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 and use it to study the 2018–2019 tariffs on steel, aluminum, and Chinese imports. We find that firms front-run tariffs by exploiting the roughly one-year lag between the initiation of the investigation into foreign trade practices and tariff implementation: Firms' imports, inventories, and number of product-country partners begin to rise a year before the tariff increase. Moreover, firms increase imports not only from the targeted product-country but also from the same product in countries unaffected by the tariff, along both the intensive and extensive margins. We then develop a dynamic trade model in which forward-looking firms hold inventories and choose their set of trade partners. We find that tariff front-running puts downward pressure on aggregate prices and expands output prior to the tariff and that these anticipatory responses generate a smoother and longer transition to the new steady state. Last, we find that anticipatory responses lead to short- and long-run trade elasticities roughly twice as large as those in the unanticipated case.

JEL Codes: E30, F11, F13, F40.

Keywords: Tariff, imports, dynamic trade model, extensive margin of trade, bill of lading

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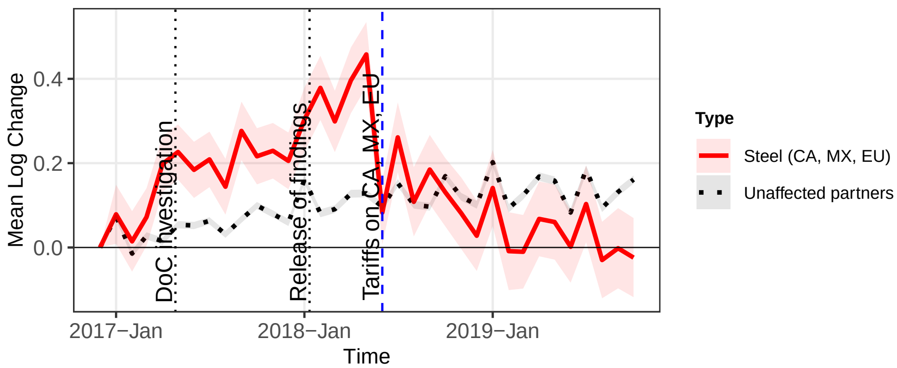
1 Introduction

After a globalization period characterized by low and stable tariffs, for the past decade, the United States has imposed and continues to impose substantial tariffs on many of its imports. The economic impacts of these tariffs on trade flows, prices, and production are debated in policy forums worldwide, and the aftermath of the tariff implementation has received considerable attention in the literature. However, less is known about the anticipatory dynamics of trade, where importers can respond to announced future tariffs, and how these early reactions shape the economic impact of tariffs.

In Figure 1, we find 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. After the investigation results were made public in January 2018 and 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. For the 14 months between the investigation and the levy of the tariff, we observe an increase in imports of steel and aluminum, with a further increase in the six-month period after the release of the investigation findings.

In this paper, we ask: How do US importers respond to a future tariff? Further, we study how the firm's anticipatory response impacts aggregate output and price dynamics. We address the first question empirically for the wave of tariff increases in 2018 and 2019, which were concentrated on steel and aluminum and products from China. Across tariffs, there was approximately a year between the start of a formal investigation and the implementation of the tariffs. By applying local projections to a novel firm-level import dataset of US public firms, we find that 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 this 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, along both the intensive and extensive margin.

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 the Section 232 investigation by the Department of Commerce and the implementation of the tariff.

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).

To address the second question, we develop a novel dynamic trade model that integrates the extensive margin of trade into an open-economy inventory model. The calibrated model matches the untargeted empirical findings: Firms respond to expected tariffs by raising import volumes, accumulating inventories, and increasing the number of partners. The firm's front-running response shapes the aggregate output and price dynamics. Pre-tariff, the increase in imports and partners puts downward pressure on prices and expands output. After the tariff, the additional inventories allow for a longer and smoother transition to the new high-tariff steady state. This mitigates the short-run economic impact of the tariff by allowing output (prices) to remain higher (lower) during the transition. We corroborate the model's predictions using the cross-industry variation in aggregate output and price data. The output (price) of the industries whose inputs are more exposed to tariffs increases by more (less) relative to the other industries in the pre-tariff period and declines by more (less) after the tariff. Last, we show that when the firm's imports respond to an anticipated tariff, the short- and long-run trade elasticities are twice as large as when the tariff is unanticipated.

Our dataset covers 5,776 US importing firms from 2012Q1 to 2019Q4, linking shipment-level import records with product-country-level tariffs and firms' financial information. Imports come from the 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. Tariffs are from the United States International Trade Commission (USITC), and firms' inventory and sales information come from Compustat North America. A technical contribution of our work is the matching of import transactions to unique Compustat firms using a text-analysis algorithm.

We focus our analysis on the waves of tariffs in 2018 and 2019, which were concentrated on steel and aluminum products and a wide breadth of products from China. The tariffs substantially impacted the firms, where at the peak of the 2019 tariffs, 40% of US importers were affected. Moreover, across tariffs, there is a common timeline where the US government started a formal investigation around a year prior to the tariff implementations.

We first examine the tariff front-running in the aggregate import data by contrasting import changes for product-countries subject to specific tariff waves against those unaffected by any of the 2018–2019 tariffs. In addition to the steel and aluminum tariff in Figure 1, we also find significant anticipatory import dynamics for the tariff waves for China, where imports began to rise six to twelve months before tariff implementation.

Then, we turn to the firm-level data and use local projections (Jorda 2005) to study the dynamic response of firms' imports, inventories, and number of partners. 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 duration between the trade investigations and the implementation of tariffs. Following the realization of tariffs, both import volumes and the number of partners decrease sharply.

Next, we explore the firm's substitution patterns—or margins of adjustment—prior to a tariff. If a partner faces a future tariff, the firm may not only adjust imports from that partner but also substitute to other source countries or different products. We find significant extensive- and intensive-margin adjustments for the products affected by the tariffs. Before the tariff, the firm is more likely to import from the affected product-country but also to begin importing the same product from unaffected countries, and the imports from these partners simultaneously increase.

Motivated by our empirical results, we develop a dynamic trade model to study the tariff front-running and to quantify how it affects aggregate prices and output dynamics. We depart from the literature by incorporating an extensive margin choice of supplier 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.

We calibrate the model to match data moments in 2015 and then use the observed tariff changes between 2015 and 2019 to simulate the firm's response. We study the perfect foresight transition from a low- to a high-tariff steady state. The model matches the untargeted firm-level anticipatory response detailed in our empirical findings. Anticipating an increase in their input price due to future tariffs, firms increase current imports and accumulate inventories. The surge in imports makes it profitable to incur the additional fixed costs of adding new suppliers. The resulting expansion of the supplier set lowers the marginal cost of the input, which further increases imports. The firm's anticipatory response shapes the aggregate output and price dynamics. Pre-tariff, the decrease in the marginal cost of the input creates downward pressure on aggregate prices (decrease by 1%) and expands output (increase by 2%).

Once the tariff is implemented, firms' imports decrease sharply as firms slowly draw down on their accumulated inventories over the next three to four quarters to meet demand. This allows aggregate output and prices to also have a smooth transition, where it takes around a year to reach the new, low-output, high-price steady state. Aggregate output drops when the tariff is implemented but remains 7% higher than the final steady state. The initial jump in prices leaves them 1.7% lower than their final steady state. Note that this is despite the full pass-through of the tariff to the price of an imported variety; however, aggregate prices are also a function of the share of firms that stock out. The inventory acquired in the pre-tariff period reduces the share of firms that stock out, which tempers the growth of aggregate prices during the transition.

We test the aggregate output and price dynamics in the model with the data. Since we do not observe output and price separately in the firm-level data, we use cross-industry variation in aggregate output and price indexes. We compare their growth before and after the tariff across industries whose inputs are differentially exposed to the tariff. We use the Industrial Production Index (IPI) for output growth and the Producer Price Index (PPI) for aggregate prices. We find that for industries whose inputs are more exposed to the tariff, 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 by less in the pre-tariff period and by more after the tariff.

To study the role of the extensive margin, a central part of our theoretical contribution, we compare our benchmark model to one where there is a unique country that supplies all the imported varieties. We find that the aggregate output and price dynamics before the tariff, found in the benchmark model and in the aggregate data, are due to the extensive-margin response. In the benchmark model, the increase in firms' sourcing set lowers the marginal cost of the input, which impacts aggregate dynamics. This mechanism is absent under a unique-supplier assumption. Post-tariff aggregate transitions look similar under both assumptions.

We quantify the role of anticipation by comparing the benchmark model, where firms know about the tariff in advance, to one where firms are surprised by the tariff. We find that additional inventories acquired when the tariff is anticipated allow firms to support a smoother and longer transition to the new high-tariff steady state. When the tariff is levied, aggregate output is 6% higher and prices are 1% lower than in the unanticipated case. Firms' anticipatory behavior dampens the short-run effects of the tariff, supporting higher output along the transition path.

Last, we show that when the tariff is anticipated, the short- and long-run trade elasticities are twice as large as when the tariff is unanticipated. When the firm anticipates the tariff, they increase their imports before the tariff, which then leads to a sharper drop in imports post-tariff since they use the additional inventories to produce.

Our paper builds on and contributes to several 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 *after* the tariff increase. Javorcik, Pierce, and Wisniewski (2026); and Alfaro and Chor (2025) study the adjustment in foreign sourcing patterns *after* the tariff implementation. 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 tariff front-running, both in the aggregate and in the firm-level data.

Second, 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 evidence of stockpiling in response to an expected tariff increases in 2018–2019. To the best of our knowledge, our paper is the first to show the front-loading of inventories and imports at the firm and firm-product-country levels. Further, we quantify how the firm's anticipatory response impacts the aggregate output and price dynamics. 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). While we remain agnostic as to how firms form their tariff expectations, we show that firms did respond to future tariff changes.

Third, 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, a finding made possible by the granularity of our data.

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).

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 and quantitative findings. Last, Section 6 concludes.

2 Data

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 comes 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) summarize its advantages and disadvantages and 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 imports, 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

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

[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

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 build a comprehensive firm-level dataset combining imports with financial information, we merge BoL with Compustat through a multi-step procedure incorporating text-analysis algorithms. The key challenge is name variation—both across shipments of the same firm within BoL and between BoL firm names and their Compustat counterparts. To map shipments to firms, we begin with the firm identifier provided by PIERS, which matches many BoL shipments directly. For unmatched shipments, we employ an approximate name-matching algorithm that first standardizes names to isolate their distinctive "core" (stripping boilerplate such as legal suffixes and common industry terms) and then matches these cores based on string similarity. For the string similarity, we utilize a 90% Levenshtein distance threshold. This threshold was chosen by validating candidate thresholds against a hand-labeled sample of 500 randomly drawn firm pairs. Among the candidates, we selected the cutoff that best maximizes the match accuracy. This procedure increases matched observations by more than 20% over the PIERS-provided firm identifiers alone. Next, to match BoL firms to Compustat firms, we apply the same standardization and matching approach to construct a correspondence, retaining pairs whose standardized names achieve at least 90% Levenshtein-distance similarity. Through these procedures, we substantially improve both the coverage and accuracy of the dataset.

2.1 Summary Statistics

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. We report summary statistics in Table 1. We highlight data patterns that we will use to interpret our empirical findings and calibrate the model. First, we observe that trade is lumpy. Across all 32

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).

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

available quarters, the mean and median firm imported only in 18 and 20 quarters, respectively (Panel (b)). Second, we observe that more than 75% of firm-quarters import an HS6 product from a single country (Panel (d)). This pattern is in line with Javorcik, Pierce, and Wisniewski (2026), who find that only large importers source a single product from multiple countries. However, firms often source multiple products from a single country. In Panel (e), on the mean and median, firm-quarters imported four and two products from a country partner.

2.2 Tariff Dynamics

The two main 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 tariffs 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, there were multiple waves of tariffs implemented for different products at different breadths. The earlier tariff waves against China focused on intermediate inputs; the scope expanded to include consumption goods in the later lists. The largest waves were Lists 3 and 4A, which covered $188 billion and $99 billion in 2017 imports, respectively.

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.

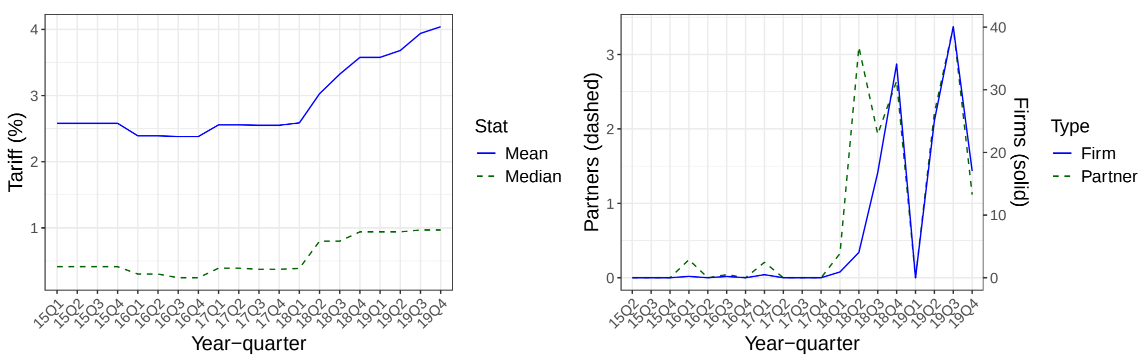
Next, we show the widespread impact of the tariffs over our sample period. Panel (a) of Figure 2 shows the mean and median tariff across all trade partners (including those with zero tariffs), defined as an HS-6 product–country pair for each quarter. The figure shows that the mean tariffs increased from 2.5% to over 4.0% between 2017Q4 and 2019Q4. Panel (b) shows the share of partners (product–countries) that

[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 (see Appendix A).

experienced a tariff increase, defined as a quarter-to-quarter increase in tariffs of more than 3 percentage points (p.p.), with a dashed line.[4] The solid line of panel (b) shows that a large share of US firms experienced a tariff increase, defined as an import-volume-weighted tariff increase of more than 1 p.p.. For example, in 2019Q3, while only 3% of partners faced a tariff increase, 40% of firms experienced a tariff increase. This shows that 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.

Figure 2: Tariff dynamics.
At the peak of tariff waves, 40% of US public firms were affected.

(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.

There were earlier tariff increases, as evidenced by two changes 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 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

[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.

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 show three sets of empirical analyses. First, using *aggregate* data, we provide descriptive evidence of front-loading of imports. For the second and third exercises, we use our *firm-level* data. We study how future tariff increases affect a firm's imports, inventories, and its set of foreign partners. Then, we analyze the firm-product-country response to understand how firms adjust their imports.

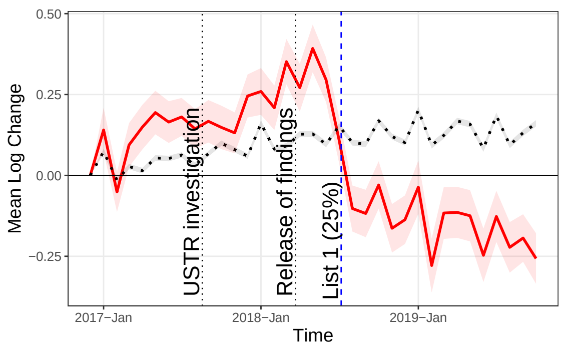
3.1 Tariff Front-Running in the Aggregate Data

As previewed in Figure 1, we first examine tariff front-running by contrasting import changes for product-countries subject to specific tariff waves against those unaffected by any of the 2018–2019 tariffs. To do so, we use the aggregate, product-country-level import data from the Census Bureau compiled by Amiti, Redding, and Weinstein (2019, 2020). 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., $\log(X_{h,c,t}) - \log(X_{h,c,2016m(t)})$, where $m(t)$ denotes the month of t to control for seasonality. We then take the average of the log change across all product-country pairs that are affected by a given tariff wave (solid red line) and compare it to the product-countries that were not affected by any tariff waves during 2018–2019 (dotted black line).

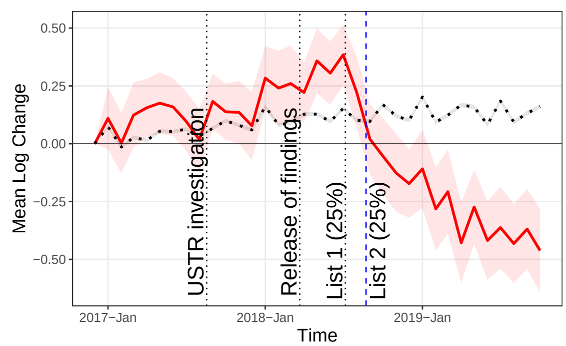
Similar to the import responses for steel and aluminum in Figure 1, Figure 3 illustrates the anticipatory import dynamics for the Chinese products subject to each tariff wave. We consider that there exists evidence of front-loading if the affected product's import growth is above the growth experienced by unaffected products. For List 1 products in panel (a), which were affected by the first China tariff wave, there is evidence of stockpiling for a year, from the USTR investigation to the tariff implementation (vertical blue dashed line). List 2 and List 3 imports in panels (b) and (c) exhibit anticipatory dynamics from around six and seven months before the tariff implementation, which coincides with the timing of the public release of investi-

Figure 3: Dynamics of products affected by tariffs against China. Generally, there exists stockpiling prior to a tariff wave.

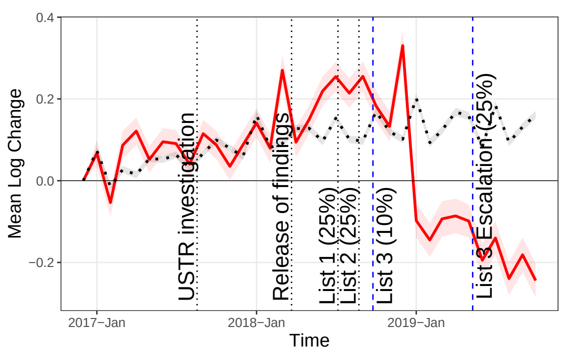
(a) List 1



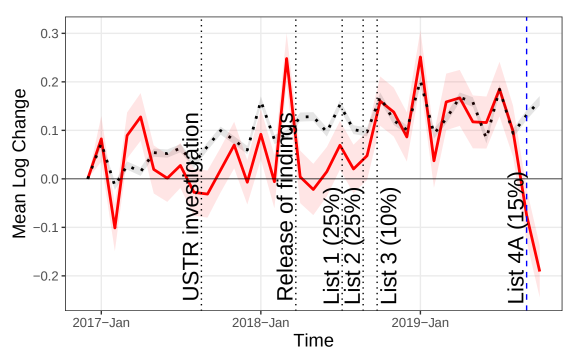
(b) List 2



(c) List 3



(d) List 4A



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 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 2.2. 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).

gation findings and the announcement of future tariffs in March 2018. Furthermore, in Panel (c), we observe the import surge for the List 3 products in late 2018, since their tariffs were originally scheduled to escalate to 25% in January 2019, which eventually occurred in May 2019. Importers likely "raced against the clock" to lock in the 10% rate before the scheduled escalation in January 2019. Unlike the Lists 1, 2, and

3, for the List 4A tariffs, we do not observe significant stockpiling, except in March 2018, around the time the public release of the USTR investigation occurred.

3.2 Tariff Front-Running in the Firm-Level Data

We now turn to the firm-level data to study how *firms* adjusted their imports in response to future tariff increases. We start by constructing an import-weighted tariff increase for a firm, which captures how exposed the firm is to a tariff change given its set of trade partners (i.e., product-country pair). We consider the *existing* set of partners defined as the cumulative set of partners the firm traded with in the past four quarters, $E_{i,t} \equiv \bigcup_{k=-4,\dots,-1} C_{i,t+k}$, where $C_{i,t}$ represents the *current* set of partners the firm traded with at time t. We make this assumption due to the lumpiness of trade discussed in Section 2.1, where a firm remains exposed to a partner's tariff in periods when it does not import from them but still relies on them in production. Then, we let $v_{i,h,c,t} = \sum_{k=-4,\dots,-1} x_{i,h,c,t+k}$ denote the *existing* import volumes, where $x_{i,h,c,t}$ represent the *current* import volume of firm i from product-country partner (h, c) at t.

Next, we define the firm-level tariff increase, $\hat{\tau}_{i,t}$, as the import-weighted average tariff change 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 product-country (h, c) at time t. 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 low-import-share partner is categorized as a tariff-increase event.

For our baseline empirical analysis, we use the dummy variable $FTI_{i,t} = 1$ which indicates that the firm i faced the tariff increase for the first time at time t; that is, $FTI_{i,t} \equiv \mathbb{1}(TI_{i,t} = 1 \text{ and } t = \min\{s : TI_{i,s} = 1\})$. The rationale for using $FTI_{i,t}$ is two-fold. First, many firms face multiple tariff increases throughout the sample period, since firms import multiple products that were subject to different tariff waves. Therefore, analyzing the pre-effects through $TI_{i,t}$ could compound the effects of serially-correlated tariff increases, which we can avoid by using $FTI_{i,t}$. Second, $FTI_{i,t}$ represents the first *realization* of the tariff, instead of the news announcement of future tariffs. From Table 2 and Figure 3, we observe that importers responded to a series of compounding signals, ranging from initial investigations to the delay of tariff escalation for the List 3 products, any of which could plausibly serve as the relevant news event. Therefore, it is difficult to isolate a single, discrete "news shock" and we define the first realization of the tariff increase as our event time t.

We study the dynamic response of a firm to a first tariff increase, $FTI_{i,t}$, using local projections (Jorda 2005). We quantify the response of imports, 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. Note that since the first major tariff increases occurred in 2018Q2, and our data ends in 2019Q4, we do not have enough variation to precisely estimate the response six quarters after the first tariff increase.

Specifically, we estimate the following 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 $y_{i,t+k}$ denotes the variable of interest, $X_{i,t}$ is a vector of firm-level controls, where we use 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.

To include as many observations as possible, we transform the variables by taking the inverse hyperbolic sine, defined as $\text{asinh}(x) \equiv \log\left(x + \sqrt{x^2 + 1}\right)$. This enables us to include zeros in our observations, unlike the logarithm. As trade is lumpy, 43% of all firm-quarters report zero imports; 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]

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

[6] The inverse hyperbolic sine is approximately linear for small values of y and approximately equal to $\log(2y)$ 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 in the next

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 first tariff increase, summarized by the estimated $\{\beta_k\}_{k=-6,\ldots 6}$. Firms that observe a tariff increase in t ($FTI_{i,t} = 1$) start to increase their imports around four quarters before the first increase in tariffs, and the imports peak a quarter before the shock. Notably, this four-quarter timing coincides with the periods between the start of the formal investigation and the tariff implementations in the data (see Table 2). After the tariff, imports decrease.

Next, the number of current partners also increases before the rise in tariffs. Panel (b) shows the estimates when $y_{i,t} = \text{asinh}(|C_{i,t}|)$, 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 a subsequent 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 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 three quarters before the tariff increase. Since imports are inventory-intensive, we interpret the firm's response to a future tariff by raising its imports and stockpiling them as inventories.

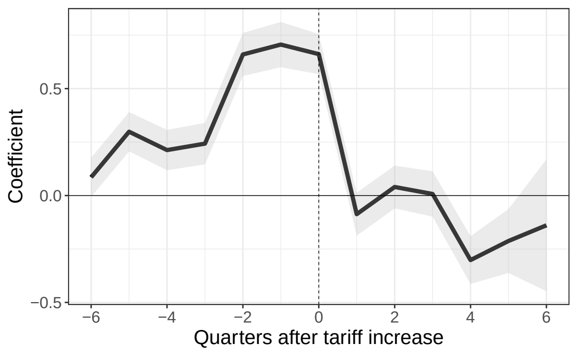
The firm's anticipatory response is robust to different specifications that we include in Appendix A. First, we obtain a similar response when using a logarithmic transformation (Figure A2). The point estimates at $k = -1$ show that current imports, the number of partners, and inventories for the tariff-affected firms are 8.9%, 5.7%, and 2.7% higher, respectively, than for the unaffected firms. In addition, in Appendix B, we show that our results robustly hold when we set the regressor as the continuous measure of firm-level tariff increase instead of the dummy variable.

Other robustness exercises include utilizing the balanced panel subset of our dataset (Figure A3); using $TI_{i,t}$ instead of $FTI_{i,t}$ as the regressor (Figure A4); assessing the

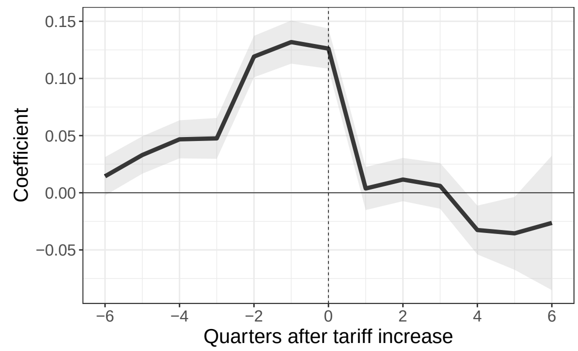
section.

Figure 4: Imports, number of partners, and inventories around a tariff increase. All three measures see an increase prior to the tariff implementation.

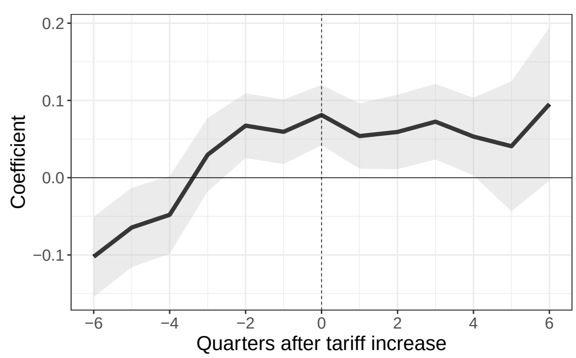
(a) Imports: $\operatorname{asinh}\left(\sum_{(h,c)\in C_{i,t+k}} x_{i,h,c,t+k}\right)$



(b) Number of partners: $\operatorname{asinh}\left(|C_{i,t+k}|\right)$



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



Note: The figures describe the estimated $\{\beta_k\}_{k=-6,\dots6}$ 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.

response of existing, instead of current, import volumes and partners (Figure A5); and adopting a Poisson Pseudo-Maximum Likelihood (PPML) specification (Silva and Tenreyro 2006) for the count of trade partners (Figure A6).

To the best of our knowledge, this is the first paper to show the import and inventory response to a future tariff at the firm level. Alessandria, Khan, and Khederlarian (2024) provide aggregate evidence of stockpiling of imports prior to China's most favored nation tariff renewal voting. Furthermore, this paper shows the US firms' anticipatory, extensive-margin import response, where they increase their set of partners before the tariff.

3.3 Margins of Import Adjustment

Leveraging the data at the partner level, we analyze which products or countries firms adjust imports from or substitute to when they expect a future tariff. To analyze the margins of import adjustment, we study the intensive- and extensive-margin responses for each of a firm's partners when the firm faces a tariff. In particular, we classify firms' partners into four types: (i) affected product–affected country, (ii) affected product–unaffected country, (iii) unaffected product–affected country, and (iv) unaffected product–unaffected country.

For example, suppose that a firm imports small direct current (DC) motors (HS6: 850131) from China. If the firm expects that these motors will be subject to a tariff (as they were under the List 1 tariff), we study whether the firm adjusts its imports of (i) the DC motors from China, (ii) the DC motors from Vietnam, (iii) single-phase alternating current (AC) motors (HS6: 850140) from China (which were not subject to the List 1 tariff), or (iv) the AC motors from Vietnam.

For the analysis, we introduce the following 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 belongs to the existing set of the firm, $TI_{i,h,c,t} \equiv \mathbb{1}(\tau_{h,c,t} > \tau_{h,c,t-1} + 0.03, \text{ and } (h,c) \in E_{i,t})$. Then, we create dummy variables that denote the set of partners for each of the groups listed above. First, (i) the affected product-affected country defined by $AA_{i,h,c,t} \equiv TI_{i,h,c,t}$. Second, (ii) the affected product-unaffected country is captured by $AU_{i,h,c,t} \equiv (TI_{i,h,c,t} = 0) \wedge (\max_{c'} TI_{i,h,c',t} = 1)$. Third, (iii) the unaffected product-affected country is denoted by $UA_{i,h,c,t} \equiv (TI_{i,h,c,t} = 0) \wedge (\max_{h'} TI_{i,h',c,t} = 1)$. Last, (iv) the unaffected product-unaffected country set is represented by $UU_{i,h,c,t} \equiv (\max_{c'} TI_{i,h,c',t} = 0) \wedge (\max_{h'} TI_{i,h',c,t} = 0) \wedge (\max_{h',c'} TI_{i,h',c',t} = 1)$, where the product-country partner (h,c) is unaffected, and no other countries supplying the product h and no products coming from the country c were affected by a tariff, but another partner that supplies to the firm i is affected by a tariff increase.

We study the response for each type of partners using local projections. Specifically, we estimate the following dynamic relationship from $k = -6$ through $k = 6$:

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

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 for each partner type, 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. One important note of caution 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. Moreover, given that our dataset ends in 2019Q4, when a firm "drops" a partner after the tariff increase, we cannot determine whether it implies the end of a long-term relationship or waiting longer to order from that partner, given the anticipatory stockpiling.

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).

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

Then, we define the probability of a new partner being added to the existing set of a firm, $PA_{i,h,c,t}$, in Equation (5). 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 $t-1$.[7]

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

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 projections. 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. The changes in the coefficients over time describe the dynamics of the estimates for that type of partner over time, and the difference from zero reflects the response difference between the partners of interest and the partners of firms whose partners never experienced a tariff increase.

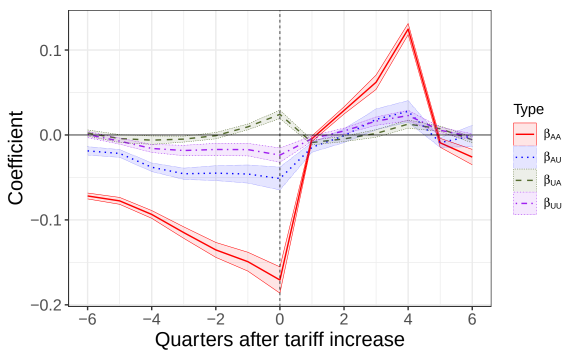
In Panel (a), the probability of dropping (i) the affected product-affected country, shown in red-dotted lines (β_{AA}), decreases sharply before the tariff and then increases right after t. This implies the firm is more willing to keep the affected partner before the tariff increase and drop them right after. A mirror-image 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. We find that, other than 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 the DC motors from China observe a tariff increase, then firms substitute towards the 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 interpret this result as firms building resilience by adding a partner that provides the same product that faces a tariff. This result echoes Flaaen,

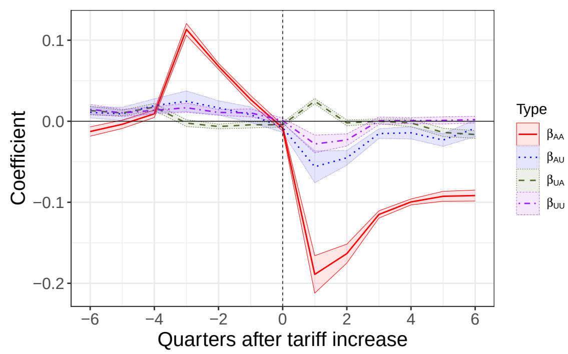
[7] We define $PA_{i,h,c,t}$ as the dummy variable denoting whether a partner in $E_{i,t}$ was in $E_{i,t-1}$. Alternatively, we could define the variable as whether a partner not in $E_{i,t-1}$ was added in $E_{i,t}$. However, doing so requires constructing the full set of all possible exporting countries for each product, which results in a large number of (h,c) combinations with zeros recorded for the variable. The resulting sparsity, with nearly all observations equal to zero, would severely attenuate the estimates and inflate the share of out-of-range predicted probabilities in the linear probability model.

Figure 5: Extensive-margin adjustments.
Significant within-product extensive-margin adjustments.

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



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



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.

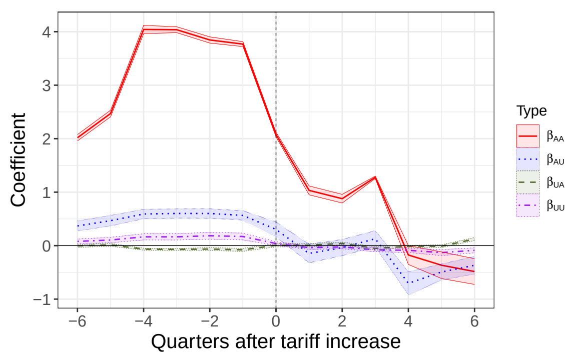
Hortaçsu, and Tintelnot (2020), who showed that the antidumping duties against washing machines from South Korea and China in the 2010s incurred a production relocation to other countries. In contrast, we do not find as big a response for the (iii) unaffected products-affected countries (e.g., AC motors 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}).

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 imports of each partner of the firm, $x_{i,h,c,t+k}$, 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 rise in imports in the intensive margin for (i) the affected partner in the red-solid line (β_{AA}). The estimated effect is shifted up, likely due to the serial correlation of the tariff increase. That is, the effect picks up responses to the other tariff changes in the past or future. A similar pattern, albeit smaller, 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 before the tariff increase. While the largest adjustment comes from the affected partners, in Appendix D we show that the firm's imports from the new affected product-unaffected country are significant: In the quarters leading up to the tariff, the median firm sourced approximately 15% of its average prior imports from these newly added unaffected-country partners. We do not see a significant intensive response in imports for the (iii) unaffected products-affected countries (green dashed lines, β_{UA}), or for (iv) other unaffected partners of the firm (purple dashed-dot lines, β_{UU}). We report the results for the existing import volume as a robustness check in Figure A7 in Appendix A.

Figure 6: Intensive-margin adjustments.
Significant within-product intensive-margin adjustments.

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



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.

4 A Model of Inventories and Sourcing Choices

The model combines elements of the inventory model of Alessandria, Kaboski, and Midrigan (2010) and multi-country sourcing from Antras, Fort, and Tintelnot (2017) 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 front-load their purchases and adjust their partners 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. The domestic representative consumer aggregates over the unit continuum of final goods. 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 number of foreign countries, where J also denotes the set of 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. 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 imposed on country j. 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, 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. This assumption allows us to avoid solving 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 E.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 E.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 E.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 front-load 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. Besides the traditional argument for efficiency gains from large orders, this outcome can be interpreted as a result of quantity discounts, where large orders are associated with a lower cost.

4.3 Inventory Manager

The inventory manager of the firm $\omega \in [0, 1]$ produces 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. 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.

We use the first order conditions of the inventory manager to analyze the mechanism of the model. Due to Proposition 2, the first order condition with respect to the input order, n, is as follows:

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

for a $k \in \{1,...,J\}$. It shows the value of the discounted value of an additional unit of inventory is equal to the marginal cost of the import manager. Combining Equation (11) with the first order condition with respect to the price of the final

[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.

good, p^f, provides insight into the inventory manager's pricing rule.

$$p^f = \frac{\epsilon}{\epsilon - 1} \left(c_k + \lambda\right). \tag{12}$$

where λ is the Lagrange multiplier on the input constraint and c_k the marginal cost of the input. 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 marginal cost. 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. Further, note that since a large inventory manager's input order, n, implies a lower marginal cost, c_k, there are incentives for the inventory manager to place large orders intermittently, which is consistent with the lumpiness of trade discussed in our empirical analysis.

4.4 Aggregate Output and Prices

The demand curve for an inventory manager, $y^f_\omega = \nu_\omega \left(p^f_\omega\right)$, comes from the domestic, representative consumer's problem. They maximize the aggregate consumption, or output, according to the following constant elasticity of substitution technology.

$$Y = \left(\int_0^1 \nu_\omega^{\frac{1}{\epsilon}} \left(y^f_\omega\right)^{\frac{\epsilon-1}{\epsilon}} d\omega\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{13}$$

The corresponding price index is given by

$$P = \left(\int_0^1 \nu_\omega \left(p^f_\omega\right)^{1-\epsilon} d\omega\right)^{\frac{1}{1-\epsilon}}. \tag{14}$$

5 Effects of Tariff Front-Running

First, we calibrate the model to match data moments in 2015. Second, using the model, we quantify firms' responses to the observed tariff changes from 2015 to 2019. Third, we show that the model matches the untargeted firm-level and aggregate data moments. Fourth and fifth, through counterfactuals, we assess the role of the extensive-margin adjustments and the role of anticipation in the aggregate output and price dynamics. Sixth, we discuss how the firm's anticipatory response can overstate the trade elasticity. Last, we show the robustness of our findings to the different choice of model parameters.

5.1 Calibration of the Model

We calibrate the model to match firm-level and aggregate moments 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. Using the simulated method of moments, 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, T_j, to match the mean number of sourcing countries and the inventory to quarterly sales ratio from our firm-level sample and the aggregate import shares 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 $f = 0.005$. We set wages, $w_j = 1$, and calibrate the technology parameters, T_j, to absorb all the initial differences across countries. Thus countries with larger import shares have higher estimated technology parameters. Similarly, 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.

We set the length of the period as 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 an annual rate of 20%. 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 1.789. We later show that the model's dynamics are robust to different values of these predetermined parameters.

We calculate the increase in country-wide tariffs as the difference between import-weighted-average tariffs from 2015 to 2019. The average tariff at t for country c is formally given by $\tau_{c,t} \equiv \frac{\sum_h x_{h,c,t}\, \tau_{h,c,t}}{\sum_{i,h} x_{h,c,t}}$, where $x_{h,c,t}$ is the aggregate import from product-country (h, c) at year t. For each country, the tariff increase is defined as the difference between the 2015 and 2019 average tariff levels, $\Delta\, \tau_c = \tau_{c,2019} - \tau_{c,2015}$.

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
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%
Elasticity of sub, $x(v)$	ρ	2	Antras, Fort, and Tintelnot (2017)
Fréchet parameter	θ	1.789	Antras, Fort, and Tintelnot (2017)
Number of countries	J	17	Sourcing countries in the third quantile

Panel C. Tariffs

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

5.2 Firm's Response to a Future Tariff

We use the model to study the firm-level and aggregate dynamics when there is a future increase in tariffs. We assume firms have perfect foresight, where they start in their low-tariff steady state, and they receive the news that tariffs will rise in four quarters (*news*). In period zero, $t = 0$, the new tariffs are implemented (*tariff*). The timeline corresponds roughly to the quarters between the investigation and the first tariff implementation on imports from China and on steel and aluminum. Tariffs rise

Table 4: Tariff increases in percentage points.

	Country	$\Delta_{2019-2015}\,\tau_c$		Country	$\Delta_{2019-2015}\,\tau_c$
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 2015 and 2019.

according to the observed increase in Table 4. In the model, at $t = 0$, the import-weighted tariff increases by 3.0%, which includes the tariff increase across all countries and the firm's substitution away from the now more expensive partners.

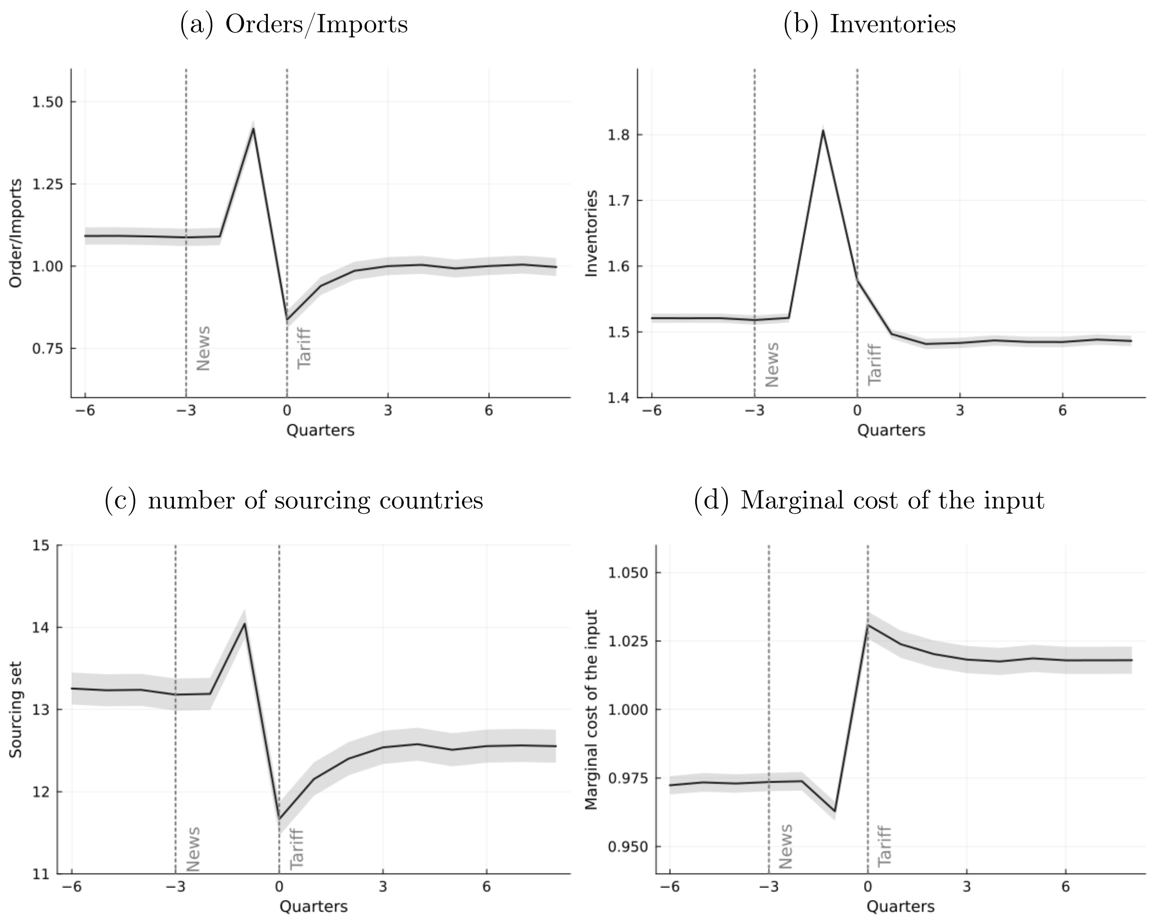
Figure 7 shows the firm-level transition of inventories, imports (i.e., orders), the number of sourcing countries, and the marginal cost of the input from the low- to the high-tariff steady-state levels, and Figure 8 shows the change in aggregate output and prices.

We first compare the low- and high-tariff steady states. The increase in tariffs causes the marginal cost of the input to increase by 4.7% in the high-tariff steady state (Panel (d), Figure 7). The tariff has a full pass-through to the price of each variety in line with Fajgelbaum et al. (2020) and Amiti, Redding, and Weinstein (2020); however, the increase in the tariff leads to a decrease in the sourcing set, which further increases the marginal cost of the input by more than the tariff. The consumer's lower demand, given the rise in prices due to tariffs, restricts the firm's ability to pay for the fixed costs of sourcing from additional countries. Therefore, on average, firms source from 0.7 fewer countries in the new steady state (Panel (c), Figure 7). Given the higher marginal costs, firms' imports decrease by 8.5% (Panel (a), Figure 7) and their inventories also decline by 2.3% (Panel (b), Figure 7). Aggregate prices increase by 2.4% (Panel (a), Figure 8), and aggregate output declines by 9.1% (Panel (b),

Figure 8) in the high-tariff steady state.

Turning our focus to the transition between the two steady states, Figure 7 shows that the model matches the untargeted firm's anticipatory response of inventories, imports (i.e., orders), and the number of sourcing countries described in Section 3. In the period before the tariff, imports increase by 30.1% relative to their initial steady-state and store them as inventories, which increases by 18.7%. The increase in their

Figure 7: Firm-level anticipatory response to a tariff increase.
Model 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 a 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 −3, they learn that the tariffs will increase at period 0 (both shown with the vertical dashed lines).

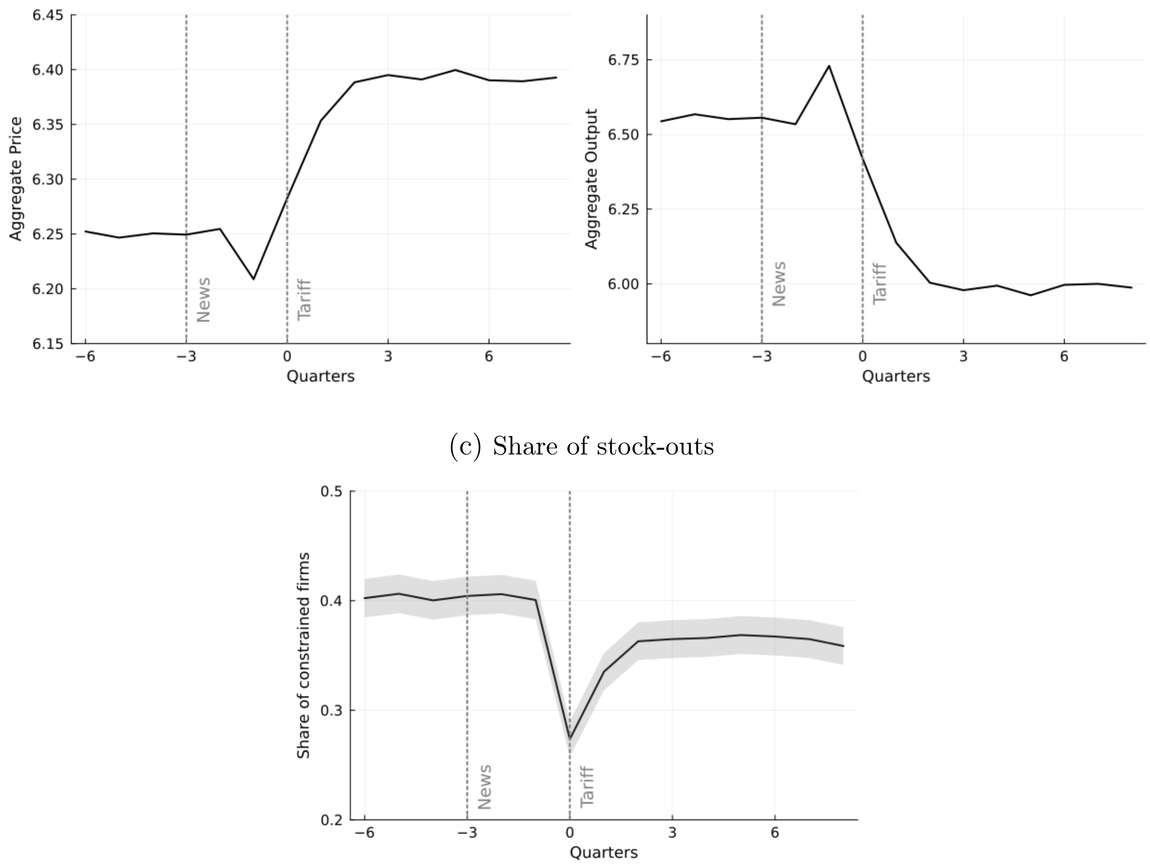
orders allows the firms to pay for an additional fixed cost to expand their sourcing set to, on average, one more country. Consistent with the empirical findings, the model shows firms intensively increase their imports from the countries that will face the tariff increase and add new countries to their set. The expansion of the extensive margin lowers the marginal cost of the imported input by 1%, as shown in Panel (d), Figure 7. The model shows the firm's anticipatory response impacts aggregate prices and output even before the tariff increase (Figure 8). Due to the decrease in

Figure 8: Aggregate response to a tariff increase.
Smooth transition to new steady state.

(a) Price of final goods

(b) Output

(c) Share of stock-outs



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 −3, they learn that the tariffs will increase at period 0 (both shown with the vertical dashed lines).

the marginal cost of the input before the tariff, the aggregate prices decline by 0.7%, and aggregate output increases by 2.0%.

In Figure 7, after the increase in tariffs, 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 after the tariff. 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 quarters until they reach their new, lower, steady state. Figure 8 shows that the firm's anticipatory response allows the aggregate output and prices to have a smooth transition to their low-output, high-price steady state. Aggregate output drops after the tariff but remains 7.1% higher than the final steady state. It takes 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 1.7% lower than their final steady state.

The transition of the aggregate variables is shaped by two forces: the change in marginal cost of the input and the share of firms that stock out, as described in Equation Equations (12) and (14). First, there is a complete pass-through of the tariff to the price of the each variety, 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 further upward pressure on prices. However, the inventories acquired prior to the tariff reduce the share of firms that stock out (Panel (c), Figure 8), which creates downward pressure on aggregate prices. Similarly, the added inventories allow for a larger share of firms to avoid stock-outs, which spreads the transition to a year.

5.3 Untargeted Moments

We compare the firm-level and the aggregate response in the model to untargeted moments in the data. The model qualitatively matches the firm-level anticipatory response in imports, inventories, and the number of sourcing countries. Further, we also observe that the aggregate response of output and prices in the model explains the cross-industry variation in the output and price dynamics before and after the tariff.

First, we compare the firm-level response before the tariff to the estimates in the data, shown in Section 3. We use the logarithmic specification, which allows us to compare the growth observed by the firm that faced the tariff relative to the firms who did not. In the data, prior to the tariff, the firm increases their imports by 8.9%, their inventories by 2.7%, and their sourcing partners by 0.74 (i.e., mean number of sourcing countries of 13 times the estimated increase of 5.7%). In the calibrated model, we find that imports are 30% higher, inventories rise by 20%, and there is a 0.7 increase in the number of partners before the tariff. The model's response of imports and inventories is higher in the model due to the assumption that production is only a function of imports.

Second, in contrast, the model matches well the changes in import shares. The import shares for 17 countries in 2019, which corresponds to the final steady state in the model, differed by, on average, 1.1 percentage points. Further details are included in Table A2 of Appendix A.

Third, we compare the model's aggregate variables response before and after the tariff to the data. Since we do not observe output and price separately in the firm-level data, we use cross-industry variation in output and price indices. We compare their growth before and after the tariff across industries whose inputs are differentially exposed to the tariff. We find that for industries whose inputs are more exposed to the tariff, their output will increase more relative to other industries before the tariff, and decline further post-tariff. Similarly, aggregate prices follow the model's prediction, where prices of the more tariff-exposed industries grow less pre-tariff and more post-tariff.

To do so, we first compute two tariff exposure measures 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, defined by $M1_j \equiv \left(\sum_{i\in j}\sum_t FTI_{i,t}\right)/(\text{number of firms in } j)$, where j denote an industry. Second, we compute the average tariff increase for firms in each industry represented by $M2_j$. The details for the measure $M2_j$ are in Appendix B. Then, we obtain data on aggregate output 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 selling prices received by domestic producers for their output. We use the seasonally adjusted series of the IPI and apply seasonal adjustments for the raw PPI data.

To compare the aggregate price and output response, we consider three periods centered around the List 3 China tariffs, 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 the investigation. Second, the *pre-tariff* period from August 2017 to August 2018 ended before the tariff for the List 3 products was implemented. Third, the *post-tariff* period is defined from September 2018 to December 2020. Then, we compute the difference in the growth rates of the average output and price indexes between the initial and pre-tariff periods and between the pre- and post-tariff periods for each industry. Table 5 shows the correlation between the difference in the growth rates of output and prices and the tariff exposure measure of the industry.

Table 5: Correlation between tariff measures and output and price growth. Data matches model's predictions.

Panel A. Output		$M1_{j,t}$	$M2_{j,t}$
(1)	$\log(IPI_{j,pre-\tau}/IPI_{j,\text{initial}})$	0.044	0.496
		(0.029)	(0.281)
(2)	$\log(IPI_{j,post-\tau}/IPI_{j,pre-\tau})$	−0.052	−0.530
		(0.025)	(0.245)
	Observations	128	128

Panel A. Prices		$M1_{j,t}$	$M2_{j,t}$
(3)	$\log(PPI_{j,pre-\tau}/PPI_{j,\text{initial}})$	−0.025	−0.157
		(0.008)	(0.061)
(4)	$\log(PPI_{j,post-\tau}/PPI_{j,pre-\tau})$	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.

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 creates downward pressure on the marginal cost of the input, which decreases aggregate prices and expands output. Table 5 shows that for industries more exposed to the tariff, their output grows by more (row (1)) and prices by less (row (3)) compared to less exposed industries before the tariff. After the tariff, the model shows a drop in aggregate output and a rise in aggregate prices. In the data, industries more exposed to the tariff grow by less after the tariff (row (2)) and their prices by more (row (4)).

5.4 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. Here, we evaluate the importance of the extensive margin 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, and thus, the marginal cost of the input is always constant.

Figure 9 shows the transition of aggregate output and prices, assuming perfect foresight, for both the benchmark model and the one with a unique country that supplies all the varieties (*no extensive margin*). To compare the response of the firms across both modeling assumptions, we set the initial marginal cost of the model without an extensive margin that yields the same initial aggregate prices as the benchmark model. We assume an increase in the tariff of 3.0%, which corresponds to the average tariff in the benchmark model.

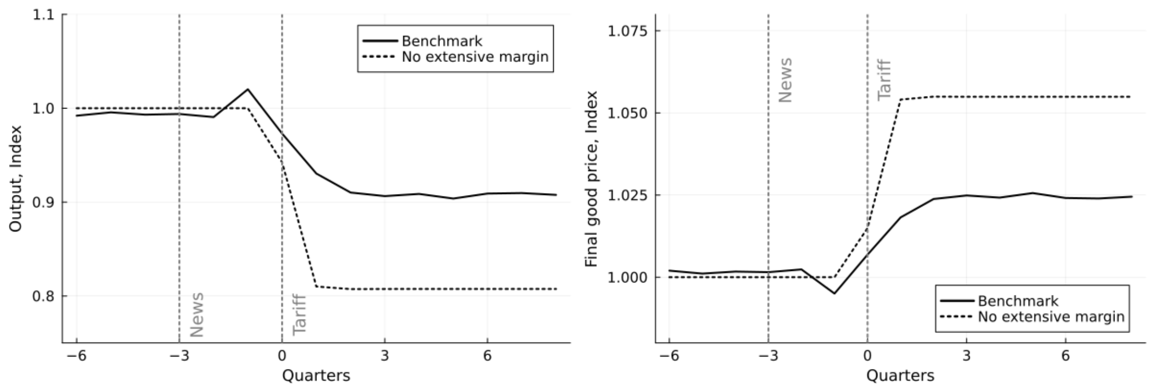
We compare the growth of output and prices across the two models. We find that the aggregate dynamics before the tariff are due to the extensive margin response. In the benchmark, the increase in imports allows the import manager to include more countries in their sourcing set, which lowers the marginal cost of the input. Thus, aggregate variables respond before the tariff: aggregate output increases and aggregate price decreases. This channel is absent in the alternative model. After the rise in tariffs, the aggregate output and price in both models observe a gradual transition to the new steady state.

5.5 Role of Anticipation

We study the role of anticipation (i.e., firms know about the future tariff in advance) on the firm's response and its impact on the transition of aggregate variables. We

Figure 9: Role of extensive margin.
Extensive margin drives aggregate dynamics before the tariff.

(a) Aggregate Output (b) Aggregate Price



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 margins. The dotted line shows the transition under the alternative model where firms do not have an extensive-margin choice and, thus, the marginal cost is constant.

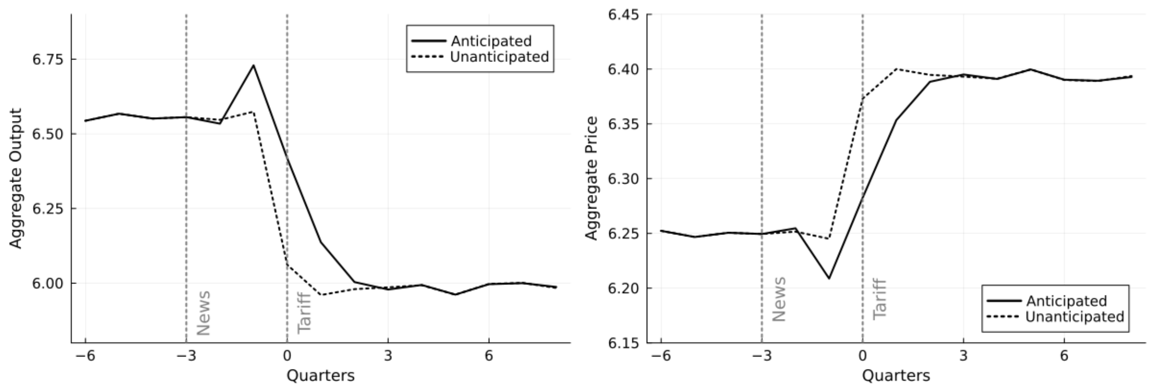
do so by comparing the perfect foresight response (*anticipated*) to the case when the firm learns about the tariff in the period it is implemented (*unanticipated*). Figure 10 summarizes the gains from anticipation, defined as the difference between the response for the anticipated case and the unanticipated one.

When the tariff is anticipated, firms can increase their imports and inventories. The additional inventories allow firms to support a longer and smoother transition to the new high-tariff steady state. Under the anticipated assumption, aggregate output is 5.9% higher when the tariff is implemented than in the unanticipated scenario and continues to be higher during the transition (Panel (a), Figure 10). Similarly, the aggregate prices when the tariff is anticipated are 1.4% lower at the time of the tariff implementation than in the unanticipated case and remain lower during the transition (Panel (b)).

Note that even if the tariff is unanticipated, there still exists a gradual transition to a new steady state for both the firm and aggregate variables. This is a feature of a model with inventories. Here, the increase in tariff forces the firm to transition to a lower-output, lower-inventory steady state. Therefore, when tariffs rise, firms already

Figure 10: Role of anticipation.
Aggregate transition is smoother when anticipated.

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



Note: The figures show the transition path of aggregate output and prices. The solid line represents the transition under the anticipated assumption: Firms have perfect foresight, where we assume they start at a low-tariff steady state, and at period -3, they learn that the tariffs will increase at period 0 (both shown with the vertical dashed lines). The dotted line shows the transition for an unanticipated tariff increase, where firms learn about the tariff change when it is implemented at period zero.

have an excess of inventories to help them slow down the transition to the new steady state. However, the transition is longer and smoother when firms can anticipate the tariff and increase their inventory.

5.6 Trade Elasticity Bias

A methodological concern in the literature is that anticipatory behavior by firms affects standard estimates of how trade responds to tariff changes. When the tariff is anticipated, the short- and long-run trade elasticities are twice as large as when the tariff is unanticipated. We compute the response of imports to the change in tariff as in Boehm, Levchenko, and Pandalai-Nayar (2023), where $\epsilon^h = \frac{\log(x_{t+h})-\log(x_{t-1})}{\log(\tau_{t+h})-\log(\tau_{t-1})}$, x_t and τ_t represent the imports from China and the corresponding tariffs.

Table 6 shows the trade elasticities across different time horizons, $h = \{0, 1, \text{long run}\}$ and for different reference periods, $t-1$. The first column, *Anticipated tariff*, details the elasticity for the case when firms can anticipate the increase in the tariff and the reference period $(t-1)$ is set to a period before the tariff implementation, as is common in the literature. The second column shows the trade elasticity for the anticipated case and when the reference period is before the *news* shock (the initiation of investigation). Last, we compare these two sets of elasticities to the case where the tariff is unanticipated in the third column.

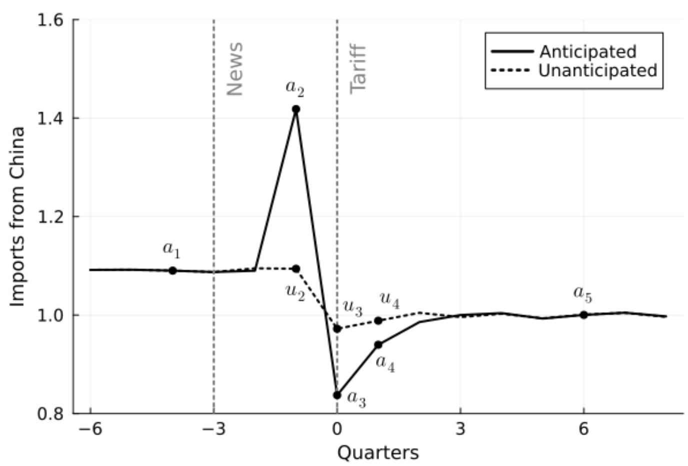
Table 6: Trade elasticity.

Anticipatory response overstates the trade elasticity.

Time	Anticipated tariff	News	Unanticipated tariff
$h = 0$	−5.7 (a2 → a3)	−3.8 (a1 → a3)	−2.7 (u2 → u3)
$h = 1$	−4.8 (a2 → a4)	−2.9 (a1 → a4)	−2.6 (u2 → u4)
Long Run	−4.4 (a2 → a5)	−2.4 (a1 → a5)	−2.4 (u2 → a5)

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 and τ_t are the imports from China and the corresponding tariff, respectively. The period $t-1$ under *news* is fixed as the period before the news of the tariff is announced, and under *anticipated 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 simultaneously announced when tariffs are implemented. In each entry, $(x \rightarrow y)$ means that the elasticity is calculated based on points x and y on Figure 11.

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.

When the firm can anticipate the tariff (Column 1), the short-run elasticity is 2.1 times larger and the long-run is 1.8 times larger than the unanticipated elasticity (Column 3). This is due to the anticipated import dynamics shown in Figure 11, which plots the response of imports from China in our model under both assumptions. When the firm can anticipate the tariff, they increase their imports before the tariff, which then leads to a sharper drop in imports afterwards since firms use their additional inventories to produce. Thus, the import dynamics overstate both the short- and long-run elasticities relative to the unanticipated case.

Further, even when the reference period is set to before the investigation (Column 2), the short-run elasticity is 1.4 times larger than in the unanticipated case. In this case, the short-run elasticity is larger than in the unanticipated short-run elasticity because imports after the tariff drop by more than in the unanticipated scenario due to the additional inventories. However, with a far enough reference period, we can recover the same long-run elasticity as in the unanticipated case. Last, note that generally when we consider the use of inventories, the short-run elasticity is higher than the long-run since firms use their inventories and imports drop when the tariff is implemented. This finding echoes that of Khan and Khederlarian (2021), who distinguish between the import and consumption elasticities, where the latter accounts for the inventories.

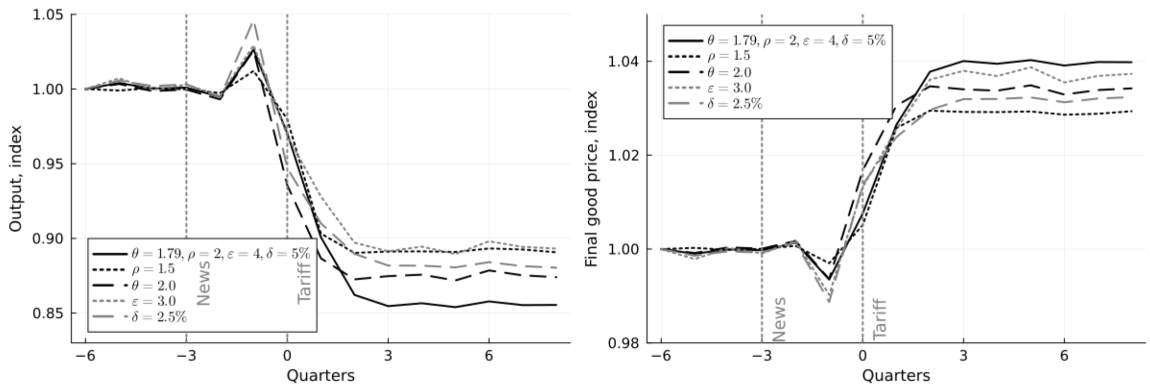
5.7 Sensitivity Analysis

The effect of firms' 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 imported inputs, ρ; the Fréchet parameter that governs the variability in countries' productivity draws, θ; the elasticity of substitution between the final good varieties, ϵ; and the storage costs of inventories, δ.

A lower value of ρ decreases the import substitutability and increases the firm's incentives to anticipate the tariff. 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 and have a smooth transition to the new steady state. Lowering the demand elasticity, ϵ, which increases the markup the firm sets, lowers the total response of output due to higher markups. A lower cost of inventory storage, δ, allows for a deeper anticipatory response that leads to a larger response of output and prices

Figure 12: Robustness exercises to different parameter values.

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



Note: The figures show the index (whose initial value is normalized at 1 at $t = -6$) for the transition path of aggregate output and prices for different values of the elasticity of substitution between the imported inputs, ρ; the Fréchet parameter that governs the variability in their productivity draws, θ; the elasticity of substitution between the final good varieties, ϵ; and the storage costs of inventories, δ.

pre-tariff and a smoother transition afterward.

6 Conclusion

We study the tariff front-running by US importers and their macroeconomic implications for the 2018–2019 tariffs on steel, aluminum, and products from China. For these tariffs, we observe a one-year lag between the start of an investigation into foreign trade practices and the associated tariff implementation. This gap allowed importers to prepare for the future tariff. We provide evidence of front-loading in the aggregate import data for the tariff-affected product-countries. Then, using a novel firm-level dataset that links shipment-level bills of lading, tariff schedules, and firms' financial information, we show that firms respond well before the policy change takes effect: They begin to increase imports, accumulate inventories, and increase the number of their trade partners a year before the tariff. Furthermore, prior to the tariff, firms not only increase their imports (along both intensive and extensive margins) from the tariff-affected product-countries, but also for the same product supplied by tariff-unaffected countries.

To quantify the impact of the firm's anticipatory response on aggregate output and prices, we develop and calibrate a novel dynamic trade model with inventory and extensive margin of importing. Using the model, we show that firms' front-loading of imports allows them to source from more countries, which consequently puts downward pressure on aggregate prices and expands output before the tariff. Moreover, the additional inventory acquired prior to the tariff allows for a smoother and longer transition to the new high-tariff steady state.

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Appendix

A Additional Tables and Figures

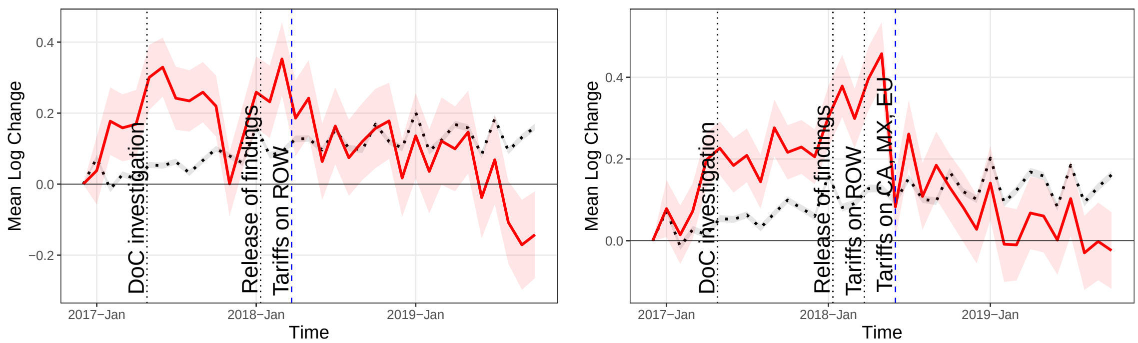
Table A1: Timeline of Section 201 safeguard tariffs on solar panels and washing machines.

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



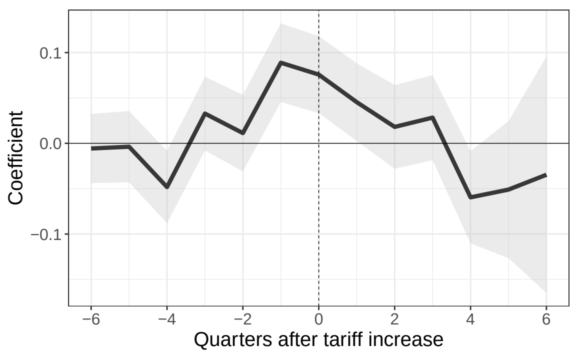
Note: The figure plots the average log change in import volumes relative to the corresponding month in 2016 (with 95% confidence intervals) across HTS10 product-country pairs. Panels (a) and (b) contrast product-countries subject to the March and June 2018 Steel and Aluminum tariffs, respectively, against those never subject to tariff increases during 2018–2019. For more institutional details, see Section 2.2. 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).

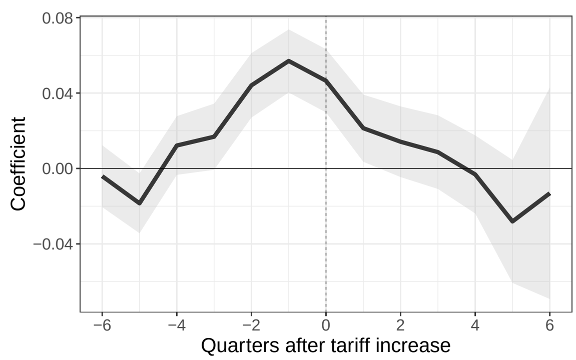
Description: The figure compares the average log import growth of products affected by each wave of steel and aluminum (SA) tariffs to that of unaffected product-countries. Panels (a) and (b) uncover that around the time the Department of Commerce started its Section 232 investigation, the SA imports 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).

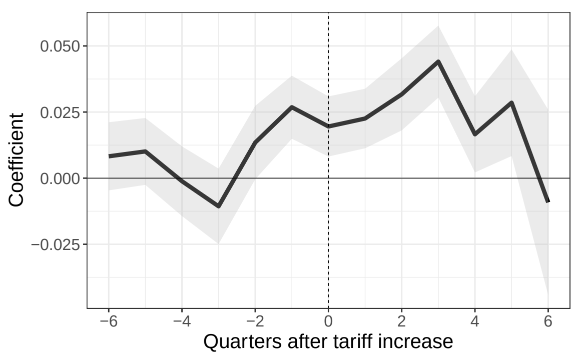
(a) Current imports: $\log\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



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



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

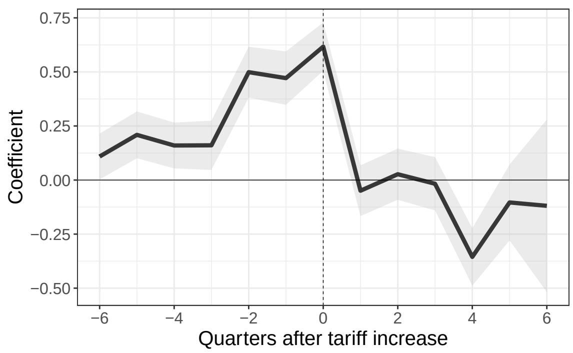


Note: The figures re-conduct the exercise in Figure 4 using log instead of asinh.

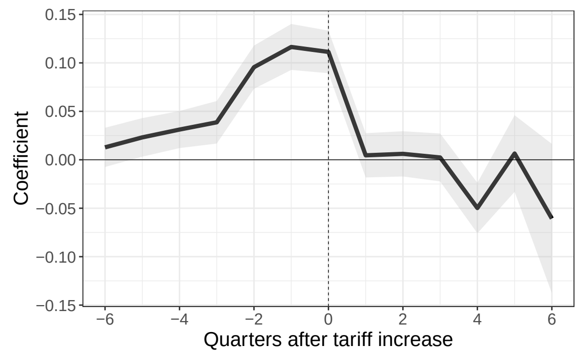
Description: Due to the nature of logarithms, observations used for graphs exclude zeros, hence abstracting from the extensive margin adjustment. Given our point estimates at $k = -1$, current imports, the number of partners, and inventories were 8.9, 5.7, and 2.7 log points higher, respectively, for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

Figure A3: Imports, number of partners, and inventories around a tariff increase (balanced panel instead of unbalanced panel).

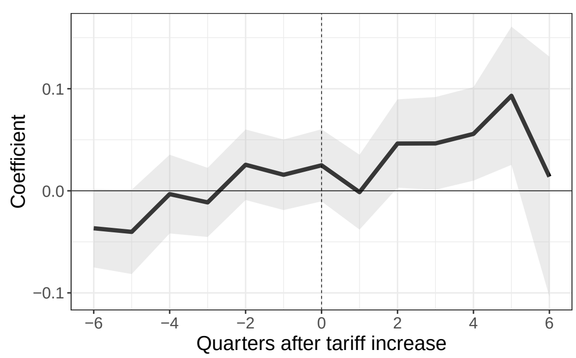
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



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



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

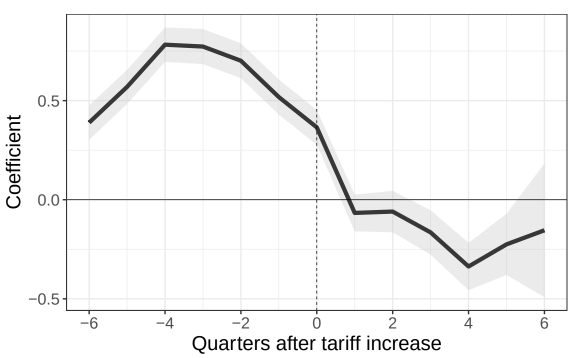


Note: The figures re-conduct the exercise in Figure 4 using a balanced panel.

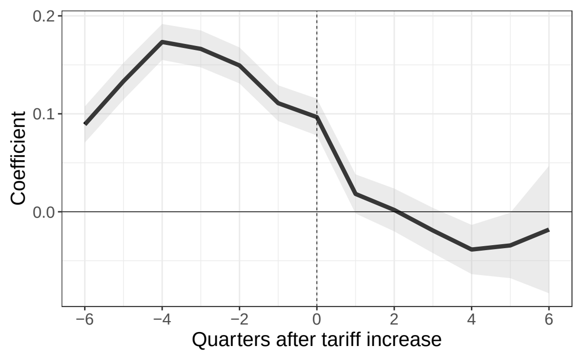
Description: We utilize an unbalanced panel as our baseline in Figure 4 to include as many firms as possible. This figure instead utilizes a balanced panel, where the set of firms is held constant across all time horizons. To construct the balanced panel, we restrict the sample to firms observed at every quarter–horizon cell and for which all dependent and control variables are non-missing. This yields 1,706 unique firms, compared to 5,776 in the unbalanced sample. The results robustly hold, ensuring that changes in panel composition across horizons do not drive the findings in Figure 4.

Figure A4: Imports, number of partners, and inventories around a tariff increase ($TI_{i,t}$ instead of $FTI_{i,t}$).

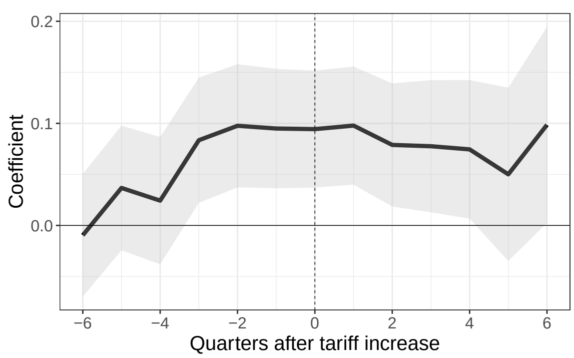
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



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



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

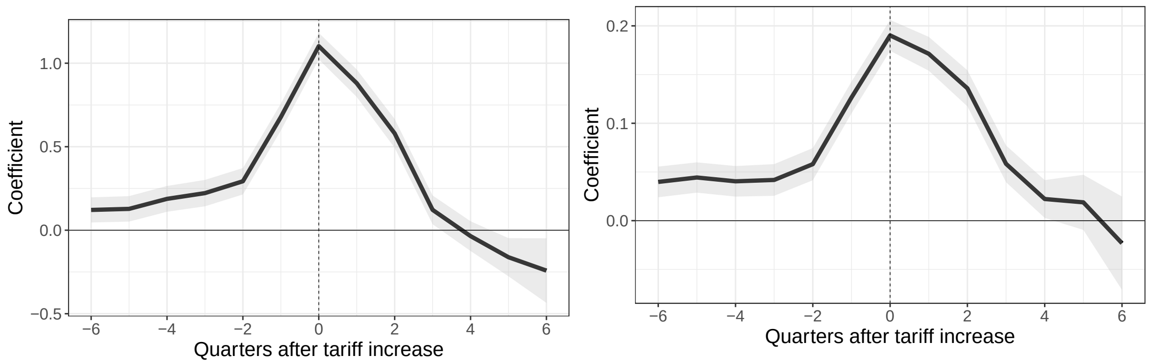


Note: The figures re-conduct the exercise in Figure 4 utilizing all tariff-increase events $TI_{i,t}$ instead of the first event $FTI_{i,t}$.

Remark: Due to the concerns about serial correlation of $TI_{i,t}$, we utilized $FTI_{i,t}$ in our main analysis.

Figure A5: *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: $\text{asinh}\left(|E_{i,t}|\right)$

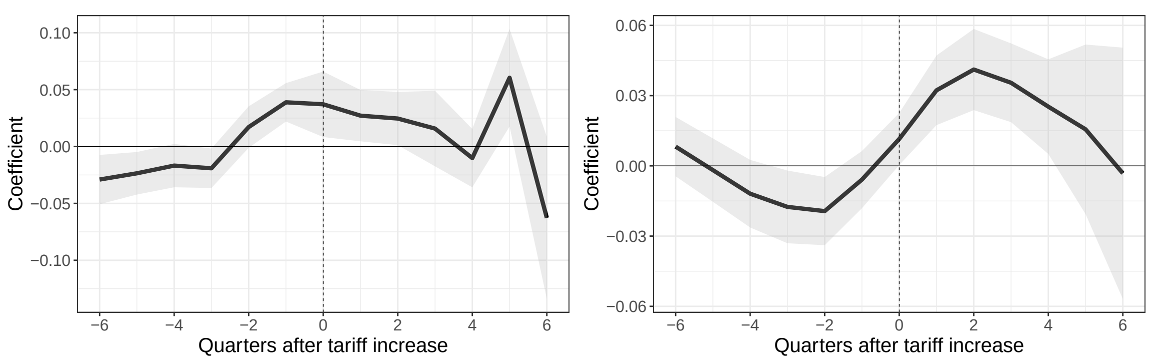


Note: The figures re-conduct the exercise in Panels (a) and (b) of Figure 4 utilizing the existing imports and the number of existing partners.

Description: 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. This figure demonstrates that that is not the case.

Figure A6: Number of current and existing partners and inventories around a tariff increase (Poisson Pseudo Maximum Likelihood (PPML) Specification).

(a) Number of current partners: $|C_{i,t}|$ (b) Number of existing partners: $|E_{i,t}|$



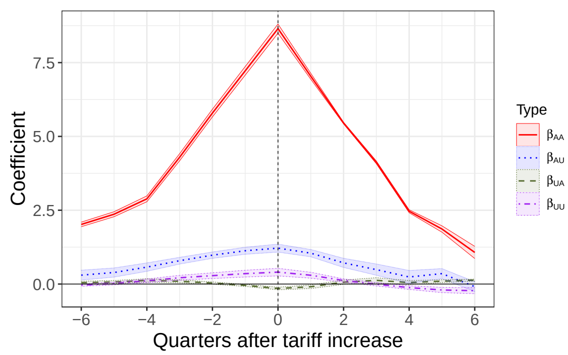
Note: For the number of current and existing partners, the figures are based on the specification below, which naturally accommodates the discrete nature of the dependent variable.

$$y_{i,t+k} = \exp\left(\beta_k FTI_{i,t} + \Gamma' X_{i,t} + \mu_i + \mu_t\right) \eta_{i,t,k}.$$

Description: $\beta_{-1} = 0.039$ in Panel (a) implies that firms experiencing a tariff increase ($FTI = 1$) have, on average, a 3.96% higher expected count of trading partners compared to untreated firms, holding all else constant. To interpret Panel (b), note that $E_{i,t} \equiv \bigcup_{k=-4,..-1} C_{i,t+k}$. Therefore, the increase in coefficients β_k from $k = -2$ through $k = 2$ suggests that firms were increasing their number of current partners from $k = -3$ to $k = -1$. Panel (b) mitigates the concern about the lumpiness of trade in Panel (a).

Figure A7: Intensive-margin adjustments (existing import volumes).

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



Note: The figures describe the estimated responses from Equation (3). Instead of *current* import volumes in Figure 6, we study the response of *existing* import volumes to mitigate the concerns regarding the lumpiness of imports.

Table A2: Import shares after the tariff (model vs. data).

		Data, 2019	Model	Difference
1	China	18.1%	19.1%	-1.0%
2	Rest of the world	19.3%	21.6%	-2.3%
3	Mexico	14.3%	15.0%	-0.8%
4	Canada	12.8%	15.0%	-2.2%
5	Japan	5.8%	7.1%	-1.3%
6	Germany	5.1%	6.7%	-1.6%
7	South Korea	3.1%	2.3%	0.8%
8	U.K.	2.5%	1.9%	0.7%
9	France	2.3%	1.5%	0.8%
10	India	2.3%	1.4%	0.9%
11	Italy	2.3%	1.4%	0.9%
12	Taiwan	2.2%	1.3%	0.9%
13	Ireland	2.5%	1.3%	1.2%
14	Vietnam	2.7%	1.2%	1.4%
15	Malaysia	1.6%	1.1%	0.6%
16	Switzerland	1.8%	1.0%	0.8%
17	Thailand	1.3%	0.9%	0.4%

Note: The table shows the import shares for the 17 largest U.S. importers in 2019, in the model and in the data, and the difference between the two. The model matches well the untargeted 2017 import shares.

B 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,

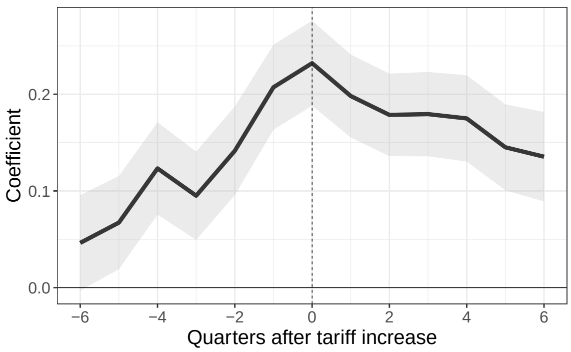
$$MS_i \equiv \max_{t'} \left\{ \log \left(\frac{1 + \tilde{\tau}_{i,t'}}{1 + \tilde{\tau}_{i,t_{i,pre}}} \right) \right\}, \text{ where } t_{i,pre} = (t-1), \text{ for } t \text{ such that } FTI_{i,t} = 1.$$

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.

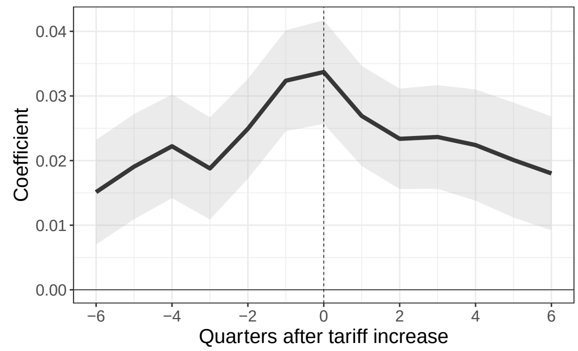
We re-run the exercise in Figure 4, utilizing $FTI_{i,t}MS_i$ instead of $FTI_{i,t}$. Figure B1 reports the results. To explain the results more concretely, suppose that a firm experiences a 25 percentage-point tariff increase ($MS_i = 0.223$). Then, in a quarter ($k = -1$) before the first tariff increase (t when $FTI_{i,t} = 1$), current imports, the number of partners, and inventories are 0.046, 0.007, and 0.19 asinh-unit points higher for treated firms compared to untreated ones.

Figure B1: Imports, number of partners, and inventories around a tariff increase (continuous measure).

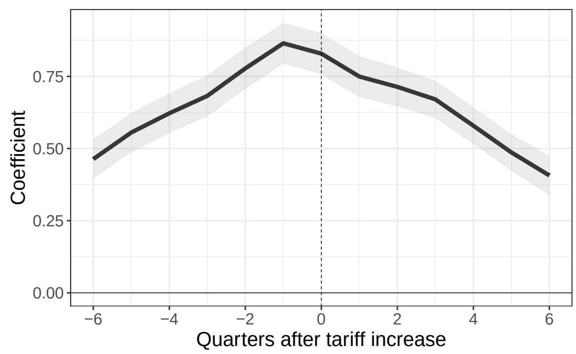
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



(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 $FTI_{i,t}$.

C Heterogeneity Across Firm Sizes

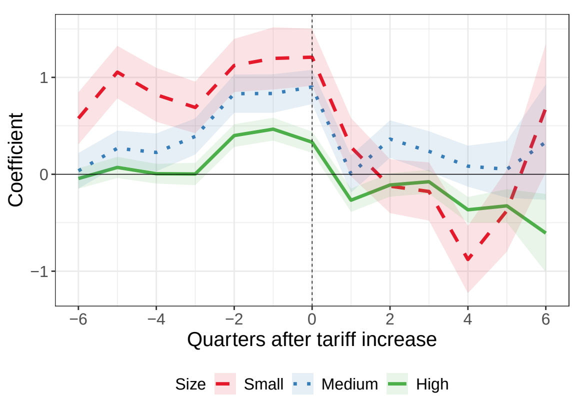
In this section, we study whether the main empirical results in Figure 4 vary across firm sizes. First, to assess the role of firm size, we assign firms to terciles (small, medium, and large) based on their average quarterly sales. (Since our sample consists of Compustat firms, even the "small" tercile is relatively large compared to the universe of US firms.) We then estimate:

$$y_{i,t+k} = \sum_{g\in\{S,M,L\}} \beta_k^g D_i^g FTI_{i,t} + \Gamma' X_{i,t} + \mu_i + \mu_t + \epsilon_{i,t,k}, \quad \text{(C1)}$$

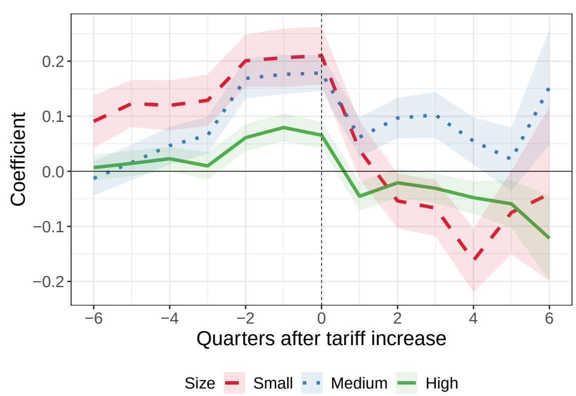
where D_i^g is a dummy variable denoting whether firm i belongs to tercile group g. Other terms are analogous to those in Equation (2). Figure C2 reports the estimation results for $\{\beta_k^g\}_{k=-6,\ldots,6}$ for each $g = S, M, L$. Regarding imports and the number of partners, Panels (a) and (b) demonstrate that the anticipatory stockpiling in both the intensive and extensive margins exists across firm size bins. For inventories, we only observe stockpiling for the first tercile (small). The possible reasons behind this result include the variation in domestic versus import share among inventories across firm sizes; however, we leave it for future research.

Figure C2: Imports, number of partners, and inventories around a tariff increase (Firm size interaction).

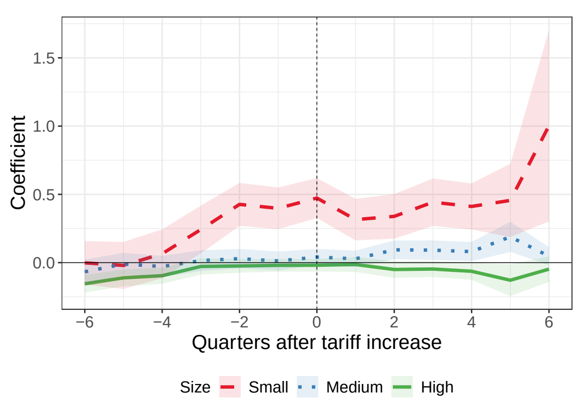
(a) Current imports: $\text{asinh}\left(\sum_{(h,c)\in C_{i,t}} x_{i,h,c,t}\right)$



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



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



Note: The figures reports the estimation results for Equation (C1).

D Magnitude of Import Adjustments: New versus Existing Country Partners

In Section 3.3, we uncovered that, in the anticipation of higher tariffs, firms adjust their imports along the within-product cross-country dimension: Both the extensive and intensive margin responses are significant for the affected product-unaffected country partners, reflected by β_{AU} (blue dotted lines in Figures 5 and 6). In this section, we assess the magnitude of the adjustments toward the affected product-unaffected country partners: Are firms ordering samples from new country sources in the anticipation of higher tariffs on another country, or are they engaging in a substantial reallocation of their import sourcing?

To address this question, we decompose the import volumes in the set of product-country partners of a firm around the time of a tariff increase. Consider firm i that imports product h. Let event time t denote the first time in which some country c supplying product h to firm i (i.e., $(h,c) \in E_{i,t}$) experiences a tariff increase. Specifically, $t = \min\{s : TI_{i,h,c,s} = 1 \text{ for some } c\}$. In our main empirical result (Figure 4), the anticipatory adjustments mainly occur at horizons $k = -2$ and $k = -1$. Therefore, we use $PA_{i,h,t} \equiv \bigcup_{k=-6,\dots,-3} \tilde{C}_{i,h,t+k}$ to denote the pre-adjustment country-partner set for firm i-product h for the periods $t-6$ through $t-3$. Note that $\tilde{C}_{i,h,s}$ represents the current country partners for firm-product (i,h) at time s. Then, we define $DA_{i,h,t} = \bigcup_{k=-2,-1} \tilde{C}_{i,h,t+k}$, which capture the country partner set during the adjustment periods $t-2$ and $t-1$.

For each firm-product pair (i,h) with event time t, we classify all country partners into four types based on their membership in $PA_{i,h,t}$ and $DA_{i,h,t}$:

(i) *Continuing*: $c \in PA_{i,h,t} \cap DA_{i,h,t}$ — countries present both before and during the adjustment period;

(ii) *Added*: $c \in DA_{i,h,t} \setminus PA_{i,h,t}$ — countries newly added during the adjustment period;

(iii) *Dropped*: $c \in PA_{i,h,t} \setminus DA_{i,h,t}$ — countries dropped during the adjustment period;

(iv) *Neither*: $c \notin PA_{i,h,t} \cup DA_{i,h,t}$ — countries absent from both sets.

Within each type, we further distinguish between *tariff-affected* countries—those for which the tariff on (h, c) increased at event time t—and *unaffected* countries. The Added-Unaffected category is of particular interest, as it captures the within-product cross-country substitution documented in the β_{AU} estimates.

To quantify the magnitude of adjustments for each country group (e.g., Added-Unaffected), we define the following metric. For each firm-product-country group (i, h, G) with event time t:

$$(\text{Country-Group Import Share})_{i,h,G} \equiv \frac{\sum_{c\in G}\left(\sum_{s\in\{t-2,t-1\}} x_{i,h,c,s}\right)\Big/2}{\sum\limits_{c'\in PA_{i,h,t}}\left(\sum\limits_{s\in\{t-6,\dots t-3\}} x_{i,h,c',s}\right)\Big/4} \tag{D2}$$

This measures, within firm-product (i, h), the average quarterly imports from country group G at $t-2$ and $t-1$ relative to the quarterly average imports of firm i for the product h from $t-6$ to $t-3$. Note that the above measure captures within-product adjustments.

Table D1: Import shares by country-group types (Unit: %).

Type	Tariff at t	Nobs.	Q1	Q2 (Median)	Q3
Added	Affected	33,883	12.3	89.8	624.8
	Unaffected	9,418	1.9	15.0	114.9
Continuing	Affected	27,340	30.5	95.4	249.0
	Unaffected	10,404	11.6	48.2	126.0

Notes: The table reports the first, second, and third quartiles for the measure from Equation (D2). Since small denominators in Equation (D2) can produce extreme values, the mean is not informative; therefore, for brevity, we do not report it.

Table D1 reports summary statistics for the import shares defined in Equation (D2). For the Added-Unaffected country group, we observe that, in the median, a firm imported 15.0% of its average previous quarterly imports during the adjustment periods. This implies that the addition to the new country is quantitatively smaller than other country categories, but still significant. Although we cannot definitively conclude whether the newly added countries are from firms ordering samples to explore the potential partnership or substantially reallocating their sourcing, we interpret the results as the new country partners having a supplementary sourcing role.

Despite the terminology "add" and "drop," the extensive margin adjustment of a firm reflects both the timing of shipments and the selection of import partners. Since import flows are lumpy—the median firm in our sample importing in only 20 of the 32 quarters in our sample—"adding" a partner means either choosing the timing of import or adding that partner to the set of suppliers. In Table D1, a median import share of 89.8% of the Added-Affected country group likely reflects the firm's choice of shipment timing instead of a new relationship with a country that is soon to be affected by higher tariffs.

E Model Details

E.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*, $T_j\,(\tau_j w_j)^{-\theta}$.

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. □

(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},

$$c\left(\mathcal{J}_\omega(n_{\text{low}})\right) n_{\text{low}} + |\mathcal{J}_\omega(n_{\text{low}})| wf \leq c\left(\mathcal{J}_\omega(n_{\text{high}})\right) n_{\text{low}} + |\mathcal{J}_\omega(n_{\text{high}})| wf. \tag{E1}$$

Likewise, for n_{high},

$$c\left(\mathcal{J}_\omega(n_{\text{high}})\right) n_{\text{high}} + |\mathcal{J}_\omega(n_{\text{high}})| wf \leq c\left(\mathcal{J}_\omega(n_{\text{low}})\right) n_{\text{high}} + |\mathcal{J}_\omega(n_{\text{low}})| wf. \tag{E2}$$

Subtracting Equation (E2) from Equation (E1) yields,

$$\left(c\left(\mathcal{J}_\omega(n_{\text{high}})\right) - c\left(\mathcal{J}_\omega(n_{\text{low}})\right)\right)(n_{\text{high}} - n_{\text{low}}) \leq 0. \tag{E3}$$

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 $\mathcal{J}_\omega(n_{\text{low}}) \subset \mathcal{J}_\omega(n_{\text{high}})$. □

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). □

E.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.

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

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