Tariff Front-Running

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Abstract

We examine US firms' responses to future tariff increases and their macroeconomic implications. We build a novel firm-level import dataset spanning from 2012 to 2019, a period covering the 2018–2019 trade war on steel, aluminum, and Chinese imports. We find a significant front-running response to tariffs. First, firms' imports, inventories, and their number of product-country partners begin to increase four quarters before a tariff increase. Second, before a specific product-country is affected by a higher tariff, firms choose to import not only from that targeted product-country but also the same products from countries unaffected by the tariff (extensive margin), alongside increasing overall import volumes for the product (intensive margin). Then, we develop a dynamic trade model where forward-looking firms decide on inventories and the intensive and extensive margins of importing. The calibrated model replicates the empirical findings. We find that firms' front-running of tariffs puts downward pressure on prices and expands output prior to the tariff and that these ex-ante responses lead to a smoother transition of prices and output to the new steady state. We show that the aggregate data corroborate this model's predictions. Last, we quantify the extent to which firms' anticipatory response results in an overstatement of the trade elasticity in both the short and long run.

JEL Codes: E30, F11, F13, F40

Keywords: Tariff, 2018–2019 trade war, imports, dynamic trade model, extensive margin of imports, bill of lading

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1 Introduction

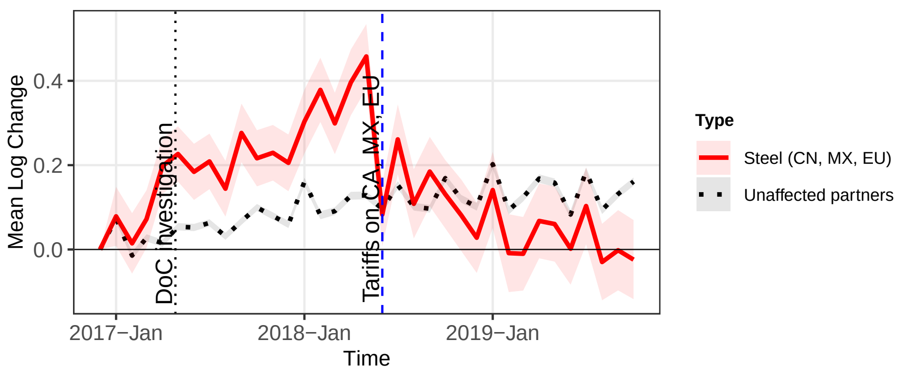
After a globalization period characterized by low and stable tariffs, for the past decade the United States has imposed and continues to impose substantial and unprecedented tariffs on many of its imports. The economic impacts of these tariffs on trade flows, prices, and production have occupied the forefront of economic policy debates worldwide. The literature has primarily focused on studying the aftermath of tariff implementation. However, the anticipatory dynamics of trade, where importers can respond to a future tariff to safeguard production, and how these early reactions affect aggregate prices and output remain largely unexamined.

In Figure 1, we find a significant front-running in US imports in response to the 2018 tariffs on steel and aluminum from Canada, Mexico, and the European Union. The Department of Commerce initiated an investigation regarding the national security threat of steel and aluminum imports in April 2017. Following the investigation results, a 25% tariff was implemented in March 2018. The figure shows the import growth, relative to 2016 imports, by comparing product-countries subject to these tariffs against those that did not experience any tariff increase. Affected imports remained higher after the investigation and further increased before the tariff surge.

In this paper, we ask: How do US firms respond to an expected increase in import tariffs? Further, we study how firms' anticipatory responses impact macroeconomic aggregates. We address the first question empirically for the wave of tariff increases in 2018 and 2019. By applying local projections to a novel firm-level import dataset of US public firms, we find that US firms front-run tariffs by increasing import volumes, the number of product-countries they import from, and inventories, starting four quarters prior to the tariff implementation. Then, we study the specific mechanisms underlying the anticipatory response. Before a specific product-country is impacted by a tariff, firms choose to import not only from the targeted product-country but also the same product from countries unaffected by the tariff surge (extensive margin), alongside increasing the overall import volumes for the product (intensive margin). Furthermore, we show that substitution towards unaffected products is quantitatively small.

To address the second question, we develop a novel dynamic trade model that in-

Figure 1: Steel and Aluminum Imports from Canada, Mexico, and the EU



Note: The figure plots the average log change in import volumes relative to the corresponding month in 2016 (with 95% confidence intervals) across HTS10 product-country pairs. It contrasts product-countries subject to the June 2018 steel and aluminum tariffs (covering $22B in 2017 imports, primarily affecting Canada, Mexico, and the EU) against those never subject to tariff increases during 2018–2019. Vertical lines mark the dates of the initiation of Section 232 investigation by the Department of Commerce and the implementation of tariff increases.

Source: Authors' calculations based on data from the Census Bureau and the US International Trade Commission (USITC), compiled by Amiti, Redding, and Weinstein (2019, 2020).

tegrates the extensive margin of trade into an open-economy inventory model. The model replicates the empirical findings: Firms respond to expected tariffs by raising import volumes, accumulating inventories, and diversifying their import partners. We find that the anticipatory response leads to a smoother transition of aggregate prices and output post-tariff, which mitigates the economic impact of the tariff. Further, the front-running behavior transmits to the aggregates even pre-tariff, where the increase in imports and partners puts downward pressure on prices and expands output. We find that the cross-industry variations in the aggregate data corroborate the model's predictions, where the output (price) of the more tariff-exposed industries increases by more (less) relative to the other industries in the pre-tariff period and declines by more (less) after the tariff. Finally, we quantify the extent to which firms' anticipatory responses result in an overstatement of the trade elasticity in both the short and long run.

Our dataset covers 5,776 unique US importing firms from 2012Q1 to 2019Q4, comprising approximately 2.7 million observations at the firm-quarter-product-country level. It tracks firms' import volumes, the specific products imported, and their source countries. The dataset integrates three primary sources. First, we acquire shipment-level bill-of-lading (BoL) data from S&P Global's Port Import-Export Reporting Service (PIERS), which captures the near-universe of US maritime imports. For each shipment, this provides the Harmonized System (HS) 6-digit product classification, imputed value in USD, and foreign partner. Second, we obtain statutory tariff data from Amiti, Redding, and Weinstein (2019, 2020) who compile monthly tariff schedules from the United States International Trade Commission (USITC) at the Harmonized Tariff Schedule (HTS) 10-digit and country level. Third, we source firm financial data from Compustat North America, which includes sales and inventory data for US public firms. A technical contribution of our work is the matching of shipment-level import transactions to unique Compustat firms using a text-analysis algorithm.

The granularity of our data allows us to reveal patterns that are hidden by aggregate statistics. Using firm-level data, we employ local projections (Jorda 2005) to study the dynamic response of firms' imports, inventories, and number of partners (i.e., product-countries). We show that firms begin to increase their imports and accumulate inventories four quarters before a tariff increase, with levels peaking just before implementation. Simultaneously, the number of import partners rises. The four-quarter lead in the firm response aligns closely with the typical duration between the formal initiation of trade investigations and the subsequent implementation of the 2018–2019 tariff waves. Following the realization of the tariff, both import volumes and the number of partners decrease sharply.

Next, we explore firms' substitution patterns—or margins of adjustment—prior to a tariff. If a firm expects a tariff increase for a specific product-country, it may not only adjust imports from that partner but also substitute toward other source countries or different products. We find significant extensive and intensive margin adjustments for the specific products affected by the tariff. When a tariff is expected for a product-country pair, the firm is more likely to import from the targeted partner and significantly increases its import volume. Further, prior to the tariff, firms begin importing the same product from unaffected countries, increasing volumes from these alternative sources as well. In contrast, substitution toward unaffected products is quantitatively small. A note of caution is as follows. Import flows are lumpy—the median firm in our sample imports in only 20 of the 32 quarters. Therefore, the extensive-margin adjustments reflect both the timing of shipments and the selection of import partners.

Among the findings, the stockpiling of imports from product-country pairs subject to higher tariffs can be tested in the aggregate data. For the tariff increase in steel and aluminum and the four tariff waves for China, as in Figure 1, we compare the aggregate import volumes for the product-countries affected by each wave against those not affected by any tariff in 2018–2019. Despite significant heterogeneity in import dynamics, we find general support for the front-loading of imports across all the tariff waves.

Motivated by our empirical results, we develop a dynamic trade model to study the front-loading and diversification observed ahead of tariffs and to assess how the anticipatory response affects aggregate prices and output. We depart from the literature by incorporating an extensive margin of supplier choice into an open-economy model with inventory, as in Alessandria, Kaboski, and Midrigan (2010). Firms face demand shocks for their output and a one-period delivery lag for inputs, which creates an incentive to hold inventories. The input is a composite of a unit continuum of tradable varieties, each of which can be sourced from different countries. We follow similar assumptions as Antras, Fort, and Tintelnot (2017) for the extensive margin: Adding a supplier country incurs a fixed cost but lowers the unit cost of input since it provides an additional cost draw for the varieties. In the model, firms anticipate future increases in tariffs that affect their input prices, and they adjust along both the intensive margin, via imports they stock as inventories, and the extensive margin by expanding and switching their set of supplier countries.

We calibrate the model to match key moments of the US economy in 2015, such as import shares of countries, the mean number of sourcing countries, and the mean of the inventory-to-sales ratio. We then quantify firms' responses to the observed tariff increases from 2015 to 2019. We study the transition from a low- to a high-tariff steady state, under the assumption of perfect foresight. The new, high-tariff steady-state features higher prices and lower output, imports, and inventories.

First, we show that the model replicates the empirical findings. Anticipating an increase in their input price due to future tariffs, firms increase current imports and accumulate inventories. The surge in orders makes it profitable to incur the additional fixed costs of accessing new suppliers. The resulting expansion of the supplier set lowers the marginal cost of the input, which further increases imports. Consequently, firms' anticipatory responses shape the dynamics of aggregate prices and output. Before the increased tariff is implemented, the expansion along the extensive margin lowers input costs, which creates downward pressure on final goods prices and expands output.

Once the tariff is implemented, firms' imports decrease sharply as firms slowly draw on their accumulated inventories over the next three to four quarters to meet demand. This run-down of inventories results in a slow adjustment of aggregate output. Aggregate prices also exhibit a gradual adjustment. We observe a complete pass-through of the tariff to the marginal cost of the input, which immediately raises the aggregate prices. However, the additional inventory acquired in the pre-tariff period reduces the share of firms constrained by stock-outs, which exerts downward pressure on aggregate prices. This second force allows for the gradual adjustment of prices.

As discussed above, our calibrated model provides novel predictions for the dynamics of prices and output before and after the tariff. We validate these predictions using cross-industry variation in tariff exposure during 2018–2019 and the dynamics of prices and output. First, we construct an industry-level tariff-exposure measure as the share of firms that experienced a tariff increase on their imports in each NAICS 6-digit industry. Then, to compare the aggregate price and output response, we define three periods: the initial period, analogous to the old steady state in the model; the pre-tariff period, when we observe firms' anticipatory responses after the formal investigation against China's trade practices began; and the post-tariff period, after the implementation of higher tariffs. Third, we construct price and output changes for each industry from the initial to the pre-tariff period and from the pre- to the post-tariff period, using the Producer Price Index (PPI) from the Bureau of Labor Statistics and the Industrial Production Index (IPI) from the Federal Reserve Board. Last, we correlate the tariff-exposure measure with the price and output changes. We find that the aggregate data patterns validate the model's predictions: Output in more tariff-exposed industries increases more relative to other sectors in the pre-tariff period and declines by more after, while aggregate prices in more exposed industries grow less in the pre-tariff period and more after tariffs are implemented.

Using counterfactuals, we study the gains from anticipation by comparing the baseline model with perfect foresight to one where the tariff is unanticipated. We find that firms' anticipatory responses dampen the effect of the tariff in the short run. Under perfect foresight, aggregate output is higher, and prices are lower throughout the transition to the new steady state than under the unanticipated scenario. Furthermore, we highlight the role of the extensive margin—the novel feature of our model—in aggregate dynamics. We do so by contrasting our results with those from an alternative model with a unique supplier, with a constant marginal cost of input. We find that the pre-tariff aggregate dynamics, the downward pressure on aggregate prices and the rise in output, are driven by the extensive-margin response. The expansion of the set of partners prior to the tariff lowers the marginal cost of input, which in turn affects aggregate outcomes. This mechanism is absent under a unique-supplier assumption.

Lastly, we use the baseline model's transition dynamics to show how firms' anticipatory behavior overstates the trade elasticity in both the short and long run. The intuition rests on two points. First, firms increase their imports in the pre-tariff period and stock them as inventories. Second, after the tariff is implemented, firms draw on these inventories for production, and imports dip below their new steady-state level. If the elasticity is computed by comparing the imports post-tariff to the period right before the tariff implementation, the elasticity is overstated both in the short and in the long run, since imports are elevated by firms' anticipatory responses. If the reference period is set to before the investigation started (before firms responded in anticipation of the tariff), then we can recover the long-run elasticity. However, the short-run elasticity continues to be overstated due to the sharp drop in imports in the periods shortly after tariff implementation. Note that this is true even in an unanticipated tariff case: During the transition to a lower-output, lower-inventory steady state, firms draw down excess inventories, causing imports to drop below their long-run steady state.

Our paper builds on and contributes to five strands of the literature. First, this paper is related to the extensive literature on the short-run impact of 2018–2019 US import tariff increases. Amiti, Redding, and Weinstein (2019, 2020); Fajgelbaum et al. (2020); and Cavallo et al. (2021) study the tariff pass-through by studying the prices and quantities of imports *after* the tariff increase. Javorcik, Pierce, and Wisniewski (2026); and Alfaro and Chor (2025) study the adjustment in foreign sourcing patterns *after* the tariff surge. In contrast, we focus on the *ex-ante* response of U.S. *firms* to an expected tariff increase. Furthermore, our findings show robust evidence of the anticipatory import response to the 2018–2019 tariffs, both in the aggregate and in the firm-level data.

Second, we contribute to the literature on trade-policy disruptions and global supply chain reorganizations (e.g., Flaaen, Hortaçsu, and Tintelnot 2020; Grossman, Helpman, and Redding 2024; Handley, Kamal, and Monarch 2024, 2025; Heise et al. 2025). To our knowledge, we provide the first evidence of an anticipatory extensive-margin adjustment and of the lack of cross-product substitution. This finding was made possible by the granularity of the data, which allows us to measure the import response at the firm-product-country level.

Third, this paper touches on the literature on how expectations or anticipation of future trade policies impact current aggregate outcomes. Alessandria, Khan, and Khederlarian (2024) provide macro-level evidence of stockpiling imports from China during the 1990s prior to the renewal vote on its Most Favored Nation (MFN) status, which, if not approved, would have raised tariffs on Chinese imports. We contribute by providing firm-level micro-evidence of stockpiling in response to an expected tariff increase in 2018–2019. To the best of our knowledge, our paper is the first to uncover the front-loading of imports at the firm and firm-product-country levels and of inventories at the firm level. Other related papers include Pierce and Schott (2016); Feng, Li, and Swenson (2017); Handley and Limão (2017); Steinberg (2019); Baley, Veldkamp, and Waugh (2020); and Khan and Khederlarian (2021*a*). While we remain agnostic as to how firms form their tariff expectations, we show that firms are indeed reacting to future tariff changes.

Fourth, this paper contributes to the literature on quantitative models of international trade. Motivated by our empirical findings, we build a model that is the first to integrate dynamic trade models with inventory accumulation (Alessandria, Kaboski, and Midrigan 2010) and extensive-margin trade models (Antras, Fort, and Tintelnot 2017; Blaum, Lelarge, and Peters 2018).

Lastly, our finding that anticipatory import stockpiling overstates the trade elasticity contributes to the literature on estimating trade elasticities at different horizons

(Boehm, Levchenko, and Pandalai-Nayar 2023; Boer and Rieth 2025) and on understanding how firms' dynamic responses to tariff changes bias standard measures of the trade response (Khan and Khederlarian 2021*b*; Alessandria et al. 2025; de Souza et al. 2025).

The rest of the paper is organized as follows. Section 2 describes our data. Section 3 presents the empirical results. Section 4 lays out the model. Section 5 discusses the calibration of the model, and Section 6 presents the quantitative findings of the effects of the firm's anticipatory responses on aggregate dynamics. Lastly, Section 7 concludes.

2 Data

We construct a firm-level dataset that includes information on US firms' imports, tariff rates faced by product-countries each period, and the firms' financial information. This section first describes the different data sources, the methodology for dataset construction, and summary statistics.

2.1 Data Sources

We combine three datasets, compiling information on firms' imports—such as products imported, partner countries, values—product-country-level tariffs across time, and firms' inventories, sales, assets, and cash flows.

The import data come from the shipment-level bill-of-lading (BoL) data from S&P Global's Port Import/Export Reporting Service (PIERS), which covers the near-universe of US maritime imports. PIERS collects raw bills of lading for almost all waterborne trade at US ports, sourced directly from US Customs and Border Protection, and assigns values in USD and an HS 6-digit code to each shipment. Regarding the usage of BoL data for international trade research, Flaaen et al. (2023) summarizes its advantages and disadvantages, and they show that the aggregate value for the US maritime imports in the BoL dataset aligns closely with the values reported by the Census Bureau.[1] Moreover, even though the data contain only maritime im-

[1] They compare Panjiva, another BoL dataset also managed by S&P Global, with the Census data.

ports, this mode of transport is the largest by value, accounting for nearly 50% of US imports in 2019.

The tariffs for the period between 2015 and 2019 are retrieved from Amiti, Redding, and Weinstein (2020, 2019), who compile the data from the United States International Trade Commission (USITC). We aggregate their data at the monthly-HTS10-country level to the quarterly-HS6-country level.[2]

The quarterly firm-level financial data come from the Compustat North America Fundamentals Quarterly. We collect information on inventories, sales, Tobin's Q, and cash flow over assets for the public firms in the dataset. Inventories are a key variable of interest in our analysis, and we use the other variables as firm-level controls in the empirical analysis.

To merge the BoL data with the Compustat, we undertake a series of data-cleaning procedures. The first issue is that there are many name variations for a firm in the BoL data, which makes it difficult to group different transactions belonging to the same firm. To overcome this, we start with a firm identifier provided by PIERS and improve the matching of transactions to firms through a text-analysis algorithm, increasing the number of matched observations by over 20%. Second, we create a firm-identifier correspondence to merge the BoL data with the Compustat data. This step entails matching firm names and firm name variations across time in both datasets. The construction of this correspondence is a crucial technical contribution of this paper, enabling all subsequent empirical analyses and model calibration.

The final dataset consists of 5,776 importing public firms and 2,677,379 importing firm–product–country pairs from 2012Q1 to 2019Q4. The granularity of our dataset enables us to study how firms adjust their imports around the tariff events, while controlling for firms' observable characteristics.

2.2 Summary Statistics

Our final dataset contains 5,776 public firms that imported at least once during 2012Q1–2019Q4. We report summary statistics in Table 1. First, it reveals a well-known pattern that trade is lumpy: Firms do not engage in imports continuously; rather, they place orders intermittently. Across all 32 available quarters, the average and median firm imported in 18 and 20 quarters, respectively (Panel (b)).

Novel insights arising from the detailed data are as follows. We observe that most firm-quarters import an HS6 product from a single country. Specifically, in Panel (d), more than 75% of importing firm-quarters source a given product from a single country. Even at the 90th percentile, importing firm-quarters source a product from two countries. We interpret our empirical results in relation to this pattern, later in Section 3.

Table 1: Summary Statistics

	Mean	Stdev	P10	P25	P50	P75	P90
(a) All firm-quarters (N = 154,783)							
Sales ($ millions)	1,401	5,459	1	15	133	669	2,710
Inventories ($ millions)	980	11,010	0	0	17	187	934
(b) Importing firms (N = 5,776)							
Importing quarters (count)	18	12	1	5	20	32	32
Importing products (count)	83	171	1	4	19	81	230
Importing countries (count)	13	16	1	2	6	17	34
(c) Importing firm-quarters (N = 104,908)							
Importing products (count)	19	40	1	2	6	18	49
Importing countries (count)	6	7	1	1	3	7	14
(d) Importing firm-quarter-products (N = 1,996,187)							
Imports ($ thousand)	3,253	116,589	2	11	57	299	1,602
Importing countries (count)	1	1	1	1	1	1	2
(e) Importing firm-quarter-countries (N = 595,113)							
Imports ($ thousand)	10,912	161,728	6	27	162	1,230	7,637
Importing products (count)	4	13	1	1	2	4	9
(f) Importing firm-quarter-product-countries (N = 2,677,379)							
Imports ($ thousand)	2,426	69,088	2	10	50	250	1,301

[2] HS is the universal 6-digit foundation used worldwide to classify products, the HTS is a country-specific extension (8–10 digits) used to determine the exact tariff rates. We take a simple average of HTS10–monthly tariff lines within an HS-6 digit and quarter. For the HS6 products that are not matched with the first six digits of HTS10 in the tariff data, we calculate their tariffs as the average within the higher-level of aggregation (i.e., HS4- or HS2-digit products).

Furthermore, we utilize the statistics for developing and calibrating the model. Panel (e) shows the number of products that a firm imports from a given country in a quarter. The mean firm imports around four products and the median two, but firms in the 90th percentile import nine. In our model, we assume that firms import multiple products from a single country. Panel (b) shows that the number of sourcing countries for importing firms is 17 at the 75th percentile, which we use as the number of countries in our model.

2.3 Tariff Dynamics

The two major product categories that faced tariff increases during our sample period are (i) steel and aluminum products and (ii) products from China. The timeline for the key events for the two tariff hikes is summarized in Table 2.

Notable points are as follows. First, the events that could lead firms to anticipate tariff increases in the future occur as early as a year prior. For example, the investigations by the Department of Commerce (for steel and aluminum) and by the United States Trade Representative (for Chinese products) began approximately 11 months before the first tariff increases.[3]

Second, the tariffs levied against China were characterized by significant breadth and depth; they not only covered a vast array of product categories but also targeted massive volumes of trade. Lists 1, 2, 3, and 4A for the tariffs against China were mutually exclusive. The composition of targeted goods shifted over time: while the earlier waves focused on intermediate inputs, the scope expanded to include consumption goods in later lists. The largest waves were Lists 3 and 4A, which covered $188 billion and $99 billion in 2017 imports, respectively.

Third, there is a sequence of "news shocks" prior to the realization of higher tariffs. For example, before the tariff increased for the Chinese products on List 3, the initiation of the USTR investigation, the President's determination on actions, and tariff increases for List 1 and 2 products comprise events when importers of List 3 products could learn about the possibility of future tariff hikes.

[3]During our sample period, there were tariff surges for solar panels and washers as well. For both product categories, the investigations began more than eight months prior to the implementation (Appendix A).

Table 2: Timeline of Tariff Increases on Steel, Aluminum, and Chinese Products

Event	Date	Description	Source	Products or Countries[b]	Value ($B)[c]
(a) Section 232: National Security (Steel and Aluminum)					
Investigation	Apr 19 & 26, 2017	DoC initiates investigation.	82 FR 19205	Steel, Alum.	–
Report	Jan 11, 2018	DoC reports findings.	DoC report	–	–
Announcement	Mar 1, 2018	Intent to impose global tariffs.	White House	All	–
Effective Date (I)	Mar 23, 2018	25% (Steel) / 10% (Alum.)	83 FR 11625	ROW[a]	18
Effective Date (II)	Jun 1, 2018	Expiration of exemptions	Proclamation 9759	Can, Mex, EU	22
(b) Section 301: Technology Transfer (China)					
Investigation	Aug 18, 2017	USTR initiates investigation.	82 FR 40213	–	–
Determination	Mar 22, 2018	President concurs with USTR.	83 FR 13099	–	–
List 1 Effective	Jul 6, 2018	25% tariff	83 FR 28710	Industrial Machinery	33
List 2 Effective	Aug 23, 2018	25% tariff	83 FR 40823	Chemicals	13
List 3 Effective	Sep 24, 2018	10% tariff	83 FR 47974	Consumer Products	188
List 3 Escalate	May 10, 2019	Rate raised to 25%	84 FR 20456	–	–
List 4A Effective	Sep 1, 2019	15% tariff	84 FR 43304	Apparel, Footwear, TVs	99
Phase One Deal	Dec 15, 2019	List 4B suspended	84 FR 69447	Cell Phones, Laptops	–

Notes: "DoC" refers to the Department of Commerce. "USTR" refers to the United States Trade Representative. "FR" refers to the Federal Register.
[a] "ROW" (Rest of World) includes countries not granted exemptions. South Korea, Brazil, and Argentina accepted quotas in lieu of tariffs.
[b] This column denotes the products or countries mainly targeted by each event.
[c] Values represent the 2017 annual import volume from the affected partners (in billions of USD), based on authors' calculation using the Census data.
[*] List 4B was scheduled to go into effect on Dec 15, 2019, covering roughly $160 billion in imports, but was suspended indefinitely following the Phase One trade agreement.

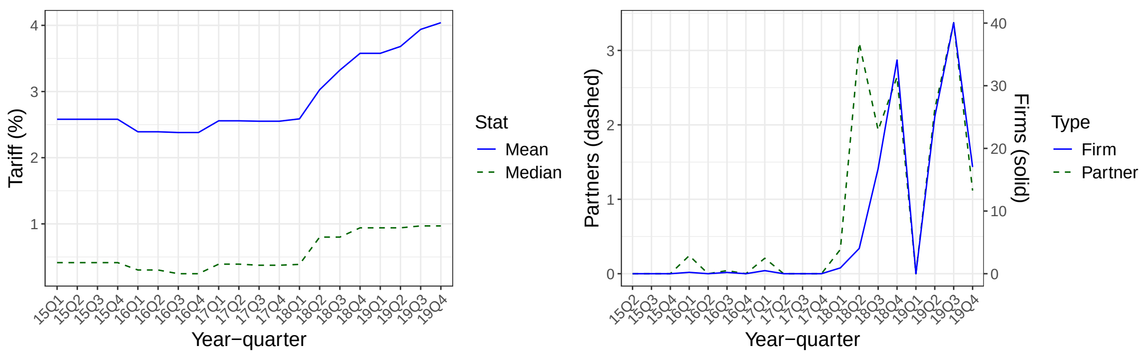
Later in Section 3.1, we discuss import responses to each of the six tariff waves (two for steel and aluminum and four for China) to provide suggestive evidence behind front-loading of imports.

Next, we describe the dynamics of the tariffs over our sample period. Panel (a) of Figure 2 shows the mean and median tariff across all trade partners (including those with zero tariffs), defined as an HS-6 product–country pair for each quarter. The figure shows that the mean and median tariffs increased significantly beginning in 2018Q1. For example, the average tariff increased from around 2.5% to over 4.0% between 2017Q4 and 2019Q4.

Panel (b) illustrates the percentage of trade partners (product–countries) that experienced a tariff increase, defined as a quarter-to-quarter increase in tariffs of more than

Figure 2: Tariff Dynamics

(a) Mean and median tariff across partners (b) % of partners and firms with tariff increases



Note: Trade partners are defined at the product–country level, where products are classified at the HS6 level. A tariff increase for a partner is defined as an increase of more than 3 p.p. A tariff increase for a firm is defined as an import-volume-weighted tariff increase of more than 1 p.p.

3 percentage points (p.p.), with a dashed line.[4] The first significant tariff increase occurred in 2018Q2, when approximately 3% of partners faced an increased tariff.

Notably, Panel (b) also describes the share of US firms that experienced a tariff increase, defined as an import-volume-weighted tariff increase of more than 1 p.p., with a solid line. The share of firms with tariff increases is much higher than the share of partners with tariff increases. For example, in 2019Q3, while only 3% of partners faced a tariff increase, 40% of firms experienced a tariff increase. This is because the affected partners are intensively imported by US firms, portraying the widespread impact of tariff hikes. This finding complements Handley, Kamal, and Monarch (2025), who find that approximately a quarter of US *exporting* firms were impacted by the import tariff increases.

There were earlier tariff increases, as evidenced by two blips in 2016Q1 and 2017Q1 visible in Figure 2b. The tariff increases observed from 2015Q4 to 2016Q1 were not the result of a broad policy shift but rather reflected smaller-scale US policy

[4] We require the cutoff to prevent spurious observations of tariff increases. Specifically, if we define a tariff increase as any positive change in tariffs (i.e., with a cutoff of 0 p.p.), 45% of product–countries would be classified as those with tariff increases from 2016Q4 to 2017Q1. This is due to the HS code updates from HS 2012 to HS 2017 and the aggregation of the HS10 to HS6 levels, and not due to the imposition of higher tariffs. For the same reason, a cutoff for the firm-level tariff increase is required.

adjustments—most notably the expiration of temporary duty suspensions on sensitive commodities, such as dairy, sugar, and processed foods, and changes in preferential programs like the Generalized System of Preferences (GSP) that raised applied tariffs on textiles, footwear, and other imports. The tariff increase in 2017Q1 primarily reflects HS code updates.

3 Empirical Analysis

In this section, we conduct three sets of empirical analyses. First, using *aggregate* data, we provide descriptive evidence of front-loading and stockpiling of imports. For the second and third exercises, we use our *micro* data. We study how future tariff increases affect a firm's imports, inventories, and its set of foreign partners. We find that firms respond well before the policy change takes effect: they import more, accumulate inventories, and expand their supplier country set. Lastly, we analyze the firm-product-country response to understand how firms adjust their imports, along both the intensive and extensive margins. When a product-country that a firm imports from is expected to be affected by a tariff hike, firms increase their imports directly from that partner, and other countries that supply the same product, in both the intensive and extensive margins.

3.1 Aggregate Import Flows Around Tariff Waves

As previewed in Figure 1, we first examine preemptive stockpiling by contrasting import changes for product-countries subject to specific tariff waves against those unaffected by any of the 2018–2019 measures. We utilize the aggregate data of Amiti, Redding, and Weinstein (2019, 2020) who compiled import and tariff data from the Census Bureau and USITC, instead of our constructed data. This is because the aggregate data provides more granularity in terms of time, includes all modes of transportation, and covers all importers. (In contrast, our dataset features quarterly frequency, maritime imports, and Compustat public firms. The strength of our dataset is that it allows us to study firm-level responses and to explore the mechanisms through which firms front-run tariffs. Furthermore, it allows us to employ more rigorous empirical specifications that control for firm, time, origin country, and product characteristics.)

Before proceeding, note that we use import values (in US dollars) as our primary measure of imports throughout this paper for two reasons. First, because our firm-level and HS6 product-level analyses in the following sections require aggregating across heterogeneous products, dollar values provide a consistent unit of aggregation where physical quantities, such as weights and volumes, do not. Second, given that Amiti, Redding, and Weinstein (2019) and Fajgelbaum et al. (2020) document complete tariff pass-through (implying stable pre- and post-tariff import prices), movements in import values primarily reflect changes in quantities, ensuring that our use of values does not distort the temporal dynamics.

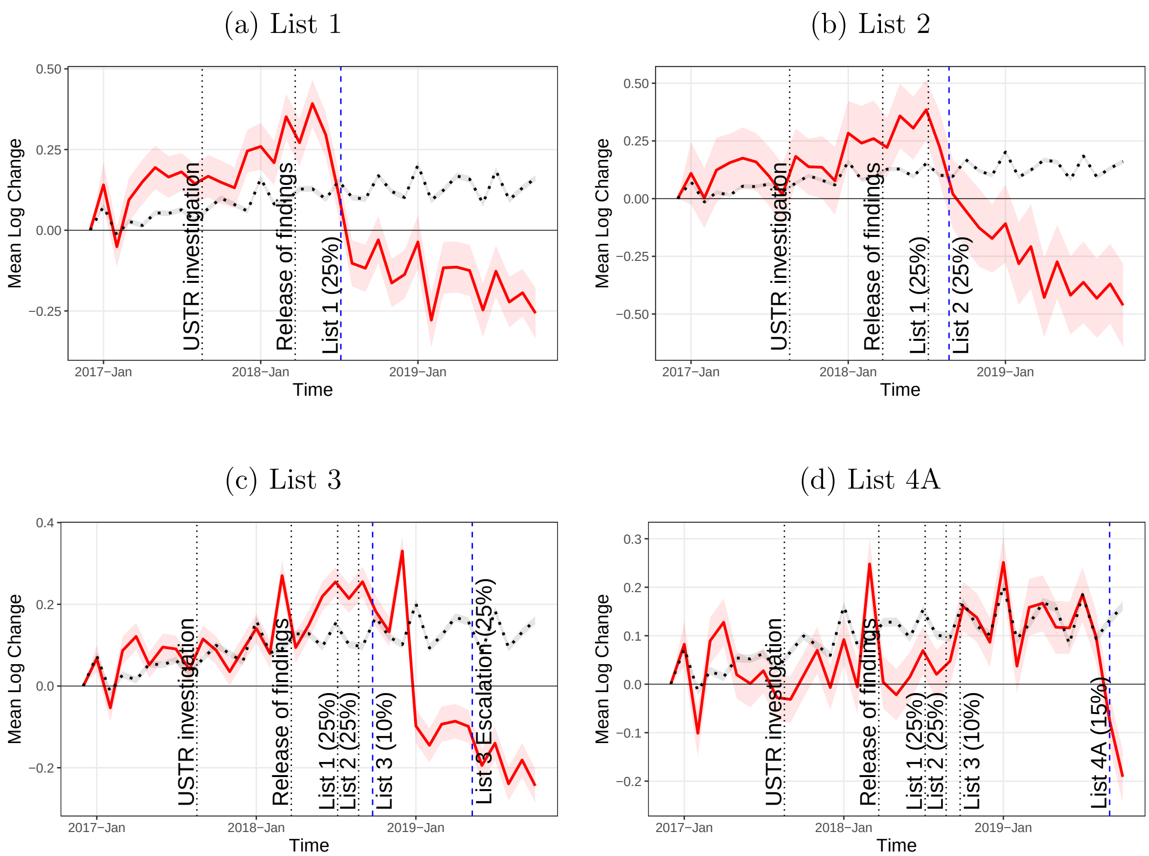
Let $X_{h,c,t}$ denote the import value for an HTS10 product-country pair (h, c) at time t. We analyze the log change of $X_{h,c,t}$ relative to the corresponding month in 2016 (i.e., $\log(X_{h,c,t}) - \log(X_{h,c,2017m(t)})$, where $m(t)$ denotes the month of t). For example, let's suppose that t is April 2018, then we measure the log growth of imports from April 2016. This is to control for seasonality, which is particularly important for consumer goods from China affected by the tariff hike. We then take the average of the log change across all product-country pairs that are affected by a given tariff wave, and compare it to the average log change of unaffected product-countries.

Figure 3 illustrates the import dynamics for Chinese products subject to each tariff wave. We generally observe a decrease in imports after the realization of higher tariffs, denoted by the blue dashed lines. However, for the ex-ante response of imports, we see significant heterogeneity. For List 1 and 2 products (Panels (a) and (b)), we uncover stockpiling of imports after the USTR initiated an investigation, with imports peaking one or two months prior to the realization of higher tariffs.

For List 3 products—the largest tariff wave, covering \$188 billion in 2017 imports—we observe multiple "anticipatory peaks." After the trade investigation and before the initial 10% levy was imposed, imports surged in March 2018 and before the implementation of the higher tariffs. On March 22, 2018, the Trump administration officially released the findings of the USTR investigation, and the President signed a memorandum directing the USTR to levy tariffs on Chinese imports. This suggests that news shocks and policy events significantly influenced import timing. We also observe substantial stockpiling prior to the eventual escalation to 25%. Notably, imports spiked in late 2018 even after the initial 10% tariff was in effect. This pattern is consistent with "a race against the clock:" importers likely accelerated shipments to lock in the 10% rate and avoid the scheduled hike to 25% (originally planned for January 1, 2019).

Unlike Panels (a)-(c), which show significant front-loading of imports, products subject to List 4A tariffs (Panel (d)) display no significant stockpiling upticks, except in

Figure 3: Dynamics of Products Affected by Tariffs Against China
(Generally, there exists stockpiling prior to a tariff wave.)



Note: The figure plots the average log change in import volumes relative to the corresponding month in 2016 (with 95% confidence intervals) across HTS10 product-country pairs. Panels (a) through (d) contrast product-countries subject to the Lists 1, 2, 3, and 4A of tariffs against China (red solid lines), against those never subject to tariff increases during 2018–2019 (black dashed lines). For more institutional details, see Section 2.3. Vertical black dotted lines mark major "anticipatory" events (e.g., the initiation of Section 301 by the USTR or earlier tariff waves). Vertical blue dashed lines indicate the date of tariff increases.

Source: Authors' calculations based on data from the Census Bureau and the US International Trade Commission (USITC), compiled by Amiti, Redding, and Weinstein (2019, 2020).

March 2018.

Two important remarks are as follows. First, we interpret the uncovered patterns in Figure 3 as suggestive evidence of policy-driven anticipation. Second, the patterns illustrate the fundamental difficulty in isolating a discrete "news shock." Importers responded to a series of compounding signals—ranging from initial investigations to the unrealized threat for List 3 products—any of which could plausibly serve as the relevant news event. Given this ambiguity, we define the effective date of the tariff increase (realization) as our event time ($t = 0$) in the subsequent analysis. By centering on the implementation date, we avoid arbitrarily selecting a news date and instead rely on pre-trends to capture the anticipatory effects.

In addition to tariffs against China, the period 2018–2019 also witnessed the imposition of tariffs on steel and aluminum imports. In Figure 1 of the Introduction, we have illustrated the change in imports for the products targeted by the June 2018 steel and aluminum tariffs. In Figure A1 of Appendix A, we illustrate the import dynamics due to the March 2018 steel and aluminum tariffs.

3.2 Firm-Level Response to Future Tariff Increases

We now turn to the firm-level data we constructed to study how *firms* adjusted their imports in response to future tariff increases. We start by constructing an import-weighted tariff for a firm, which captures how exposed the firm is to a tariff change given its partner set. Due to the observed infrequent trade shipments at the firm level in the data—we discussed the lumpiness of trade in Section 2.2—we consider the *existing* set of partners, $E_{i,t}$. It is defined as the cumulative set of partners the firm traded with in the past four quarters, $E_{i,t} \equiv \bigcup_{k=-4,..-1} C_{i,t+k}$, where $C_{i,t}$ represents the *current* set of partners the firm traded with at time t. Then, we use $x_{i,h,c,t}$ to denote the current import volume of firm i from product-country partner (h, c) at t, and let $v_{i,h,c,t} = \sum_{k=-4,...,-1} x_{i,h,c,t+k}$ denote the existing import volumes.

Next, we define the firm-level tariff, $\hat{\tau}_{i,t}$, as the import-weighted tariff across the existing imports of the firm at time t:

$$\hat{\tau}_{i,t} \equiv \frac{\sum_{(h,c)\in E_{i,t}} v_{i,h,c,t}(\tau_{h,c,t} - \tau_{h,c,t-1})}{\sum_{(h,c)\in E_{i,t}} v_{i,h,c,t}}, \tag{1}$$

where $\tau_{h,c,t}$ represents the tariff on the product-country (h, c) at time t. Further, we define a dummy variable, $TI_{i,t} = 1$, if the firm tariff increases by more than one percentage point, $\hat{\tau}_{i,t} > 0.01$, and zero otherwise. We set a low, yet positive, threshold to ensure that neither a small degree of tariff increase nor a tariff increase for a product-country partner that does not account for much of the firm's imports is categorized as a tariff-increase event.

We also define a dummy variable $FTI_{i,t} = 1$ which indicates that the firm i faced the tariff increase ($TI_{i,t} = 1$) for the first time at time t. Specifically, $FTI_{i,t} \equiv \mathbb{1}(TI_{i,t} = 1 \text{ and } t = \min\{s : TI_{i,s} = 1\})$. For our baseline empirical analysis, we utilize the $FTI_{i,t}$ instead of $TI_{i,t}$ because our focus is to study the front-running behavior of firms in response to a future tariff increase. There have been multiple tariff waves throughout 2018–2019—as shown in Section 2.3—firms often face several tariff increases. Therefore, analyzing the pre-effects through $TI_{i,t}$ could compound the effects of serially-correlated tariff increases. By contrast, using $FTI_{i,t}$ allows us to more cleanly identify the anticipatory response prior to the first tariff increase. Furthermore, importantly, instead of the dummy variable $FTI_{i,t}$ as the main regressor, we can also utilize the continuous measure of firm-level tariff increase and show that our results are consistent across both measures in Appendix B.

We study the dynamic response of the firm to a first tariff increase, $FTI_{i,t}$, using local projections following Jorda (2005). We quantify the response of import volume, the number of partners the firm trades with, and inventories. We regress the variable of interest at different horizons around the first tariff increase, from -6 to $+6$ quarters. (Since the first major tariff increases occur in 2018Q2, and since our data ends in 2019Q4, we do not have enough variation to concisely estimate the response six quarters after the first tariff increase. Note that extending our dataset beyond 2019 will not likely enable us to robustly estimate the response after the sixth quarter, since the COVID-19 pandemic started in early 2020.)

Specifically, we estimate the equation for $k = -6, ..., 6$:

$$y_{i,t+k} = \beta_k \, FTI_{i,t} + \Gamma' X_{i,t} + \mu_i + \mu_t + \epsilon_{i,t,k} \tag{2}$$

where $y_{i,t+k}$ denote the variable of interest, $X_{i,t}$ is a vector of firm-level controls (log sales, Tobin's Q, and cashflow over assets), and μ_i and μ_t are the firm and time fixed effects.[5] We estimate the coefficients, β_k, to capture the response of the variable of interest at time $t+k$ to an increase in tariff in quarter t.

Our empirical specification is to include as many data observations as possible. Related to this, three remarks are as follows. First, to obtain $y_{i,t+k}$, we transform the variables by taking the inverse hyperbolic sine, defined as $\text{asinh}(x) \equiv \ln\left(x+\sqrt{x^2+1}\right)$. This enables us to include zeros in our observations, unlike the logarithm. As trade is lumpy, 43% of all firm-quarters report zero imports (and therefore zero import partners), log scale excludes these observations, which would lead to a substantial loss of useful variation, especially for the identification of the fixed-effect terms.[6]

Second, since our panel data is unbalanced, not all 5,776 public firms in our sample have observations for all 32 quarters. On average, one firm has observations on Compustat for 27 quarters. Therefore, the underlying number of firm-quarter observations for each β_k differs across time horizon k. Constructing the balanced panel is possible, but at the cost of losing firms that do not populate all 32 quarters.

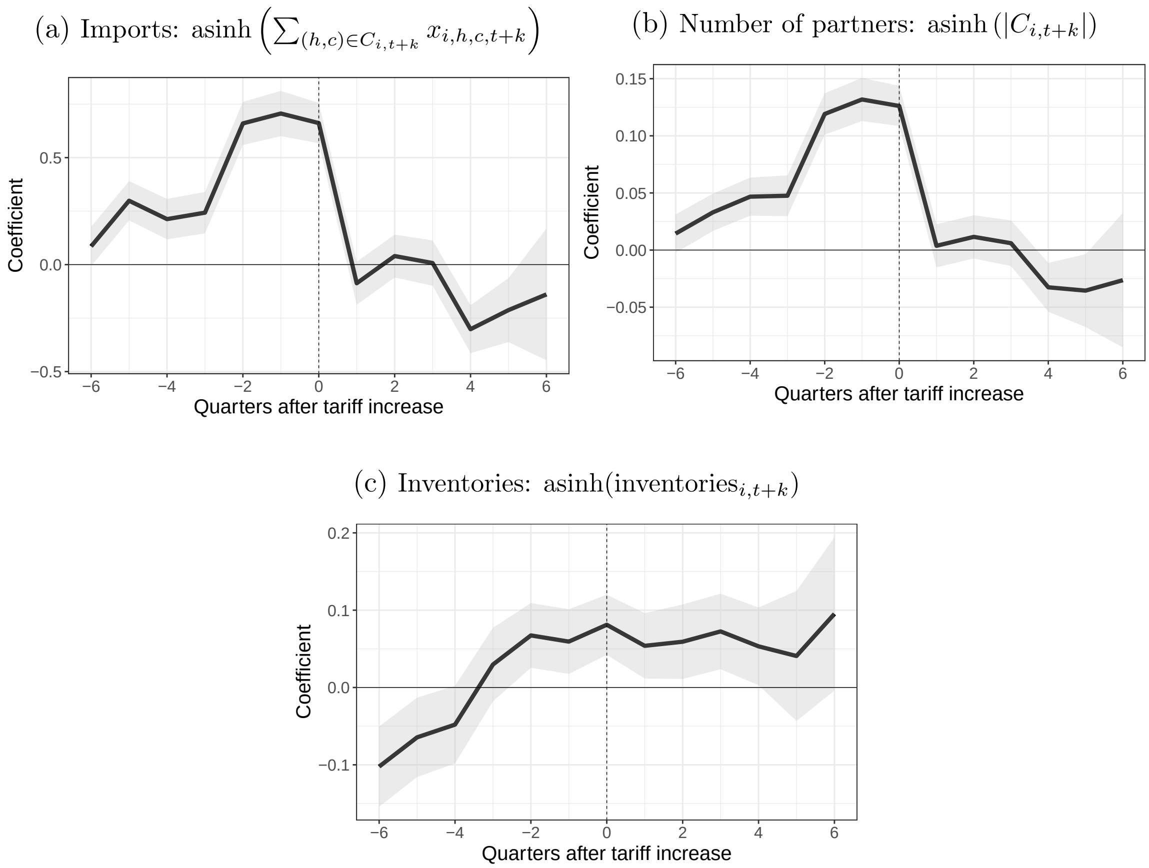
Third, for our y variable, instead of changes, $\text{asinh}(y_{i,t+k}) - \text{asinh}(y_{i,t-1})$, we use the level $\text{asinh}(y_{i,t+k})$. The rationale is twofold: First, we can include firms that show up at time $t+k$ but not at $t-1$. Second, since our key interest is on the anticipatory effect, and the aggregate data shows suggestive evidence of early front-loading of imports (Section 3.1), what reference time to choose (e.g., $t-1$) is not straightforward.

Turning to our results, first, we consider the firm's current import volume response to a rise in tariffs, by estimating Equation (2) where $y_{i,t} = \text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$, the sum of all current imports. Panel (a) of Figure 4 shows the dynamic response before and after the tariff increase, summarized by the estimated $\{\beta_k\}_{k=-6,\ldots 6}$. Firms that expect a tariff increase ($FTI_{i,t}=1$) start to increase their imports around four quarters before the first increase in tariffs, and the imports peak a quarter before the shock. After the tariff increase, imports decrease.

[5] Tobin's Q and cash flow over assets are winsorized at 99% level.

[6] The inverse hyperbolic sine is approximately linear for small values of y and approximately equal to $\ln(2y)$ for large positive values, thereby behaving similarly to a logarithm for large magnitudes while preserving zero observations. The inverse hyperbolic sine transformation faces the scaling issue (Chen and Roth 2024). Scaling up or down observations by a constant can yield arbitrary quantitative results. One of the recommendations by Chen and Roth (2024) is to analyze intensive and extensive margins separately, and we explicitly account for the extensive margin separately for

Figure 4: Imports, Number of Partners, and Inventories Around a Tariff Increase
(All three measures see an increase prior to the realization of higher tariffs.)



Note: The figures describe the estimated $\{\beta_k\}_{k=-6,...6}$ in Equation (2), for imports, the number of partners, and inventories. The shaded area indicates the range of one standard error above and below the estimate.

Next, the number of current partners (i.e. products-countries that a firm is importing from) also increases before the rise in tariffs. Panel (b) shows the estimates when $y_{i,t} = \text{asinh}(|C_{i,t}|)$, the number of current partners, where firms increase the number of partners around three quarters before the tariff hike. The qualitative pattern is similar to that of import volume response, with an anticipatory increase and the following decrease.

Since imports carry long lead times and higher fixed costs compared to domestic sourcing, importing firms tend to hold larger inventories (Alessandria, Kaboski, and

the firm-partner-level analysis in the next subsection.

Midrigan 2010). Thus, in Panel (c) of Figure 4, we estimate the impact of the tariff on the firm's quarterly inventory data, where $y_{i,t} = \text{asinh}(\text{inventories}_{i,t})$. Firms that are affected by the tariff hike increase their inventories starting four quarters before the tariff increase. Since, imports are inventory intensive, we can interpret Panel (a) and (c) that firms prepare for a future increase in tariffs by raising their imports and stockpile them as inventories.

Three remarks are in order. First, the qualitative similarity between the responses of import volumes and the number of partners suggests that the intensive and extensive margins are responding hand-in-hand to the change in tariffs. This pattern motivates how we incorporate the extensive margin into the model.

Second, the lumpiness of trade could imply that the results merely reflect the shift in the time of order and shipment of imports, instead of significant stockpiling or the increase in the number of partners. As a robustness exercise, in Figure A4 of Appendix A, we study the response of the existing import volumes and the number of existing trade partners, and the results robustly hold. Further, we conduct additional robustness checks when we use as the regressor the continuous measure of firm-level tariff increase (Appendix B) or the dummy for the tariff increase, $TI_{i,t}$, instead of the first tariff increase, $FTI_{i,t}$ (Figure A3 in Appendix A).

Third, the inverse hyperbolic sine transformation does not lend itself to as clean an interpretation as logarithms. In Figure A2 of Appendix A, we re-conduct the exercise using log transformations, which excludes firms with zero imports and thus abstracts from the extensive margin. Given our point estimates at $k = -1$, the current imports, the number of current partners, and inventories were 8.9, 5.7, and 2.7 percent higher, respectively, for treated (tariff-affected) firms.

To the best of our knowledge, this is the first paper to show the import and inventory response to a future rise in tariff at the firm-level; Alessandria, Khan, and Khederlarian (2024) provide aggregate evidence of stockpiling of imports for China's most favored nation tariff renewal voting. Further, the extensive margin response, where firms increase their set of partners before the rise in tariffs, is a novel fact we show in this paper.

Furthermore, we contribute to the literature on the 2018–2019 tariff war. Despite their focus on tariff pass-through after the implementation, Amiti, Redding, and Weinstein (2020, ARW); Fajgelbaum et al. (2020, FGKK); and Cavallo et al. (2021, CGNT) discuss the anticipation effects of tariffs. ARW find no pre-trends in imports before the tariff shock, and FGKK find moderate anticipatory effects. Unlike the two papers that utilized aggregate data, CGNT find significant stockpiling of imports and inventories of US retailers ex-ante. We discover that, both in our firm-level data and aggregate import data, the front-running effects are significant.

3.3 Margins of Import Adjustment

In the previous section, we show the firm-level forward-looking response of imports, the number of import partners, and inventories to a tariff increase. Particularly, we demonstrated that firms adjust their imports along both the extensive and intensive margins, on which we provide detailed views in this section.

Making use of the data at the partner (product-country) level, we analyze which product-countries firms adjust or substitute to when they expect a future increase in tariff. As a preview of our results, before the tariff hike, we find that firms increase their imports from partners that would face higher tariffs in advance of the tariff implementation. We also find a positive forward-looking import response for alternative countries that supply the same product. On the extensive margin, prior to the tariff surge, firms become less likely to drop and more likely to add the product-country directly affected by the tariff. We discover similar qualitative pattern for the other countries that supply the same product.

One note of caution for the extensive margin is as follows. Despite the usage of terms "drop" and "add," the adjustment reflects both the timing of shipments and the selection of import partners. Since import flows are lumpy—the median firm in our sample imports in only 20 of the 32 quarters—"adding" a partner means either choosing the timing of import or adding that partner to the set of suppliers.

Towards the results, when a particular firm's import partner is expected to face a tariff increase, we analyze the intensive and extensive margin response of all the firm's partners. This is to analyze the possible substitution patterns due to higher tariffs. In particular, we classify firms' partners into four types:

(i) Affected product-affected country

(ii) Affected product-unaffected country

(iii) Unaffected product-affected country

(iv) Unaffected product-unaffected country

To illustrate with an example, if (i) small DC motors (HS6: 850131) from China are expected to face an increased tariff, we ask whether a US firm that was importing the DC motors from China adjust their imports for not only (i), but (ii) the same product from Vietnam, (iii) single-phase AC motors (HS6: 850140) from China, or (iv) the AC motors from Vietnam.[7] Comparison across the four types of partners sheds light on the adjustment made by the firm on the affected partner, and whether the firm substitutes towards other countries or products.

For the analysis, we first introduce some notations. We define a dummy variable at the firm-partner level, $TI_{i,h,c,t}$, which indicates a tariff increase of more than 3 percentage points for a product-country that belong to the existing set of the firm:

$$TI_{i,h,c,t} = \begin{cases} 1, & \text{if } \tau_{h,c,t} > \tau_{h,c,t-1} + 0.03, \text{ and } (h,c) \in E_{i,t}, \\ 0, & \text{otherwise.} \end{cases}$$

Using $TI_{i,h,c,t}$, we create dummy variables denoting whether (i,h,c,t) belongs to each of the four types of partners. (i) $AA_{i,h,c,t} \equiv TI_{i,h,c,t}$ denotes that the product-country partner (h,c) who is one of firm i's existing partner is affected by the tariff increase at t. (ii) $AU_{i,h,c,t} \equiv (TI_{i,h,c,t} = 0) \wedge (\max_{c'} TI_{i,h,c',t} = 1)$ denotes that the product-country partner (h,c) is unaffected, but another country, c', that supplies that product, h, to firm i is affected by a higher tariff. (iii) $UA_{i,h,c,t} \equiv (TI_{i,h,c,t} = 0) \wedge (\max_{h'} TI_{i,h',c,t} = 1)$ denotes that the product-country partner (h,c) is unaffected, but another product, h', supplied by the same country, c, to firm i is affected. (iv) $UU_{i,h,c,t} \equiv (\max_{c'} TI_{i,h,c',t} = 0) \wedge (\max_{h'} TI_{i,h',c,t} = 0) \wedge (\max_{h',c'} TI_{i,h',c',t} = 1)$ denotes that the product-country partner (h,c) is unaffected; the countries supplying product h and no products coming from country c were affected by tariff; but some other partners that supply to firm i

[7] The HS6 product 850131 was targeted by List 1 tariff and the HS6 product 850140 was targeted by List 3 tariff.

is affected by a tariff increase.

We estimate the response for the four types of the partners using local projections. We quantify the intensive and extensive margin response of the partners of the firm around a tariff increase. To do so, we estimate the following dynamic relationship from $k = -6$ through $k = 6$:

$$\begin{aligned} y_{i,h,c,t+k} \;=\; & \beta_{AA,k} AA_{i,h,c,t} \;+\; \beta_{AU,k} AU_{i,h,c,t} \;+\; \beta_{UA,k} UA_{i,h,c,t} \;+\; \beta_{UU,k} UU_{i,h,c,t} \;+ \\ & \Gamma' X_{i,t} \;+\; \mu_i \;+\; \mu_h \;+\; \mu_c \;+\; \mu_t \;+\; \epsilon_{i,h,c,t,k}, \end{aligned} \tag{3}$$

where $y_{i,h,c,t+k}$ denotes our variable of interest; and $X_{i,t}$ is a vector of firm-level controls, where we include Tobin's Q, cash flow over assets, and the logarithm of sales. We include firm, product, country, and time fixed effects.

3.3.1 Extensive Margin

To study the extensive margin response of each type of partner, we examine whether the tariff increase for a partner affects the probability of affected and unaffected partners being dropped from or added to the *existing* (i.e. cumulative) set of partners. First, we define the probability of a firm dropping a partner, $PD_{i,h,c,t}$, which happens when a firm i imports from a partner at $t-5$ but did not import from them between $t-4$ to $t-1$. The definition is shown in Equation (4). Then we define the probability of a new partner being added to the existing set of a firm, $PA_{i,h,c,t}$. A firm adds a new partner if the firm i did not import from the partner (h, c) between $t-5$ and $t-2$, but imported from them at $t-1$. The probability of adding a partner is shown in Equation (5).

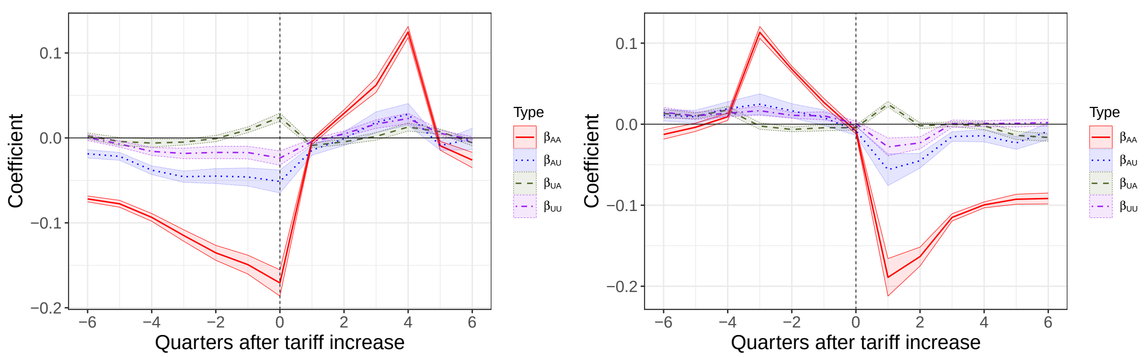
$$PD_{i,h,c,t} = \begin{cases} 1 & \text{if } (h,c) \in E_{i,t-1} \;\wedge\; (h,c) \notin E_{i,t} \\ 0 & \text{if } (h,c) \in E_{i,t-1} \;\wedge\; (h,c) \in E_{i,t} \end{cases} \tag{4}$$

$$PA_{i,h,c,t} = \begin{cases} 1 & \text{if } (h,c) \notin E_{i,t-1} \;\wedge\; (h,c) \in E_{i,t} \\ 0 & \text{if } (h,c) \in E_{i,t-1} \;\wedge\; (h,c) \in E_{i,t} \end{cases} \tag{5}$$

We study how the probability of each type of partner being added or dropped surrounding a tariff increase by estimating a linear probability model through local projection. To do so, we set the variable of interest in Equation (3), $y_{i,h,c,t+k}$, equal to $PD_{i,h,c,t+k}$ and $PA_{i,h,c,t+k}$, and the estimates are shown in Figure 5. Note that the changes in the coefficients over time describe the dynamics of the estimates for that type of partner over time, whereas the difference from zero, and from each other, denotes the difference in the estimated effect across partner groups.

Figure 5: Extensive Margin Adjustments
(Significant within-product extensive-margin adjustments)

(a) Prob. of being dropped: $PD_{i,h,t+k}$ (b) Prob. of being added: $PA_{i,h,t+k}$



Note: The figures describe the estimated responses from Equation (3). The shaded area indicates the range of one standard error above and below the estimate. The estimates β_{AA}, β_{AU}, β_{UA}, and β_{UU} reflect the effects of tariff increase on (i) affected product-affected country, (ii) affected product-unaffected country, (iii) unaffected product-affected country, and (iv) unaffected product-unaffected country, compared to the other firm-product-countries where firm-quarter was not affected by any tariff increase.

In Panel (a), the probability of dropping (i) the affected product-affected country, shown in red-dotted lines (β_{AA}), decreases sharply before the tariff hike, and then increases right after t. This implies the firm is more willing to keep the affected partner before the tariff increase, and drop them right after. A similar response for the affected partner is shown in Panel (b), where the probability of adding an affected partner is high before the tariff increase, and drops quickly after.

Figure 5 also offers insight into firms' import substitution patterns. When a partner is expected to get affected by tariff increase, a firm can adjust across-country or across-product. We find that, other than the adjusting for the affected partners, the most significant extensive margin of adjustment is on (ii) the affected product-unaffected country denoted by the blue-solid lines (β_{AU}). For example, this implies that when DC motors from China observe a tariff increase, then firms substitute towards DC motors from Vietnam. The probability of dropping (adding) the affected product-unaffected country partner decreases (increases) before the tariff on the affected partner, and increases (decreases) after. We do not find as big a response for the (iii) unaffected products-affected countries (e.g., AC motors from China), denoted by the green dashed lines (β_{UA}) or for (iv) other unaffected partners of the firm, shown by the purple dashed-dot lines (β_{UU}). We can interpret this result as the following. Firms build resilience by adding more countries to their partner set that provide the same product that will face an increase in tariff. This result echoes Flaaen, Hortaçsu, and Tintelnot (2020) who showed that the antidumping duties against washing machines from South Korea and China in the 2010s incurred a production relocation to other countries.

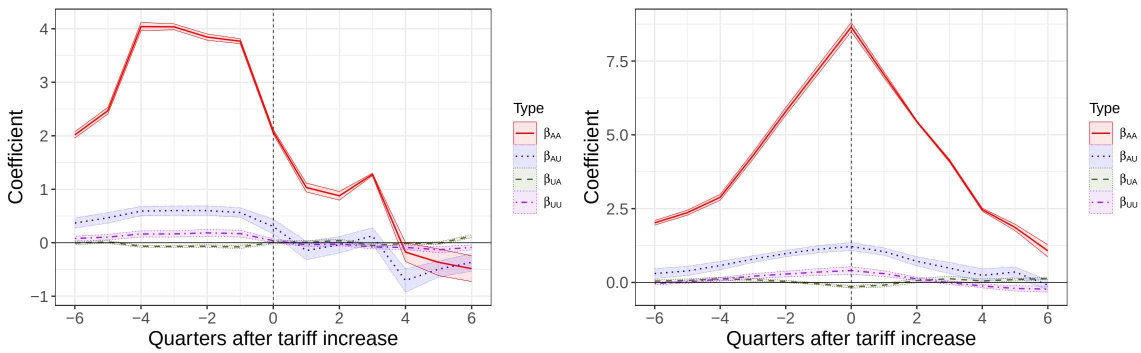
3.3.2 Intensive Margin

Next, we turn to analyze the intensive margin response of each type of partner. To do so, we use as our variable of interest the current and existing imports of each partner of the firm, $x_{i,h,c,t+k}$ and $v_{i,h,c,t+k}$, transformed using the inverse hyperbolic sine to estimate Equation (3). Figure 6 describes the estimation results. As with the extensive margin, we can see the significant stockpiling effects in the intensive margin for (i) the affected partner in the red-solid line (β_{AA}). The estimated effect is shifted up due to the serial correlation of tariff increase dummy. Thus, the effect picks up past and/or future responses of the changes in tariffs. After the tariff increase, firms decrease their imports from the affected partners. A similar pattern is observed for (ii) the affected product-unaffected country, in the blue-dotted line (β_{AU}). It shows that the firms increase their imports of the affected product also from unaffected countries (e.g., DC motors from Vietnam) before the tariff increase. We do not see a significant intensive response in imports for the (iii) unaffected products-affected countries (e.g., AC motors from China), denoted by the green dashed lines (β_{UA}) or for (iv) other unaffected partners of the firm, shown by the purple dashed-dot lines (β_{UU}).

To sum up the empirical analysis, we find new evidence that in the expectation of tariff increase, firms tend to increase imports, inventories, and the number of trade

Figure 6: Intensive Margin Adjustments
(Significant within-product intensive-margin adjustments)

(a) Current import volume: $\text{asinh}(x_{i,h,c,t+k})$ (b) Existing import volume: $\text{asinh}(v_{i,h,c,t+k})$



Note: The figures describe the estimated responses from Equation (3). The shaded area indicates the range of one standard error above and below the estimate. The estimates β_{AA}, β_{AU}, β_{UA}, and β_{UU} reflect the effects of tariff increase on (i) affected product-affected country, (ii) affected product-unaffected country, (iii) unaffected product-affected country, and (iv) unaffected product-unaffected country, compared to the other firm-product-countries where firm-quarter was not affected by any tariff increase.

partners. After the tariff implementation, they decrease them. We investigate the margins of adjustment. We find that both intensively and extensively, the most significant adjustment was toward the directly affected partners. The second most important margin is toward the affected products-unaffected country partners. These features are the motivation of the model we build in the next section, which will allow us to quantify the importance of taking into account the forward-looking behavior of firms towards tariff increases.

4 A Model of Inventories and Sourcing Choices

We build a model in which firms source inputs from foreign producers and stock them as inventory. It takes one period from the placement of the order for foreign inputs to arrive. Firms face uncertain demand for their output. The one-period delivery lag and demand uncertainty create incentives for firms to stock inventory. Firms have expectations about future tariffs and can adjust their imports and inventories before a change in tariffs.

The model combines elements of the inventory model of Alessandria, Kaboski, and Midrigan (2011) and multi-country sourcing from Antras, Fort, and Tintelnot (2017, AFT, hereafter) to develop a multi-country trade model with inventory management. We depart from the literature by allowing firms to adjust both the intensive margin, where firms stock up on their inputs via inventories, and the extensive margin, where firms choose foreign partners to source inputs from. In the model, when firms expect the tariff on their inputs to increase in the future, they can strategically frontload their purchases and adjust their sourcing partnerships before tariffs rise.

4.1 Environment

Time is discrete and indexed by $t \in \{0, 1, 2, ...\}$. The domestic economy is populated by a unit continuum of monopolistically competitive firms. Each firm faces a demand shock to its final good output, which is independent and identically distributed (i.i.d.) across time and firms. Each firm produces a differentiated final good using a unit of inputs. We model the firm as comprising two managers: an inventory manager and an import manager.

The inventory manager faces a dynamic problem. In each period, they set the price and quantity of the final good and place orders for the composite input with the import manager. The delivery of foreign inputs takes one period, which reflects the delivery lag due to international trade. This along with the i.i.d. demand shock generates incentives for the inventory manager to hold inventories. The inventory depreciates at a constant rate if carried over to the next period. The inventory manager's optimal policy accounts for both current demand shocks and the future cost of inputs, which depend on tariff rates.

The import manager solves a static cost-minimization problem. They produce the intermediate input by aggregating a unit continuum of imported varieties with a constant elasticity of substitution (CES) technology. Each variety is available from J foreign countries, where J also denotes the set of all foreign countries. To minimize the cost of fulfilling the input order by the inventory manager, the import manager chooses the set of countries to source from. Importing from a specific country incurs a fixed cost; however, it grants the importer one additional cost draw for the unit of imported inputs, which lowers the marginal cost of the input.

We assume partial equilibrium to focus on the domestic firms' importing and inventory decisions in response to tariff shocks. The production costs in foreign countries are exogenous. Each foreign country $j \in J$ has technology to produce all input varieties, and the suppliers of each variety face perfect competition. Imports from country j are subject to tariff τ_j, which are commonly applied to all varieties.

4.2 Import Manager

We characterize the firm's problems recursively by beginning with the static cost-minimization problem of the import manager. For each firm, indexed by $\omega \in [0, 1]$, the import manager fulfills the input order—placed by the firm's inventory manager—by aggregating a unit continuum of intermediate varieties. To economize on notations, we omit subscript ω that denotes a firm, unless there exists potential confusion. Production follows a standard CES technology with an elasticity of substitution ρ,

$$y^i = \left(\int_0^1 x(\upsilon)^{\frac{\rho-1}{\rho}} d\upsilon \right)^{\frac{\rho}{\rho-1}} \tag{6}$$

Each variety υ can be sourced from J potential countries. To source varieties from the suppliers in the country j, the import manager needs to pay a fixed cost, f_j, in domestic labor whose price is given by w. The suppliers producing varieties $\upsilon \in [0, 1]$ in country $j \in J$ behave competitively and produce the variety with unit labor requirements $a_j(\upsilon)$. The importer can procure variety υ from country j at total cost $\tau_j a_j(\upsilon) w_j$. The variable τ_j captures the current tariff and the transportation cost of shipping the variety from the country j to the domestic economy. The wage in country j, w_j, is exogenously given. Note that, for simplicity, we assume that a tariff is applied to a country, and it is not country-variety specific. This assumption allows us to obtain a closed-form solution for part of the import manager's problem and is in line with the majority of the tariffs imposed in 2018–2019.

Given a set of countries the import manager decides to source from, $\mathcal{J}$, the cost of purchasing a variety υ, $z(\upsilon, \mathcal{J})$, is the minimum of the price across the suppliers of the countries in the sourcing set, $z(\upsilon, \mathcal{J}) = \min_{j \in \mathcal{J}} \{\tau_j \, a_j(\upsilon) \, w_j\}$. Last, the importer chooses the optimal set of sourcing countries, $\mathcal{J}$, by minimizing their marginal and fixed costs, subject to meeting the demand from the inventory manager, denoted by

n, as described in Equation (7). The optimal sourcing set, $\mathcal{J} \subseteq J$, is defined by the indicator variables, I_j, which take a value of one if the country j belongs to the optimal set, $\mathcal{J} = \{j \in J : I_j = 1\}$.

$$\begin{aligned} \min_{\{x(v)\}_{v\in[0,1]},\{I_j\in\{0,1\}\}_{j=1}^{J}} \quad & \int_0^1 z(v,\mathcal{J})\, x(v)\, dv + w \sum_{j=1}^{J} I_j\, f_j \\ \text{s.t.} \quad & y^i \geq n, \\ & \mathcal{J} = \{j \in J : I_j = 1\}, \\ & z(v,\mathcal{J}) = \min_{j\in\mathcal{J}} \{\tau_j\, a_j(v)\, w_j\}. \end{aligned} \tag{7}$$

The above shows the trade-off that the import manager faces: adding a country j to the set $\mathcal{J}$ incurs a fixed cost of f_j; however, it also grants an additional cost draw for $z(v,\mathcal{J})$ for all varieties v.

We impose additional assumptions on the problem. First, we assume the unit labor requirements for the variety productions are drawn from a country-specific Fréchet distribution, as in Eaton and Kortum (2002), where the $\Pr(a_j(v) \geq a) = e^{-T_j a^{\theta}}$. The state of technology in the country j is summarized by T_j, and θ controls the variability in the productivity draws across varieties. With this assumption, we can derive the marginal cost of producing the aggregated input, as in Antras, Fort, and Tintelnot (2017), which is given by

$$c(\mathcal{J}) = \gamma \left(\sum_{k\in\mathcal{J}} T_k\, (\tau_k\, w_k)^{-\theta} \right)^{-\frac{1}{\theta}}, \tag{8}$$

where $\gamma = \Gamma\left(\frac{\theta+1-\rho}{\theta}\right)^{\frac{1}{1-\rho}}$ is a constant with $\Gamma(\cdot)$ denoting the Gamma function.

The import manager has more incentives to add countries with higher technology parameter, T_j, or lower tariffs, τ_j, or wages, w_j, which lower the marginal cost of the input, $c(\mathcal{J})$. Further, adding an additional country to the sourcing set, $\mathcal{J}$, also lowers the marginal cost of the input. Given Equation (8), we can rewrite the import manager's extensive margin choice as below, where $p(n)$ denotes the average cost of the input:

$$p(n)n = \min_{I_j \in \{0,1\}_{j=1}^{J}} \left(c(\mathcal{J})\, n + w \sum_{j \in J} I_j\, f_j \right). \tag{9}$$

Further, following Blaum, Lelarge, and Peters (2018), we assume the fixed cost of adding a supplier country to the sourcing set is common across countries, $f_j = f,\ \forall j \in \mathcal{J}$. Thus, the import manager adds the countries to the optimal sourcing set according to their rank in terms of *sourcing potential*, $T_j\,(\tau_j w_j)^{-\theta}$. The importer adds countries to the sourcing set until the marginal cost reduction of an additional country is greater than the fixed cost f. Without this assumption, we have to solve a combinatorial problem to find the optimal sourcing set among the 2^J possible sets. Moreover, the assumption allows us to tractably compute how a change in tariffs may alter the rank of the country.

A higher demand for the aggregate input from the inventory manager gives more resources to the import manager, which allows them to include more countries in their optimal sourcing set and set a lower marginal cost. The relationship between the demand of the input, or the intensive margin response, and the optimal sourcing set, or extensive margin response, is formally outlined in the proposition below.

Proposition 1. *The optimal sourcing set given input demand, $\mathcal{J}(n)$, satisfies the following properties:*

(i) If $k \in \mathcal{J}(n)$ and $T_k\,(\tau_k\, w_k)^{-\theta} \leq T_j\,(\tau_j\, w_j)^{-\theta}$, then $j \in \mathcal{J}(n)$.

(ii) If $n_{low} < n_{high}$, then $\mathcal{J}(n_{low}) \subset \mathcal{J}(n_{high})$, and $c\,(\mathcal{J}(n_{low})) \geq c\,(\mathcal{J}(n_{high}))$.

The proof is provided in the Appendix C.1. Part (i) of Proposition 1 highlights that the countries will be added based on their ranking of sourcing potential. Part (ii) shows that the optimal sourcing set is increasing in the input demand, and the marginal cost is decreasing in the input demand. With Proposition 1, it is easy to see that the optimal sourcing set can be arranged according to input demand thresholds, where the importer will choose to add a country j_k (k-th country in the sourcing-potential ranking) if the demand is higher than a specific threshold, $n > n_k$. Given this, the marginal cost of the importer is constant within each interval of input demand, as outlined in Proposition 2.

Proposition 2. *Let j_k denote the k-th country according to the sourcing-potential ranking, n_k the associated demand threshold for the country to be added to the optimal sourcing set, and c_k the marginal cost when sourcing from top k countries based on the ranking. Then, from Equation (9),*

$$\frac{\partial(p(n)n)}{\partial n} = c_k, \text{ if } n \in (n_k, n_{k+1}).$$

Note that $n_{J+1} = \infty$.

The proof is derived from Proposition 1 and Equation (9). This proposition provides useful insight for the inventory manager's problem in determining final good prices in the following section and in simplifying the solution in Appendix C.2.

To analyze the impact of tariff changes, let $\vec{\tau}$ denote the vector of tariffs $[\tau_1, \tau_2, ..., \tau_J]$. We can refine the notations for the price of input and marginal costs so that they depend on the tariff vector: $p(n, \vec{\tau})$ and $c(\mathcal{J}(\vec{\tau}))$. The following proposition outlines the impact of an increase in a country's tariff on the input price and marginal costs.

Proposition 3. *Suppose that for country j, their tariff strictly increases from τ_j to τ_j', and let $\vec{\tau}$ and $\vec{\tau}'$ denote the tariff vectors before and after this increase, respectively. Then, for all $n \geq 0$, $p(n, \vec{\tau}') \geq p(n, \vec{\tau})$.*

The proof of the proposition is in Appendix C.1. The proposition states that the price of the input is weakly increasing in tariffs. Propositions 2 and 3 highlight the key mechanism through which the model rationalizes our empirical finding. The future increase in the tariff of a country in the firm's sourcing set creates incentives for the inventory manager to frontload their inputs today (intensive margin). As their input orders rise, the import manager can expand their sourcing set today (extensive margin), which lowers their marginal cost.

4.3 Inventory Manager

The inventory manager of the firm $\omega \in [0, 1]$ operates under monopolistic competition. They set the price and quantity of the final good, place input orders with the import manager, and make inventory decisions. They solve the following dynamic problem to maximize the discounted value of current and expected future profits.[8]

$$
\begin{aligned}
V(s,\nu,p(n,\vec{\tau})) = \max_{p^f,y^f,s',n} & \left(p^f y^f - p(n,\vec{\tau})n + \beta \mathbb{E}_{\nu'}\left[V(s',\nu',p(n',\vec{\tau}))\right]\right) \\
& \text{s.t.} \\
& y^f = \nu \left(p^f\right)^{-\epsilon}, \quad \text{(demand)} \\
& y^f = x, \quad \text{(technology)} \\
& x \leq s, \quad \text{(input constraint)} \\
& s' = (1-\delta)(s-x+n). \quad \text{(law of motion for inventory)}
\end{aligned} \tag{10}
$$

The inventory manager's dynamic problem is characterized by their revenue minus the cost of input orders, n, plus the discounted expected value of future profits. The manager's constraints are as follows. First, they face the CES demand from the consumer with an i.i.d. firm-specific demand shock, denoted by ν.[9] The manager sets the price of the final good, p^f, thereby determining the quantity sold to consumers, y^f. Second, they have a linear technology that transforms the input, x, to the final good. Third, the amount of inputs they can use to produce is constrained by their start-of-the-period inventory stock, s, which captures the one-period delivery lag of the order, n. Fourth, the next period's inventory stock, s', is determined by the law of motion, where s' is the sum of the input order today, n, and the amount of inventory that is left over after production today, $s-x$, which depreciates at a constant rate δ. The combination of the demand shocks and the one-period delivery lag of the input creates incentives for the inventory manager to stock inventories.

The first order condition with respect to the price of the final good, p^f provides insight

[8] We assume perfect foresight for our model calibration. In this case, the value function depends on the full future paths of tariffs. However, we can incorporate the probability of a tariff to be implemented in the future instead.

[9] The demand function can be derived by assuming that a representative consumer has the following utility function, along with normalization of the aggregate price index: $C = \left(\int_0^1 \nu_\omega^{\frac{1}{\epsilon}} \left(y_\omega^f\right)^{\frac{\epsilon-1}{\epsilon}} d\omega\right)^{\frac{\epsilon}{\epsilon-1}}$.

into the pricing rule for the final good.

$$p^f = \frac{\epsilon}{\epsilon - 1}\left(\beta(1-\delta)\frac{\partial \mathbb{E}_{\nu'}\left[V(s',\nu',p(n',\vec{\tau}))\right]}{\partial s'} + \lambda\right), \tag{11}$$

where λ is the Lagrange multiplier on the input constraint. If the firm is unconstrained in the amount of inputs they need to satisfy the demand, then the price will be equal to the markup, $\epsilon/(\epsilon-1)$, times the discounted value of an additional unit of inventory. If the inventory manager is constrained due to a high demand shock today relative to inventories, then the price of the input will rise until demand is met. In the steady state, the fraction of inventory managers that is constrained creates upward pressure in the final good prices.

Due to Proposition 2, the first order condition with respect to the input order, n, is as follows:

$$\beta(1-\delta)\frac{\partial \mathbb{E}_{\nu'}\left[V(s',\nu',p(n',\vec{\tau}))\right]}{\partial s'} = c_k, \tag{12}$$

for a $k \in \{1, ..., J\}$. Equations (11) and (12) together imply that

$$p^f = \frac{\epsilon}{\epsilon - 1}\left(c_k + \lambda\right). \tag{13}$$

Equation (13) shows the relationship between the final good prices and the intensive and extensive margin choices of the firm. For example, if the input order they place is low, then the import manager will have fewer countries in the sourcing set, which increases the marginal cost, c_k. On the other hand, if the inventory manager places a large order n, then the marginal cost, c_k, will be low. Further, given that large orders allow for a larger sourcing set, and thus a lower marginal cost of the input, there is an incentive for the inventory manager to place large orders intermittently, which is consistent with the lumpiness of trade, discussed in our empirical analysis.

The equation also reveals the relationship between the current inventory stock and the final good prices. A large initial inventory implies a lower probability of the firm being input-constrained ($\lambda = 0$). The opposite argument holds for a low initial inventory.

In the next section, we calibrate the model to match key moments of the U.S. economy and quantify the firm's response to future tariff increases. Further, we quantify the importance of the firm's anticipatory response in softening the transition of the aggregate outcomes.

5 Model Calibration

In this section, we describe how to use the model to quantify the firm's anticipatory response to a future rise in tariffs. First, we calibrate the model to match moments of the U.S. economy in 2015, and then we use the observed tariff changes between 2015 and 2019 to simulate the firm's response. A summary of the model parameters is provided in Table 3. We calibrate the fixed cost of importing, f, the variance of demand, σ_ν, and the technology parameters of the Fréchet distribution for each sourcing country to match the mean number of sourcing countries, the inventory to quarterly sales ratio, and the import shares from our sample in 2015. We assume the demand distribution is log-normal with a mean equal to one. As a result, the calibrated model observes a variance of demand equal to $\sigma_\nu = 0.78$ and the fixed cost of adding a country to the sourcing set equals $f = 0.005$. Note that the variance of demand can be interpreted as a parameter that summarizes all the different sources of uncertainty the firm faces—e.g., demand and productivity shocks. Note that the technology parameter, T_j, absorbs all initial differences across countries, and thus countries with larger import shares have higher estimated technology parameters.

We set the length of the period to be a quarter, according to our data availability. The discount factor, β, is set to $0.96^{1/4}$, which corresponds to a 4% annual interest rate. Following Richardson (1995), we set the storage costs, δ, equal to 5.0%, which implies a 20% annual rate. The elasticity of demand for a firm's final good variety, ϵ, is equal to 4.0, which corresponds to a 33% markup set by the final good firm. Following Antras, Fort, and Tintelnot (2017), we set the elasticity of substitution between the varieties demanded for the input, ρ, equal to 2.0 and the Fréchet parameter, θ, which governs the variability of productivity draws across varieties, to the value of 1.789. We show robustness checks of our quantification to different values of the predetermined parameters. Last, we set the number of countries, J, equal to 17, which corresponds to the third-quartile number of source countries per firm in our sample.

The estimated increase in tariffs is obtained using the difference of the import-weighted-average tariff for the J countries between 2015 to 2019. Formally, let

Table 3: Moments for the US Economy and Parameters

Panel A. Calibrated parameters

Parameter		Value	Data	Model
			Mean sourcing countries, 2015	
Fixed cost importing	f	0.005	13.0	13.2
			Mean inventories to sales, 2015	
Variance of demand	σ_ν	0.78	2.1	2.2
Technology parameter	T_j		Import shares, 2015	
1 China		0.82	21.5%	22.4%
2 Rest of the world		0.74	19.5%	20.3%
3 Mexico		0.51	13.2%	14.1%
4 Canada		0.51	13.2%	14.1%
5 Japan		0.27	5.8%	6.6%
6 Germany		0.26	5.6%	6.2%
7 South Korea		0.15	3.2%	2.4%
8 U.K.		0.12	2.6%	2.0%
9 France		0.10	2.1%	1.6%
10 India		0.09	2.0%	1.5%
11 Italy		0.09	2.0%	1.5%
12 Taiwan		0.08	1.8%	1.4%
13 Ireland		0.08	1.7%	1.3%
14 Vietnam		0.08	1.7%	1.3%
15 Malaysia		0.07	1.5%	1.2%
16 Switzerland		0.06	1.4%	1.1%
17 Thailand		0.06	1.3%	1.0%

Panel B. Predetermined parameters

Parameter		Value	Description
Number of countries	J	17	Sourcing countries in the third quantile
Fréchet parameter	θ	1.789	Antras, Fort, and Tintelnot (2017)
Elasticity of sub, $x(\upsilon)$	ρ	2	Antras, Fort, and Tintelnot (2017)
Interest rate	β	$0.96^{1/4}$	4% annual interest rate
Storage rate	δ	0.05	20% annual rate (Richardson 1995)
Elasticity of sub, y^f_ω	ϵ	4	Markups of 33%

Panel C. Estimated parameters

Parameter		Moment
Tariff increase	$\Delta\,\tau_j$	Increase in average tariffs: 2015 - 2019 (See Table 4.)

$\tau_{t,j} = \frac{\sum_{i,h} x_{i,h,j,t}\,\tau_{h,j,t}}{\sum_{i,h} x_{i,h,j,t}}$ where $x_{i,h,j,t}$ denotes firm i's imports from product h, country j, at time t. For each country, the tariff increase is defined as the difference between the 2015 and 2019 average tariff levels, $\Delta\,\tau_j = \tau_{2019,j} - \tau_{2015,j}$.

Table 4: Tariff Increases in Percentage Points

	Country	$\Delta_{2019-2015}\,\tau_j$		Country	$\Delta_{2019-2015}\,\tau_j$
1	China	15.05	11	Italy	0.14
2	Rest of the world	0.00	12	Taiwan	0.25
3	Mexico	0.21	13	Ireland	0.00
4	Canada	0.32	14	Vietnam	0.00
5	Japan	0.18	15	Malaysia	1.70
6	Germany	0.13	16	Switzerland	0.07
7	South Korea	0.00	17	Thailand	0.81
8	U.K.	0.00			
9	France	0.10			
10	India	0.12			

Note: The table shows the import shares for the 17 largest U.S. importers in 2015, including an aggregate for the Rest of the World, and the difference in the import-weighted-average tariffs for each country between the start of 2015 and 2019.

6 Effects of Tariff Front-Running

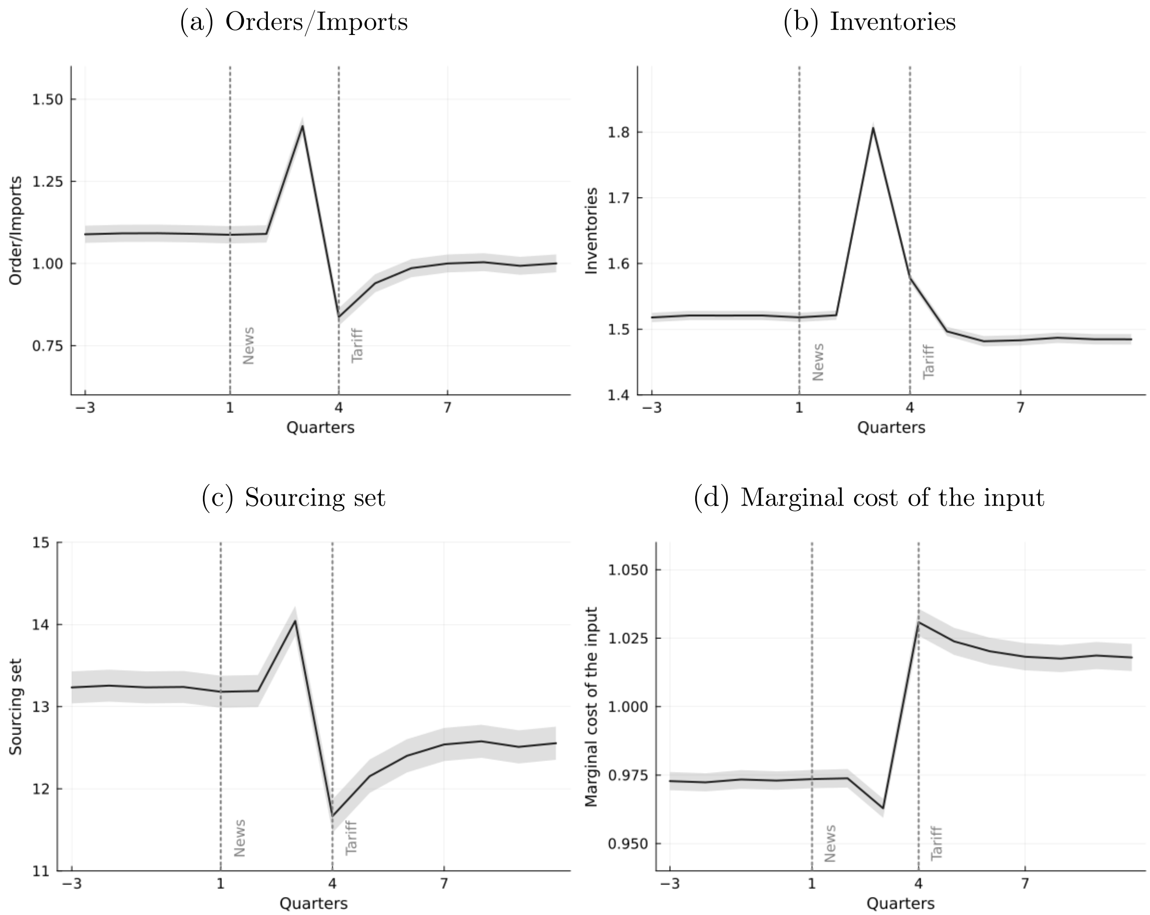
The model matches the observed patterns of the firm's anticipatory response, and we quantify its role in the macroeconomic response of aggregate output and prices. First, we discuss the firm's transition under the assumption of perfect foresight of a future tariff increase. We find that the firm's increase in inventories and the expansion of their sourcing set slow down the transition of aggregate output and prices. Then, we discuss the role of anticipation and the extensive margin in the model to match the data patterns. Last, we show that the firm's anticipatory response is robust to different model specifications.

6.1 Firm's Response to a Future Tariff Increase

We use the model to estimate the firm and aggregate changes when there is an expected increase in tariffs. We assume firms have perfect foresight, where they start in their low-tariff steady-state at time $t = 0$, and in period one, $t = 1$, they learn that tariffs will rise in three quarters (*news*). In period four, $t = 4$, the new tariffs are implemented (*tariff*). The timeline corresponds to the quarters between the initiation of the investigation and the first tariff implementation on imports from China and on steel and aluminum. Tariffs rise according to the historical increase in Table 4. While we assume certainty over the tariff increase, the model allows for the introduction of a probability over the tariff implementation. First, we compare the low- to the high-tariff steady state, and second, we discuss how the variables respond in the pre- and post-tariff transition.

Figure 7 shows the firm-level transition of inventories, imports (i.e., orders), the sourcing set, and the marginal cost of the input from the low- to the high-tariff

Figure 7: Firm-level Anticipatory Response to a Tariff Increase
(Model successfully replicates the empirical findings.)



Note: The figures show the transition path of the average of the orders, inventories, sourcing set, price of the input, and the 95% confidence interval for unit continuum of inventory managers and importer managers. Firms have perfect foresight, where we assume they start at a low tariff steady state, and at period one, they learn that the tariffs will increase in period four (shown with the vertical dashed line). The periods after the tariff describe the transition to the new, high-tariff steady state.

steady-state levels, and Figure 8 shows the change in aggregate output and prices.

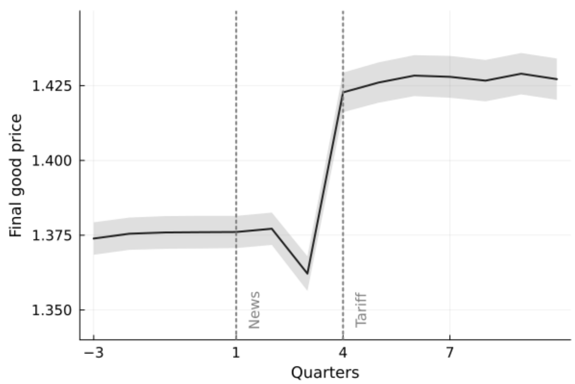
To compare the old and new steady states, the import-weighted tariff increases by 3.1%, which includes the tariff increase across all countries and the firm's substitution away from the now more expensive partners. (The role of substitution is relevant, and it lowers the increase in tariffs by 0.5 p.p.) The increase in tariffs causes the marginal cost of the input to increase by 4.7% (Panel (d), Figure 7). The tariff has a full pass-through to the price of the variety, in line with Fajgelbaum et al. (2020) and Amiti, Redding, and Weinstein (2020); however, due to the decrease in the sourcing set, the marginal cost of the input increases by more than the tariff. The consumer's lower demand, given the rise in prices, restricts the firm's ability to pay for the fixed costs of sourcing from multiple countries. The import managers, on average, source from 0.7 fewer countries in the new steady state (Panel (c), Figure 7). Thus, there are efficiency losses from the tariff increase, since an additional partner decreases the marginal cost of the unit continuum of varieties the import manager needs to produce the input. The final good price increases by 4.0% (Panel (a), Figure 8), similar to the increase in the price of the input given our linear production assumption for the final goods. Aggregate output declines by 9.5% (Panel (b), Figure 8), and imports by 8.5% (Panel (a), Figure 7). Inventories decline, though only by 2.1% (Panel (b), Figure 7). In the final steady-state, the inventory-to-sales ratio increases since firms source from fewer countries and firms' incentives to order more imports less frequently rise.

Figure 7 shows that the model matches the untargeted anticipatory response of inventories, imports (i.e., orders), and the sourcing set described in the empirical findings. Panel (a) shows the anticipatory response of imports, where imports increase by 30% relative to their initial steady-state value. They store their added imports as inventories, as shown in Panel (b), where the stock increases by 19% before the rise in tariffs. The increase in the order by the inventory manager allows the import manager to pay for additional fixed costs to expand their sourcing set to more countries. As in the empirical findings, the model shows firms intensively increase their imports from the countries that will face the tariff increase and add new countries to their set. The expansion of the extensive margin lowers the marginal cost of the imported input by 2%, as shown in Panel (d), which then further increases the imports and thus inventories.

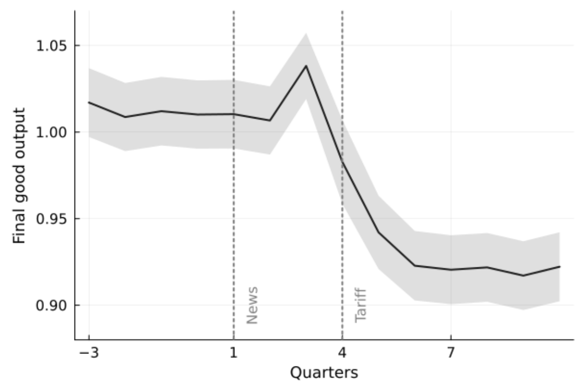
The firm's anticipatory response has effects on the aggregate prices and output even before the tariff increase, as shown in Figure 8. Between the news and tariff implementation, the price of the final goods declines by 1.0% due to the decrease in marginal costs, which permeates to a rise in aggregate output of 2.1%. The increase in output creates consumption gains for the consumer, where aggregate consumption, $C = \left(\int_0^1 y_\omega^{\frac{\epsilon-1}{\epsilon}} d\omega \right)^{\frac{\epsilon}{\epsilon-1}}$, increases by 2% as well.

Figure 8: Aggregate Response to a Tariff Increase
(Smooth transition to new steady state)

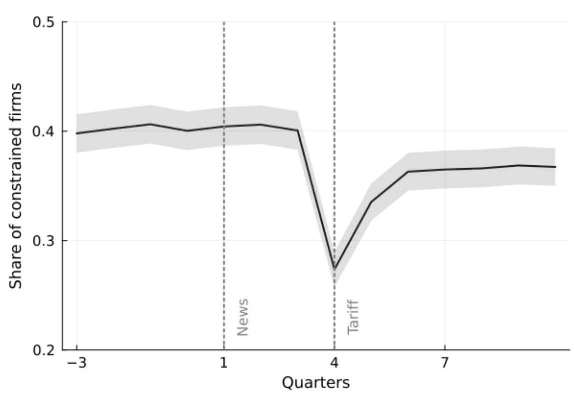
(a) Price of final goods



(b) Output



(c) Constrained share of firms



Note: The figures show the transition path for the aggregate output, prices, the share of constrained firms, and the 95% confidence interval for unit continuum of inventory managers and importer managers. Firms have perfect foresight, where we assume they start at a low tariff steady state, and at period one, they learn that the tariffs will increase in period four (shown with the vertical dashed line). The periods after the tariff describe the transition to the new, high-tariff steady state.

In Figure 7, after the increase in tariffs, the imports initially decrease by more than their final steady state. Since firms have the accumulated inventories to smooth out their production, they need not order as much when the tariff increases. The decrease in imports creates a contraction of the sourcing set, and thus the price of the input overshoots. Inventories slowly decrease for three to four periods until they reach their new, lower, steady state.

In Figure 8, the firm's anticipatory response allows the aggregate output and prices to have a smooth transition to their new steady state. When tariffs rise, output falls, and prices rise, yet not to their final level. Aggregate output drops in period four, when tariffs are implemented, but remains 6.6% higher than the new, lower steady state. It takes around four quarters for output to reach its new level. Prices follow a similar transition to output. Initially, prices rise in response to the tariff; however, the initial jump leaves prices 0.4% lower than their new steady state. There is a complete pass-through of the tariff to the marginal cost, which impacts aggregate prices immediately. Additionally, the decrease in the number of sourcing partners around the tariff implementation further increases the marginal cost of the imports, which puts upward pressure on prices. However, when inventories are high, the share of firms that are constrained in the amount of inputs they can use to produce decreases, as shown in Panel (c), which creates downward pressure on aggregate prices. This force allows for a slow transition of aggregate prices to their new steady state.

6.2 Model Validation via Cross-Industry Variation

We test the model predictions on aggregate output and prices in the period before and after the tariff implementation using cross-industry variation in tariff exposure during 2018 and 2019. We find that for industries whose inputs are more exposed to the tariff increase, their output will increase more relative to other industries in the periods pre-tariff and decline further post-tariff. Similarly, aggregate prices follow the model's prediction, where exposed industries grow less in the pre-tariff period and more after the tariff.

To do so, we compute a tariff exposure measure across industries leveraging our firm-level data. First, we consider the share of firms in each NAICS 6-digit industry that observed a tariff increase in their imports. Formally, letting j denote an industry,

$M1_j = \left(\sum_{i\in j}\sum_t FTI_{i,t}\right)/(\#\text{ of firms in } j)$. (See Section 3.2 for the definition of $FTI_{i,t}$.) Second, we compute the average tariff increase of firms in each industry represented by $M2_j$ (see the definition of firm-level tariff increase, MS_i, in Appendix B). Data on aggregate output comes from the Industrial Production Index (IPI), provided by the Federal Reserve Board, which measures the real output of all establishments in the United States. Aggregate price data comes from the Bureau of Labor Statistics (BLS) Producer Price Index (PPI), which measures the average change over time in the selling prices received by domestic producers for their output. We use the seasonally adjusted series of the IPI and conduct seasonal adjustments for the raw PPI data.

To compare the aggregate price and output response, we consider three periods of analysis, centered around the products from China in List 3, which impacted the largest volume of imports, as described in Table 2. First, we consider the *initial* period from January 2016 to July 2017, which ends right before the USTR initiated an investigation regarding China's acts, policies, and practices. Second, the *pre-tariff* period from August 2017 to August 2018, ending before the tariff for the List 3 products was implemented. Third, the *post-tariff* period is defined from September 2018 to December 2020.

We compare the difference in the growth rates of the average output and prices between the initial and pre-tariff periods and between the pre- and post-tariff periods across industries that are differentially exposed to the tariff. The results are provided in Table 5.

We find that aggregate output and prices behave in the data as the model predicts. In the model, before the tariff rise, the anticipatory response of the firm, in particular the expansion of the sourcing set, creates downward pressure on the marginal cost of the input and thus on aggregate prices. Therefore, in the pre-tariff period, the model predicts that the price set by industries whose inputs are more exposed to the tariff should decrease more than the less-exposed industries. The downward pressure on prices in the model impacts aggregate output, which rises in the pre-tariff period. So, we expect the output of the more exposed industries to grow by more than the less-exposed industries. Post-tariff, the output (prices) of the more tariff-exposed industries should decrease (increase) by more than the less exposed industries.

Table 5: Correlation Between Tariff Measures and Output and Price Growth
(Cross-industry variation validates the model prediction.)

	$M1_{j,t}$	$M2_{j,t}$
Output		
$\log(IPI_{j,pre-\tau}/IPI_{j,\text{initial}})$	0.044	0.496
	(0.029)	(0.281)
$\log(IPI_{j,post-\tau}/IPI_{j,pre-\tau})$	-0.052	-0.530
	(0.025)	(0.245)
Observations	128	128
Price		
$\log(PPI_{j,pre-\tau}/PPI_{j,\text{initial}})$	-0.025	-0.157
	(0.008)	(0.061)
$\log(PPI_{j,post-\tau}/PPI_{j,pre-\tau})$	0.011	0.113
	(0.008)	(0.063)
Observations	257	257

Note: The table shows the regression results for $\log(y_{j,t}/y_{j,t-1}) = \beta_0 + \beta\, \mathrm{M}_{j,t} + \epsilon_j$ and reports the estimated coefficient, β, and its standard error.

Table 5 shows the correlation between the tariff exposure and the output and price growth across industries for the pre- and post-tariff periods. Both measures of tariff-exposure exhibit similar results. They show that the output (price) of the tariff-exposed industries increased (decreased) more in the pre-tariff period than in their initial period, supporting the aggregate output and price dynamics observed in the model. In the post-tariff period, the output (price) of the more exposed industries decreased (increased).

6.3 Role of Anticipation

We study the role of anticipation on the firm's response and its impact on the transition of aggregate variables. We do so by comparing the perfect foresight response to the case when the firm learns about the tariff the period it is implemented (*unanticipated*). Figure 9 summarizes the gains from anticipation, defined as the difference between the response for the anticipated (i.e., perfect foresight) case and the unanticipated one. As a preview, allowing the firms to protect their production process before the tariff rises creates a smoother transition to the new steady state.

In the anticipated case, firms know about the tariff increase and thus can stockpile their imports as inventories before the tariff rise. After the tariff increases in period four, the firm's inventories are higher for the next three to four periods under the anticipated assumption. In this case, firms were able to stock additional imports, which allowed for inventories to remain higher and create a smoother transition. Further, the additional inventories under perfect foresight imply lower import orders, and thus the import manager's sourcing set decreases by more. This creates upward pressure on both the marginal cost of the input and the final good price immediately after the rise in tariffs. This effect is attenuated under the unanticipated assumption.

The added protection from the anticipatory effects leads to a smoother and better transition for the aggregate variables. Under the perfect foresight assumption, aggregate output is 5.2% higher when tariffs are implemented than in the unanticipated scenario and continues to be higher during the transition to the new steady state. Similarly, the final good prices under the perfect foresight assumption are 0.3% lower in period four than in the unanticipated scenario and remain lower during the transition. The firm also generates more sales when they can prepare for the rise in tariffs and are, on average, 2.2% higher during the three quarters of the transition.

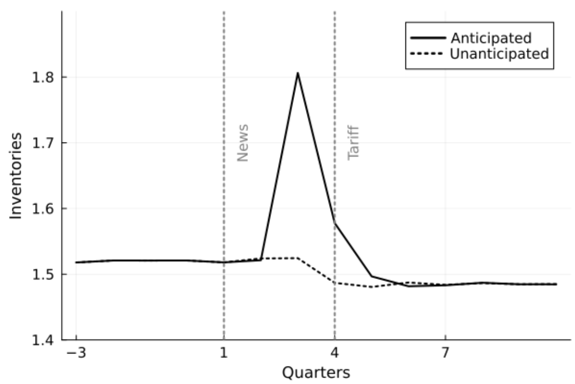
Note that even in the unanticipated scenario, there is a gradual transition (albeit to a lesser degree than the perfect foresight case) to a new steady state across the firm and aggregate variables. This is due to the assumption that tariffs are increasing, and thus firms are transitioning to a lower-output, lower-inventory steady state. Therefore, when tariffs rise, firms already have an excess of inventories to help them slow down the transition to the new steady state.

6.4 Role of the Extensive Margin

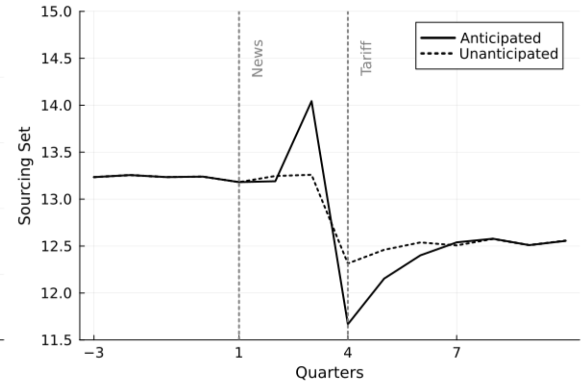
The theoretical contribution of the model is centered around the firm's ability to adjust both in the intensive margin, by increasing imports and stocking them as inventories, and extensively, by sourcing their inputs from multiple partners. This assumption allows the model to match the firm's anticipatory response shown in the empirical findings. Here, we evaluate the importance of the extensive margin choice in determining the aggregate price and output dynamics. To do so, we compare our benchmark model to one where the firm can only source from one country, thereby removing the extensive margin choice, and thus, in this case, the marginal cost of the

Figure 9: Role of Anticipation
(Aggregate output and prices exhibit smoother transition post tariff.)

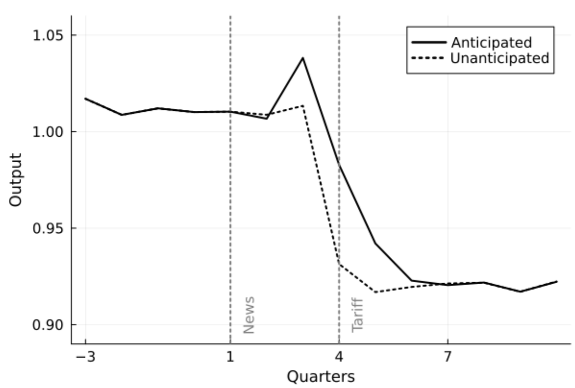
(a) Inventories



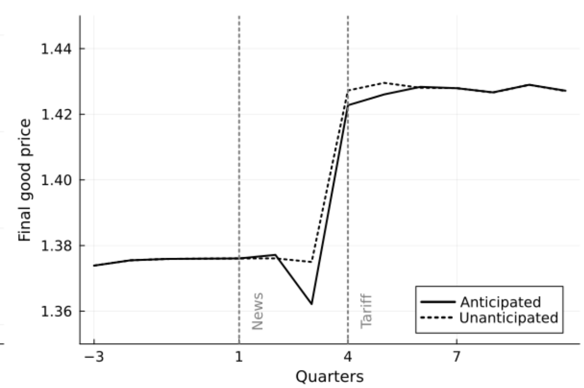
(b) Sourcing set



(c) Aggregate output



(d) Price of final goods



Note: The figures show the transition path of the mean of inventories, the sourcing set, aggregate output, and the final good price for the unit continuum of inventory managers and importer managers. The solid line represents the transition under perfect foresight, where firms learn at period one that tariffs will increase in period four (shown with the vertical dashed line). The dotted line shows the transition for an unanticipated tariff increase, where firms learn about the tariff change when it is implemented in period four.

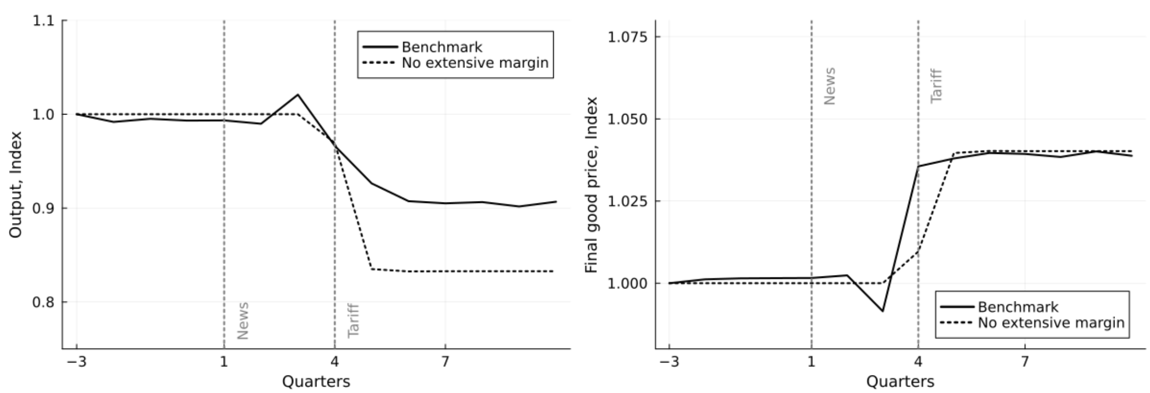
input is always constant.

Figure 10 shows the transition of aggregate output and prices, assuming perfect foresight, for both the benchmark model and one with a unique country that supplies all the imported varieties (*no extensive margin*). To compare the response of the firms across both modeling assumptions, we first internally estimate the marginal cost of the input such that the aggregate prices in both economies are at the same level, both in the initial and final steady states. Note, this does not imply the rest of the variables will have the same mean, and thus we use indices to compare the response along the transition.

We find that the aggregate output and price dynamics before the tariff implementation are due to the extensive margin response. In the benchmark model, as firms stockpile their imports as inventories, the increase in orders allows for the import manager to include more partners in their sourcing set. This creates efficiency gains, and the marginal cost of the input declines. Thus, aggregate output increases, and the final good price decreases before the tariff increase. These dynamics are lost in the model without an extensive margin since the stockpiling of inputs has no effect on the marginal cost of the input, and thus aggregate output and prices remain constant. After the rise in tariffs, both models show a gradual transition of the aggregate output and price. However, in the benchmark model, in the periods immediately after the tariff implementation, the marginal cost of the input rises by more than the new steady-state level, creating an upward pressure on aggregate prices that is not present in the model without an extensive margin.

Figure 10: Role of Extensive Margin
(Extensive margin drives aggregate dynamics before a tariff increase.)

(a) Aggregate output (b) Price of final goods



Note: The figures show the growth of the transition path for the aggregate output and prices. The solid line represents the transition for the benchmark model, where firms can adjust both in the extensive and intensive margin. The dotted line shows the transition under the model assumption where firms do not have an extensive margin, and the price of the input is constant.

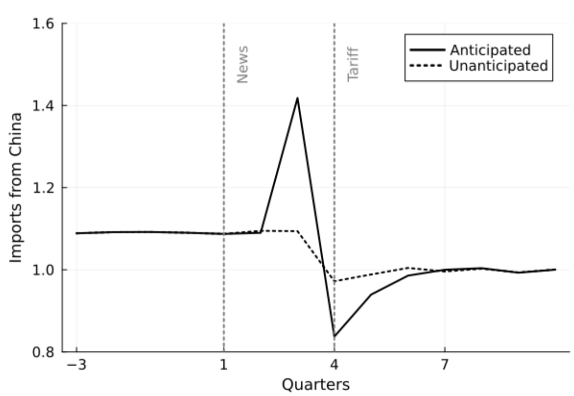
6.5 Trade Elasticity Bias Due to Front-Running

A methodological concern in the literature is that anticipatory behavior by firms distorts standard estimates of how trade responds to tariff changes. This is especially relevant when the anticipatory response starts long before the tariff is implemented. For example, Figure 4 in our empirical section shows that the firm's imports increased for three to four quarters before the rise in tariffs in 2018–2019.

We use our estimated model to highlight how the firm's anticipatory response can overstate the trade elasticity in both the short and the long run. Figure 11 illustrates the response of imports from China in our model. (China is the largest supplier who faced the largest increase in tariff, as shown in Table 4.) When the firm anticipates an increase in tariffs, they increase imports pre-tariff. Then, the firm uses its inventories in the periods immediately after the tariff, which leads to a sharp decrease in imports. Slowly, imports transition to their new, lower steady state.

We compute the response of imports to the change in tariff as in Boehm, Levchenko, and Pandalai-Nayar (2023), where $\epsilon^h = \frac{\log(x_{t+h})-\log(x_{t-1})}{\log(\tau_{t+h})-\log(\tau_{t-1})}$ and x_t and τ_t represent the import flows from China and the tariffs for Chinese imports. Traditionally, the literature benchmarks the reference period, $t-1$, to the period prior to the tariff implementation. Depending on the length of the anticipatory response, we show that this could lead to a significant bias.

Figure 11: Response of Imports from China to an Increase in Tariff



Note: The figures show the transition path of the mean of imports from China in response to their increase in tariffs, for both the anticipated and unanticipated assumptions.

Table 6 shows the trade elasticities for different time horizons, $h = \{0, 1, 2, \text{long run}\}$

and for different reference periods: t defined as tariff implementation or news shock (whose empirical analogue is the initiation of investigation). Long-run is defined as when the model fully transitions into the new steady state. Column one details the elasticity for the case when firms can anticipate the rise in the tariff and the reference period, $t-1$, is fixed to the period before the tariff implementation. When the tariff changes, there is a large response of imports, where the elasticity ($h = 0$) equals -5.7, and it slowly increases as imports rise to their new steady state. The long-run elasticity is still overstated at -4.4, given that we are comparing the final imports to a high import period due to the firm's anticipatory response.

Instead, if we fix the reference period, $t-1$, to before the tariff news announcement, thereby controlling for the firm's anticipatory response, the trade elasticity at $h = 0$ equals -3.8, and the long run equals -2.4 (see column two). Even in this case, the trade elasticity continues to be overstated since firms use their inventories and decrease imports in the short run.

Table 6: Trade Elasticities Across Specifications

(Anticipatory response overstates the trade elasticity.)

	Tariff	News	Unanticipated
$h = 0$	-5.7	-3.8	-2.7
$h = 1$	-4.8	-2.9	-2.6
$h = 2$	-4.5	-2.6	-2.5
Long Run	-4.4	-2.4	-2.4

Note: The table shows the model's response of imports to a one-time change in tariff over different time periods, where $\epsilon^h = \frac{\log(x_{t+h})-\log(x_{t-1})}{\log(\tau_{t+h})-\log(\tau_{t-1})}$ and x_t is the import flow. The period $t-1$ under *news* is fixed as the period before the news of the tariff is announced, and under *tariff* the period $t-1$ is fixed as the period before the tariff implementation. Under the *unanticipated* scenario, the import flows correspond to the simulation where the news is announced when tariffs are implemented.

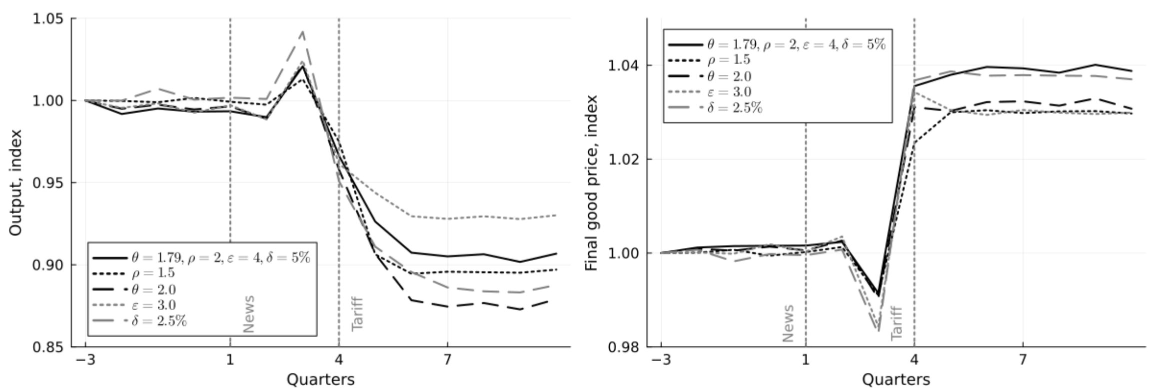
Note that when a firm can stock inventory, even if the tariff is unanticipated, the short-run elasticity continues to be distorted. The third column of Table 6 shows that in the unanticipated case, the response of imports in the short run (in absolute value) is slightly larger than in the long run. Since the firm is transitioning from a high-output to a low-output steady state, the natural excess of inventory allows them to decrease their imports when the tariff rises, although by less than in the anticipated scenario, as shown in Figure 11. Khan and Khederlarian (2021*b*) make a similar point in their work, where they distinguish between trade flows and consumption. Their estimates of the elasticity drop (in absolute magnitude) from -4.2 when using import flows to -2.7 when using consumed imports, which is similar to the change observed between our elasticities in the anticipated (-5.7) and unanticipated (-2.7) scenarios. Further, our long-run elasticity of -2.4 is similar to the estimate by Boehm, Levchenko, and Pandalai-Nayar (2023) and Yilmazkuday (2019).

6.6 Sensitivity Analysis

The effect of the firm's anticipatory response on aggregate output and prices is robust to different parameter values. Figure 12 shows the transition of aggregate output and prices for different values of the elasticity of substitution between the final good varieties, ϵ, the storage costs of inventories, δ, the elasticity of substitution between the imported inputs, ρ, and the Fréchet parameter that governs the variability in their productivity draws, θ.

Figure 12: Robustness Analyses for the Transition of Aggregate Output and Prices

(a) Aggregate output (b) Price of final goods



Note: The figures show the index of the transition path of aggregate output and prices for different values of the elasticity of substitution between the final good varieties, ϵ, the storage costs of inventories, δ, the elasticity of substitution between the imported inputs, ρ, and the Fréchet parameter that governs the variability in their productivity draws, θ.

A lower cost of inventory storage, δ, allows for a deeper anticipatory response that leads to a larger response of output and prices pre-tariff and a smoother transition afterwards. Lowering the demand elasticity, ϵ, which increases the markup the firm sets, has a similar effect on the aggregate output and price transition. A lower value of ρ decreases the import substitutability and increases the benefit of the anticipatory effect. Similarly, a higher value of the Fréchet parameter, θ, reduces the volatility within the range of imports across countries, which lowers the benefit of adding an additional country to the sourcing set. Both limit the firm's ability to substitute away from the tariff, which creates further incentives to protect their production process and have a smooth transition to the new steady state.

7 Conclusion

We provide novel firm-level evidence on how US importers adjust their imports in anticipation of future tariff increases. Using a rich dataset that links shipment-level bills of lading, product–country-level tariff schedules, and firms' financial information, we show that firms respond well before the policy change takes effect: They increase import volumes, accumulate inventories, and diversify their supplier base toward unaffected countries. These adjustments occur along both the intensive and extensive margins, with the largest changes observed for the affected product–country pairs and alternative source countries of the affected product.

To rationalize these findings, we develop a dynamic trade model in which firms adjust along the intensive margin, through import volumes and inventory holdings, and the extensive margin, by adjusting their set of countries to import from. In the model, a future rise in tariffs creates incentives to increase current imports and accumulate inventories. This increase in import volume allows the firm to support a larger set of supplier countries, which lowers the cost of the input.

We find that firms' anticipatory responses lead to a smoother transition of aggregate output and prices by mitigating the impact of tariffs on higher prices and lower output. Further, the expansion along the extensive margin lowers the input cost, which puts downward pressure on prices and expands output before the tariff is implemented.

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Appendix

A Additional Tables and Figures

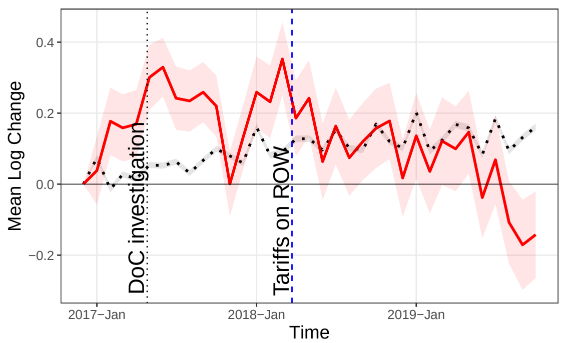
Table A1: Timeline of Section 201 Safeguard Tariffs on Solar Panels and Washing Machines

Event	**Date**	**Description**	**Source**	**Products**	**Value($B)**[a]
(a) Solar Panels (Crystalline Silicon Photovoltaic Cells and Modules)					
Investigation	May 17, 2017	ITC institutes investigation following petition by Suniva.	82 FR 25331	Solar Cells/Modules	–
Determination	Sep 22, 2017	ITC votes 4-0 finding imports caused serious injury.	82 FR 45313	–	–
Announcement	Jan 23, 2018	President signs Proclamation 9693 imposing tariffs.	83 FR 3541	–	–
Effective Date	Feb 7, 2018	30% tariff on modules; TRQ on cells (2.5GW exempt).	Proclamation 9693	CSPV Modules	5.6
(b) Large Residential Washers					
Investigation	Jun 5, 2017	ITC institutes investigation following petition by Whirlpool.	82 FR 27075	Washers	–
Determination	Oct 5, 2017	ITC votes 4-0 finding imports caused serious injury.	82 FR 48113	–	–
Announcement	Jan 23, 2018	President signs Proclamation 9694 imposing tariffs.	83 FR 3553	–	–
Effective Date	Feb 7, 2018	TRQ: 20% on first 1.2M units; 50% on excess.	Proclamation 9694	Res. Washers	2.0

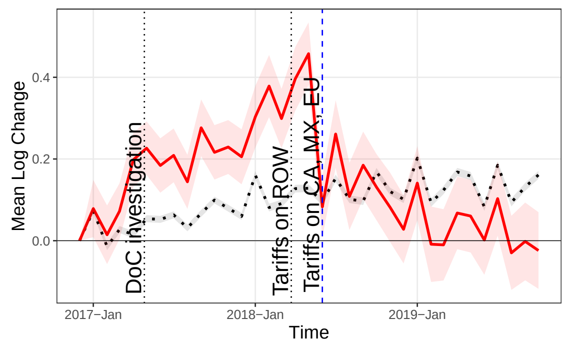
Notes: “ITC” refers to the US International Trade Commission. "FR" refers to the Federal Register. “TRQ” refers to Tariff-Rate Quota.
[a] Values represent the 2017 annual import volume (in billions of USD).

Figure A1: Dynamics of Product-Countries Affected by Steel and Aluminum Tariffs

(a) Rest of the world



(b) Canada, Mexico, and EU



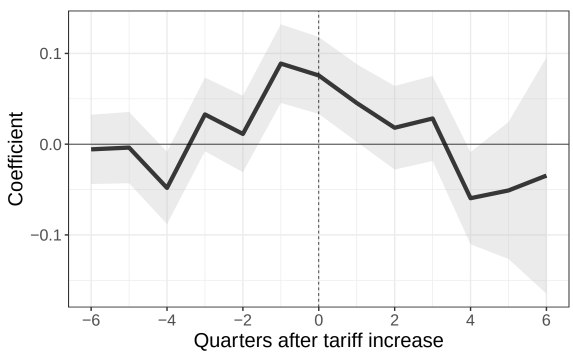
Note: The figure plots the average log change in import volumes relative to the corresponding month in 2016 (with 95% confidence intervals) across HTS10 product-country pairs. Panels (a) and (b) contrast product-countries subject to the March and June 2018 Steel and Aluminum tariffs, respectively, against those never subject to tariff increases during 2018–2019. For more institutional details, see Section 2.3. Vertical black dotted lines mark major "anticipatory" events (e.g., the initiation of Section 232 by the Department of Commerce). Vertical blue dashed lines indicate the date of tariff increases.

Source: Authors' calculations based on data from the Census Bureau and the US International Trade Commission (USITC), compiled by Amiti, Redding, and Weinstein (2019, 2020).

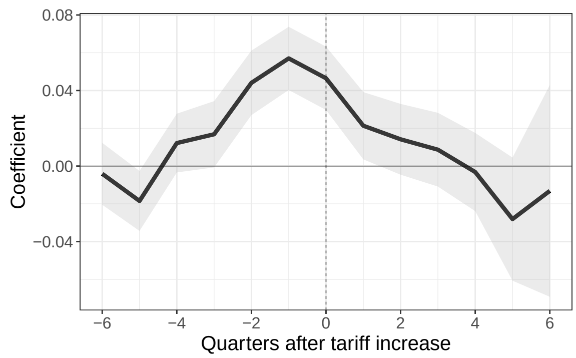
Description: The figure compares the average log import growth of products affected by each wave of steel and aluminum (SA) tariffs to that of unaffected product-countries. Panels (a) and (b) uncover that around the time the Department of Commerce started its Section 232 investigation, the SA imports have risen. Furthermore, in Panel (b), we can observe stockpiling of SA products from Canada, Mexico, and the EU, before the higher tariffs are realized. Perhaps unsurprisingly, the imports decrease after the higher tariffs are realized.

Figure A2: Imports, Number of Partners and Inventories Around a Tariff Increase (Logarithms instead of Inverse Hyperbolic Sines)

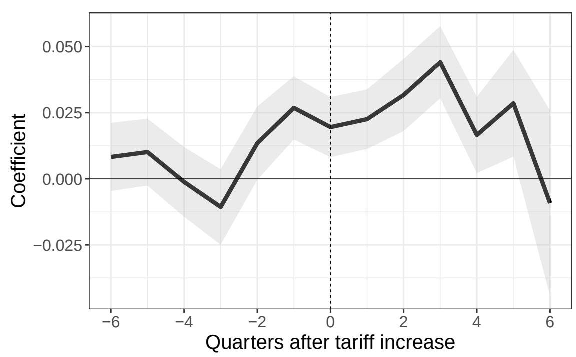
(a) Current imports: $\log\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



(b) Number of current partners: $\log\left(|C_{i,t}|\right)$



(c) Inventories: $\log(\text{inventories}_{i,t})$

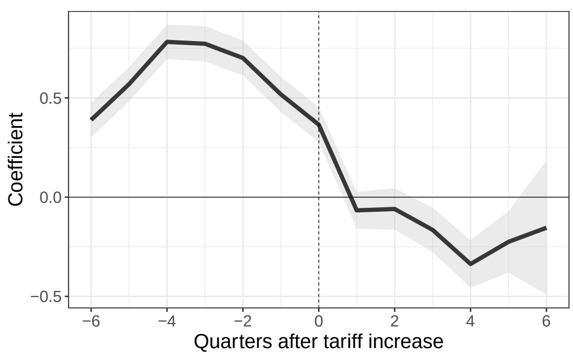


Note: The figures re-conduct the exercise in Figure 4 using log instead of asinh.

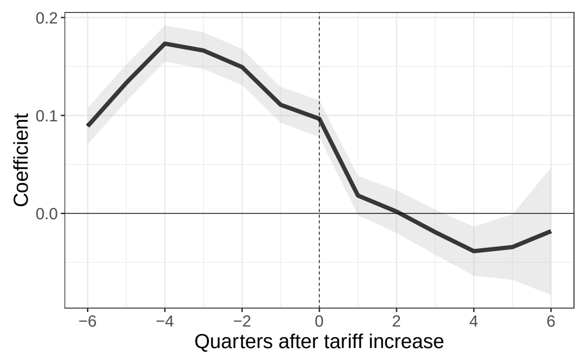
Description: Due to the nature of logarithms, observations used for graphs exclude zeros, hence abstracting from the extensive margin adjustment. Given our point estimates at $k = -1$, current imports, the number of partners, and inventories were 8.9, 5.7, and 2.7 log points higher, respectively, for the treated firms.

Figure A3: Imports, Number of Partners and Inventories Around a Tariff Increase ($TI_{i,t}$ instead of $FTI_{i,t}$)

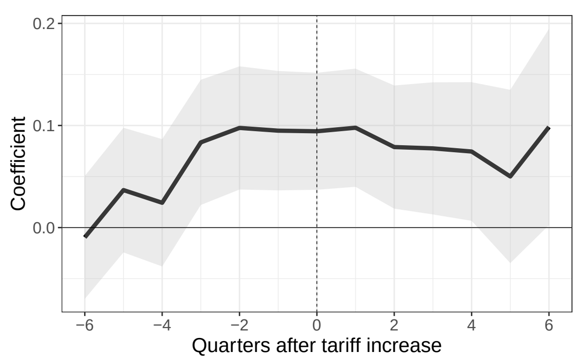
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



(b) Number of current partners: $\text{asinh}\left(|C_{i,t}|\right)$



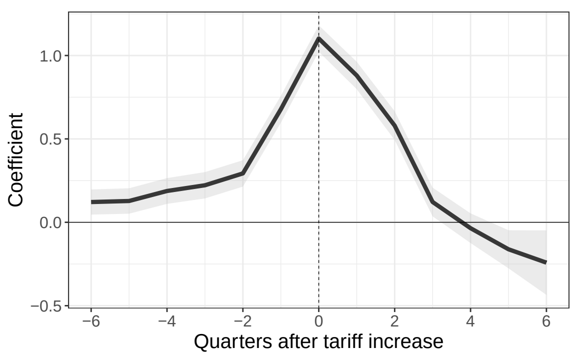
(c) Inventories: $\text{asinh}(\text{inventories}_{i,t})$



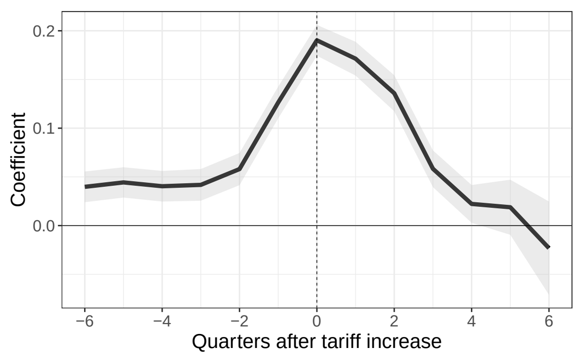
Note: The figures re-conduct the exercise in Figure 4 utilizing all tariff-increase events $TI_{i,t}$ instead of the first event $FTI_{i,t}$.

Figure A4: *Existing* Import Volumes and the Number of *Existing* Partners Around a Tariff Increase

(a) Existing imports: $\text{asinh}\left(\sum_{(h,c)\in E_{i,t+k}} v_{i,h,c,t}\right)$



(b) Number of existing partners: $\text{asinh}\left(|E_{i,t}|\right)$



Note: The figures describe the estimated $\{\beta_k\}_{k=-10,...6}$ from Equation (2). The shaded area indicates the range of one standard error above and below the estimate.

B Firm-level Analysis with a Continuous Measure of Tariff Increase

We have focused on the tariff-increase dummies for our analyses. However, since the magnitude of shocks can affect the quantitative results, here we explore the continuous measure of tariff increase shocks. In Equation (2), instead of $FTI_{i,t}$, we utilize $FTI_{i,t}MS_i$. The magnitude of tariff increase for firm i, MS_i is defined as follows. If $FTI_{i,t} = 1$, for some t,

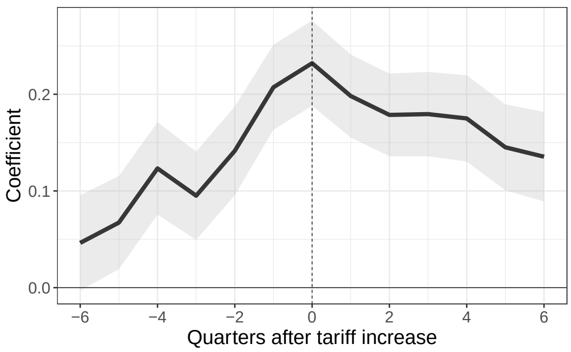
$$MS_i \equiv \max_{t'} \left\{ \log \left(\frac{1 + \tilde{\tau}_{i,t'}}{1 + \tilde{\tau}_{i,t_{i,pre}}} \right) \right\}, \text{ where } t_{i,pre} = (t-1), \text{ for } t \text{ such that } FTI_{i,t} = 1.$$

If $FTI_{i,t} = 0$, for all t, $MS_i \equiv 0$. In the above, $\tilde{\tau}_{i,t}$ denotes the current-import-volume-weighted tariff for firm i at time t. MS_i measures, for a firm that ever experienced a tariff increase, the maximum log-average tariff factor relative to the period just before the first tariff increase. Therefore, $FTI_{i,t}MS_i$ represents the maximum magnitude of the tariff increase for a firm, if a firm ever experienced a tariff hike. The rationale of not using time varying magnitude of shock is as follows. Suppose that we utilize $MS_{i,t+k} \equiv \log \left(\frac{1+\tilde{\tau}_{i,t+k}}{1+\tilde{\tau}_{i,t_{i,pre}}} \right)$. For the period before the tariff hike (i.e., $t + k \leq t_{i,pre}$), if both import composition and tariffs are stable, $MS_{i,t+k}$ will be close to zero. This makes the study of anticipatory effects difficult.

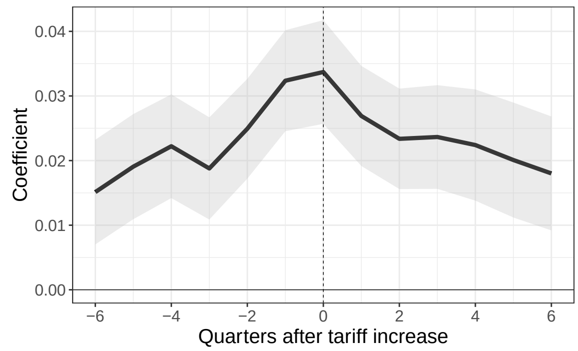
We re-run the exercise in Figure 4, utilizing $FTI_{i,t}MS_i$ instead of $FTI_{i,t}$. Figure B1 reports the results.

Figure B1: Imports, Number of Partners and Inventories Around a Tariff Increase (Continuous Measure)

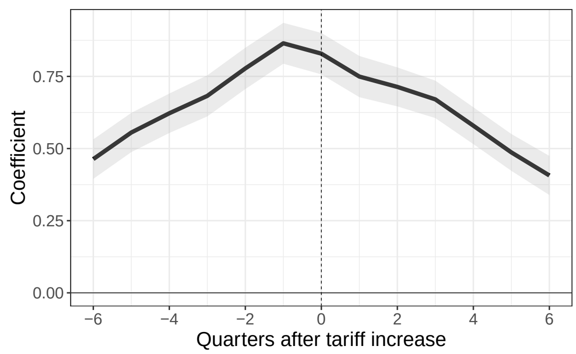
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



(b) Number of current partners: $\text{asinh}\left(|C_{i,t}|\right)$



(c) Inventories: $\text{asinh}(\text{inventories}_{i,t})$



Note: The figures re-conduct the exercise in Figure 4 utilizing continuous measure $FTI_{i,t}MS_i$ instead of a dummy variable $TIF_{i,t}$.

C Model Details

C.1 Import Manager

In this section, we provide proofs for the propositions in the main text. For notational ease, let Ξ_j denote the *sourcing potential*, $T_j\left(\tau_j w_j\right)^{-\theta}$.

Proposition 1. *The optimal sourcing set given input demand, $\mathcal{J}_\omega(n_\omega)$, satisfies the following properties:*

(i) If $j \in \mathcal{J}_\omega(n_\omega)$ and $\Xi_{j'} \leq \Xi_j$, then $j' \in \mathcal{J}_\omega(n_\omega)$.

(ii) If $n_{low} < n_{high}$, then $\mathcal{J}_\omega(n_{low}) \subset \mathcal{J}_\omega(n_{high})$, and $c\left(\mathcal{J}_\omega(n_{low})\right) \geq c\left(\mathcal{J}_\omega(n_{high})\right)$.

Proof for Proposition 1: (i) Suppose not. Consider two sourcing sets $\mathcal{J}_\omega$ (the original optimal sourcing set) and $(\mathcal{J}_\omega \setminus \{j\} \cup \{j'\})$. Since the latter provides the lower cost of sourcing the input, it leads to the contradiction. $\square$

(ii) Suppose that $\mathcal{J}_\omega(n_{\text{low}}) \supsetneq \mathcal{J}_\omega(n_{\text{high}})$. (Note that due to (i), the only three possible cases are $\mathcal{J}_\omega(n_{\text{low}}) \supsetneq \mathcal{J}_\omega(n_{\text{high}})$, $\mathcal{J}_\omega(n_{\text{low}}) = \mathcal{J}_\omega(n_{\text{high}})$, and $\mathcal{J}_\omega(n_{\text{low}}) \subsetneq \mathcal{J}_\omega(n_{\text{high}})$.) Since $\mathcal{J}_\omega(n_{\text{low}})$ is the optimal sourcing set for demand n_{low},

$$c\left(\mathcal{J}_\omega(n_{\text{low}})\right) n_{\text{low}} + |\mathcal{J}_\omega(n_{\text{low}})| wf \leq c\left(\mathcal{J}_\omega(n_{\text{high}})\right) n_{\text{low}} + |\mathcal{J}_\omega(n_{\text{high}})| wf. \tag{C1}$$

Likewise, for n_{high},

$$c\left(\mathcal{J}_\omega(n_{\text{high}})\right) n_{\text{high}} + |\mathcal{J}_\omega(n_{\text{high}})| wf \leq c\left(\mathcal{J}_\omega(n_{\text{low}})\right) n_{\text{high}} + |\mathcal{J}_\omega(n_{\text{low}})| wf. \tag{C2}$$

Subtracting Equation (C2) from Equation (C1) yields,

$$\left(c\left(\mathcal{J}_\omega(n_{\text{high}})\right) - c\left(\mathcal{J}_\omega(n_{\text{low}})\right)\right)\left(n_{\text{high}} - n_{\text{low}}\right) \leq 0. \tag{C3}$$

Since $n_{\text{high}} > n_{\text{low}}$, the above implies that $c\left(\mathcal{J}_\omega(n_{\text{high}})\right) \leq c\left(\mathcal{J}_\omega(n_{\text{low}})\right)$. In other words, the variable cost under the sourcing set $\mathcal{J}_\omega(n_{\text{high}})$ is lower than under $\mathcal{J}_\omega(n_{\text{low}})$. Since fixed costs are also lower for $\mathcal{J}_\omega(n_{\text{high}})$ (as $|\mathcal{J}_\omega(n_{\text{low}})| > |\mathcal{J}_\omega(n_{\text{high}})|$), to source input n_{low} the total cost is lower with sourcing set $\mathcal{J}_\omega(n_{\text{high}})$ than with $\mathcal{J}_\omega(n_{\text{low}})$. This contradicts the optimality of $\mathcal{J}_\omega(n_{\text{low}})$ for demand n_{low}. $c\left(\mathcal{J}_\omega(n_{\text{low}})\right) \geq c\left(\mathcal{J}_\omega(n_{\text{high}})\right)$ trivially follows from $\mathcal{J}_\omega(n_{\text{low}}) \subset \mathcal{J}_\omega(n_{\text{high}})$. $\square$

Proposition 3. *Suppose that for country j, tariff strictly increases from τ_j to τ_j', and let $\vec{\tau}$ and $\vec{\tau}'$ denote the tariff vectors before and after this increase, respectively. Then, for all $n_\omega \geq 0$, $p_\omega(n_\omega, \vec{\tau}') \geq p_\omega(n_\omega, \vec{\tau})$.*

Proof of Proposition 3: Before the tariff change, the import manager solves the cost minimization problem, given the set of sourcing capabilities $\{\Xi_1, ..., \Xi_J\}$. Note that given w, f, θ, and ρ, the manager's problem only depends on the sourcing capabilities. After the tariff change the sourcing capability of j decreases. Denoting the decreased sourcing capability as Ξ_j', now the firm solves the cost minimization problem given $\{\Xi_1, ..., \Xi_{j-1}, \Xi_j', \Xi_{j+1}, ..., \Xi_J\}$. Since the set of sourcing capabilities is "worse," the cost minimization yields weakly higher total costs in Equation (9). $\square$

C.2 Inventory Manager

Proposition 2 allows us to solve the inventory manager's dynamic problem in Equation (10) in an interval-wise fashion. Specifically, based on the proposition, we can solve J value functions, one for each interval of demand threshold, where the marginal cost of supplying the input is constant. Then, we find the optimal order policy by finding the maximum value function among the J value functions, in the following fashion. This simplifies our value function iteration algorithm.

$$V(s, \nu, p(n, \vec{\tau})) = \max\{V_1, V_2, ..., V_k, ..., V_J\}.$$

$$\begin{aligned}
V_k(s, \nu, p(n, \vec{\tau})) = \max_{p^f, y^f, s', n} & \left\{ p^f y^f - p(n, \vec{\tau})n + \beta \mathbb{E}_{\nu'}\left[V(s', \nu', p(n', \vec{\tau}))\right] \right\} \\
\text{s.t. } & y^f = \nu(p^f)^{-\epsilon}, \\
& y^f = x, \\
& x \leq s, \\
& s' = (1-\delta)(s - x + n), \\
& n \in [n_k, n_{k+1}), \\
& \frac{\partial(p(n, \vec{\tau})n)}{\partial n} = c_k.
\end{aligned}$$