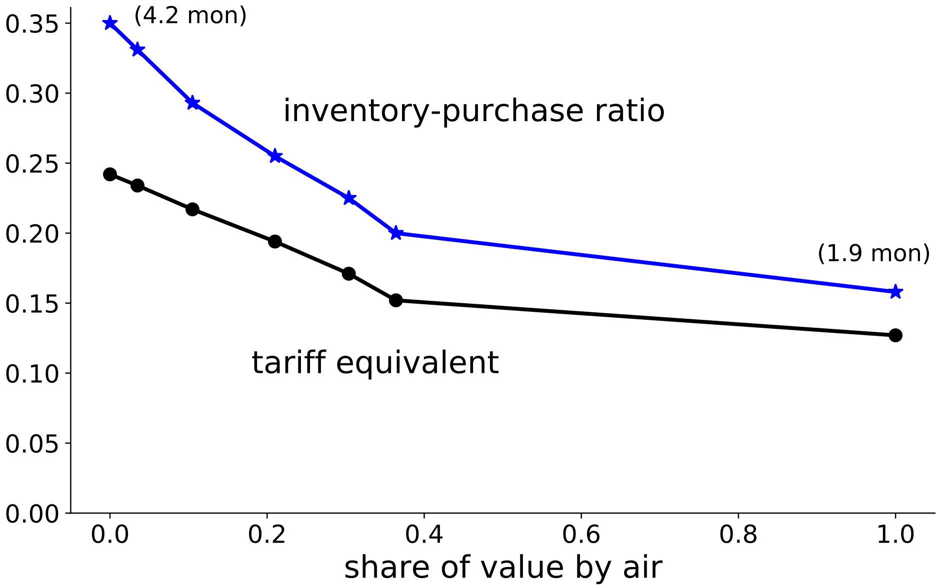
Policy Functions: Imports Intensity



The value of air shipping and inventories

- Vary air-freight price holding fixed costs same: τ^a/τ^s
- Increasing air freight premium
  - Reduces sales & transactions
  - Increases inventories: 1.9 months $\rightarrow$ 4.2 months
  - Fewer, larger shipments but firm sales more stable

Response to changes in air freight prices



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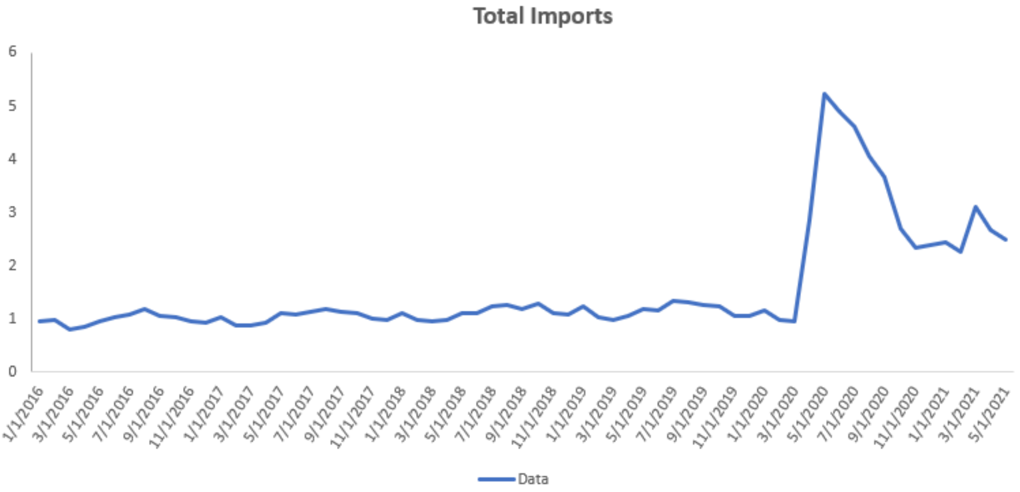
  - Fewer, larger shipments but firm sales more stable
- Tariff-equivalent of shipping costs and time
  - Counterfactual world: No shipping time or cost, but tariff on imports
  - What tariff makes the counterfactual world as profitable as the multi-modal world?

	air share	tariff
air freight expensive	0	25
air freight cheap	1	13

Responding to large shocks: COVID & PPE

- In the spirit of COVID's effect on PPE trade
- Introduce several shocks to capture change in imports and shift to air.
  - Demand shock (Permanent and transitory)
  - Transitory cost shock
  - Increased uncertainty

Imports in Model



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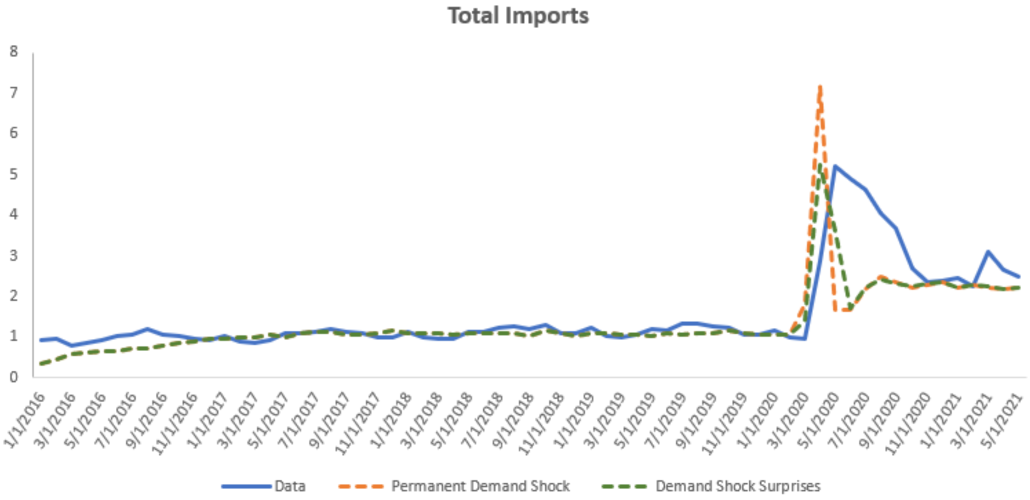

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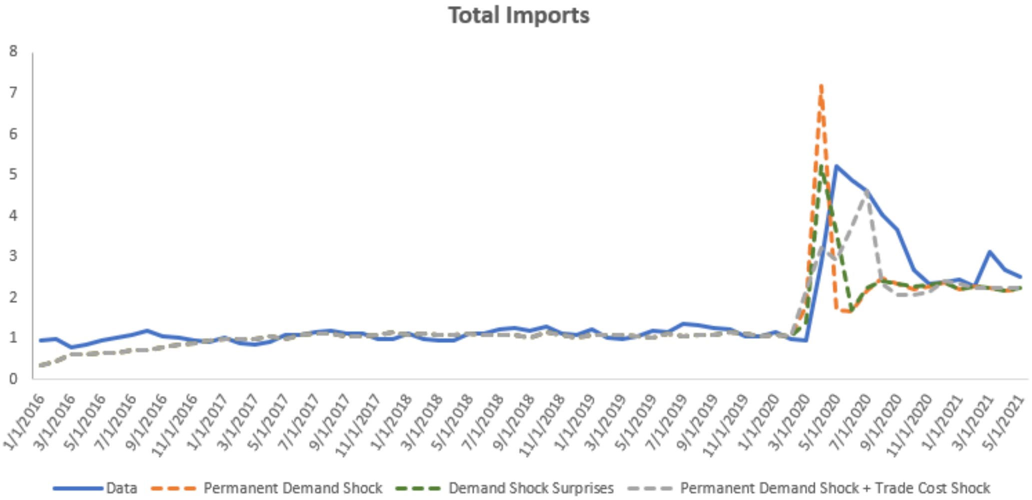

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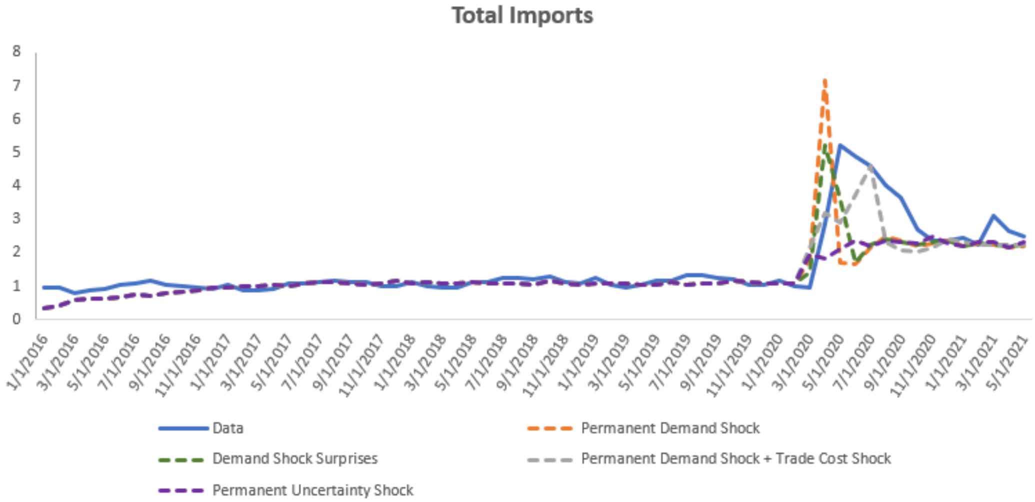
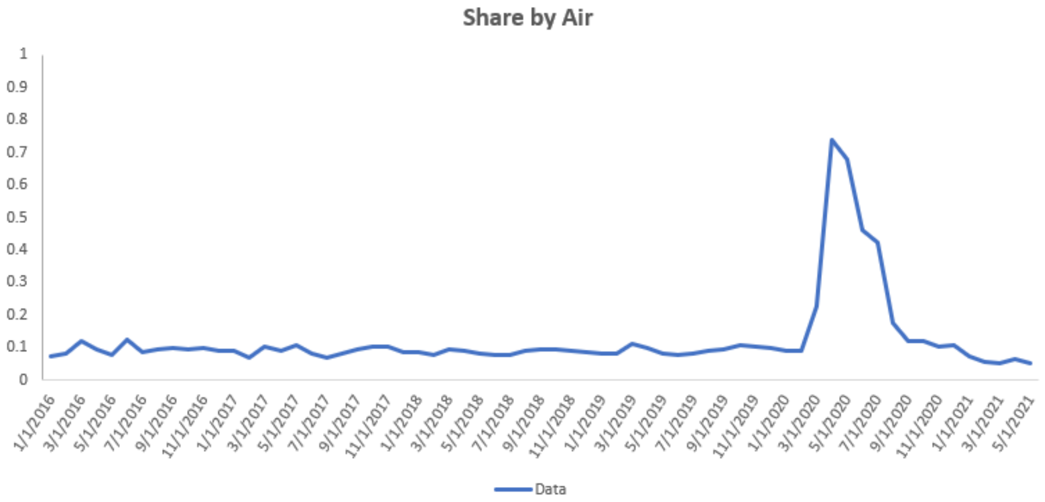


Share by Air in Model



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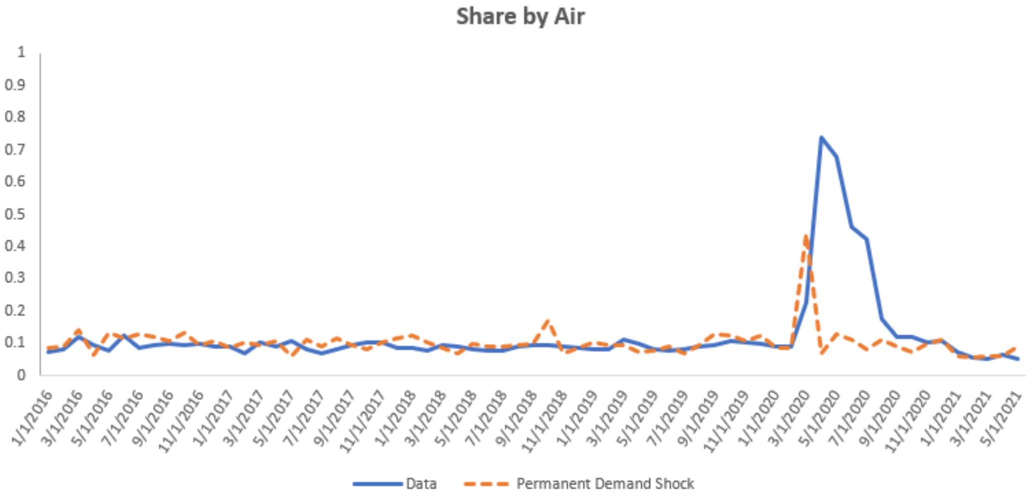

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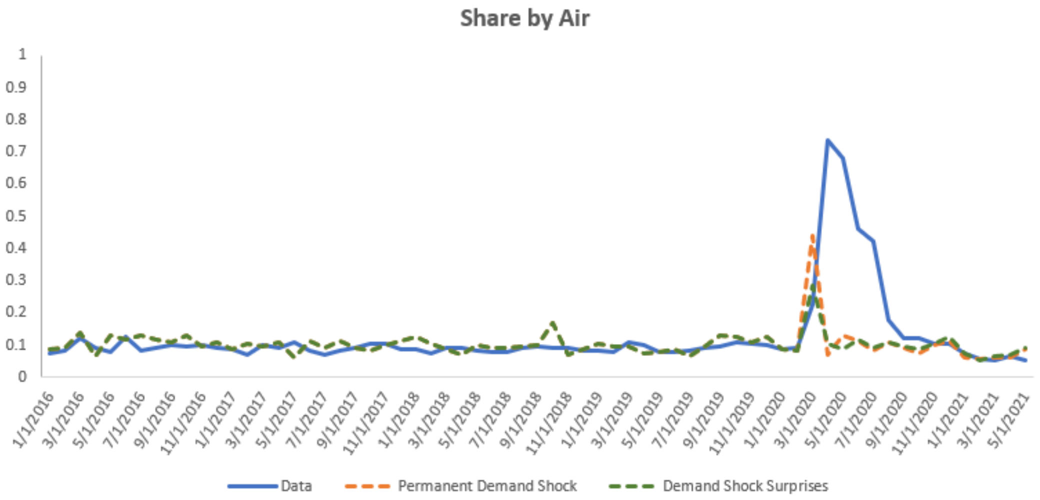

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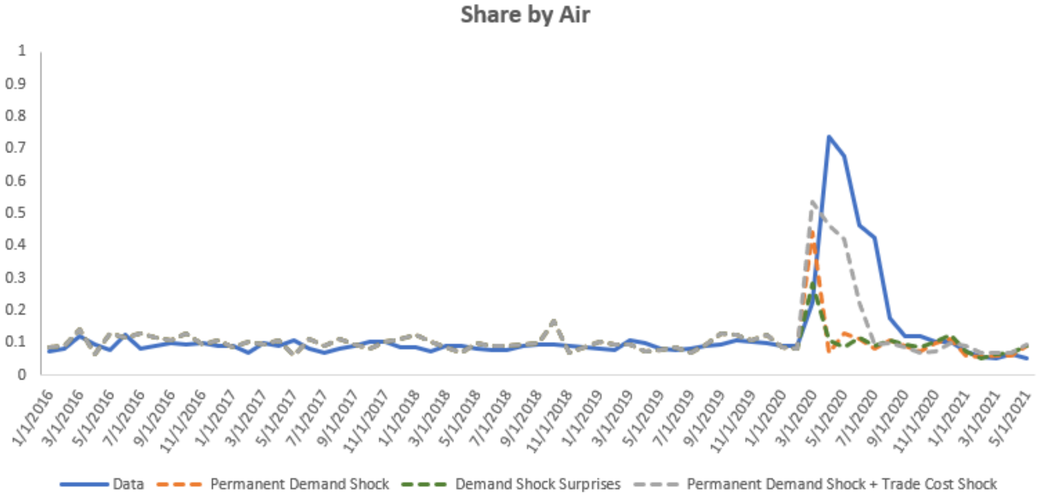

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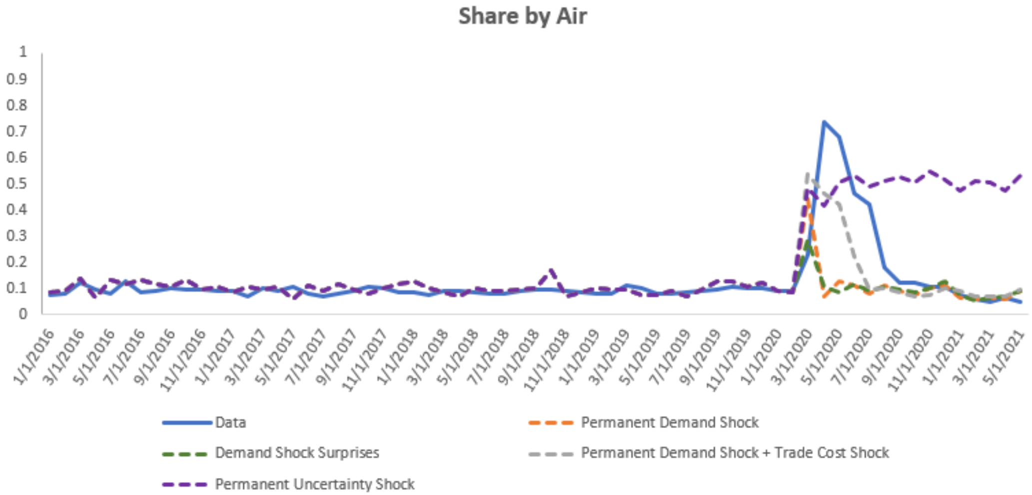
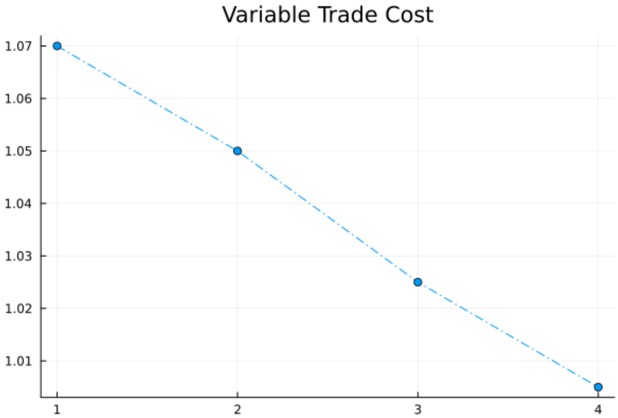


Variable Trade Cost Path



Takeaways

- Firms use inventories AND shipment modes to prepare/adjust to shocks
- Speeding up trade increases resources in short-run, option not available domestically.
- Owing to trade, there are more resources available to respond to shocks in short-run.
- Basic model makes it too easy for firms to use fast shipments to fill demand spikes in normal times.

Appendix

Table A1: Number of transactions conditioning on transport mode

	$\log(N)$			
	Pure Boat	Pure Air	Pure Either	Mixed
$\log(V)$	0.549***	0.519***	0.537***	0.604***
	(149.57)	(156.47)	(218.79)	(114.34)
airshare			0	0.388***
			(.)	(7.31)
N	65,744	79,980	145,724	16,431
Adj. R-squared	0.703	0.706	0.707	0.828
HS FE	Y	Y	N	Y
HS-Mode FE	N	N	Y	N
Country FE	Y	Y	Y	Y
NAFTA	Yes	Yes	Yes	No

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A2: Number of transactions and the lumpiness of trade

	log(N)	
log(V)	0.657***	0.502***
	(443.60)	(235.43)
airshare	0.490***	0.400***
	(71.47)	(69.53)
land	0.372***	0.177***
	(28.44)	(15.77)
HH-dist		-0.562***
		(-73.15)
HH-time		-1.346***
		(-136.14)
N	267986	267986
Adj. R-squared	0.870	0.903

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Firms

- Continuum of monopolistic competitors
- Firm j begins period with inventory $s(j)$, demand shock $\nu(j)$

$$d(p, \nu) = p(j)^{-\theta} \nu(j)$$

- Chooses inputs ordered by boat $m^s(j)$ or air $m^f(j)$ [can do both]
- If firm places an order: $m(j) > 0$
  - Cost of ocean shipping ϕ^s or air ϕ^f
  - τ is air shipping premium
- Firm's state is (s_t, ν_t)
- Timing: observe demand $\rightarrow$ place order(s) $\rightarrow$ observe delivery $\rightarrow$ set prices

Firm optimization

$$V(s,\nu) = \max\{V^a(s,\nu),\ V^n(s,\nu)\}$$

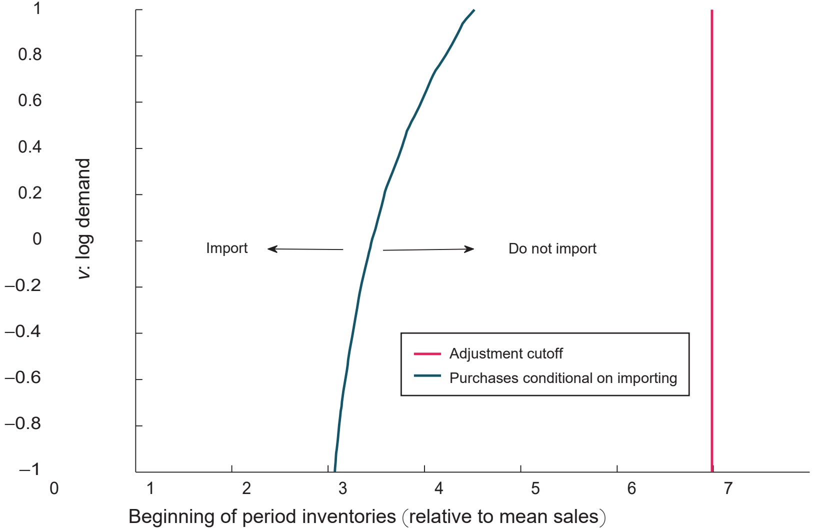
- Value of not placing an order

$$V^n(s,\nu) = \max_{p,d,m} \pi(d(p,\nu)) + \mathbb{E}_{\nu'} QV(s',\nu')$$
$$\text{s.t. } s \geq d(p,\nu)$$
$$s' = (1-\delta)(s - d(p,\nu))$$

- Value of placing an order

$$V^a(s,\nu) = \max_{p,m^f,m^s} \pi(d(p,\nu)) - p^m(\tau^f m^f + m^s) - \text{costs} + \mathbb{E}_{\nu'} QV(s',\nu')$$
$$\text{s.t. } s \geq d(p,\nu) + m^f$$
$$s' = (1-\delta)(s - d(p,\nu) + m^f + m^s)$$
$$\text{costs} = \phi^f I_{m^f>0} + \phi^s I_{m^s>0}$$

Decision Rules - slow



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