Rising Import Tariffs, Falling Export Growth: When Modern Supply Chains Meet Old-Style Protectionism*

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Abstract

We examine the impacts of the 2018-2019 U.S. import tariff increases on U.S. export growth through the lens of supply chain linkages. Using 2016 confidential firm-trade linked data, we document the implied incidence and scope of new import tariffs. Firms that eventually faced tariff increases on their imports accounted for 84% of all exports and they represent 65% of manufacturing employment. For all affected firms, the implied cost is $900 per worker in new duties. To estimate the effect on U.S. export growth, we construct product-level measures of import tariff exposure of U.S. exports from the underlying firm micro data. More exposed products experienced 2 percentage point lower growth relative to products with no exposure. The decline in exports is equivalent to an *ad valorem* tariff on U.S. exports of almost 2% for the typical product and almost 4% for products with higher than average exposure.

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1 Introduction

From 2018 through 2019, the United States imposed a series of wide-ranging increases in import tariffs. By August of 2019, $290 billion of U.S. imports - about 12% of the total - were subject to an average tariff increase of 24 percentage points.[1] The scale of these tariffs against specific products and countries, and the subsequent retaliation, has drawn comparisons to the Depression-era tariff wars of the 1930s.[2] However, the structure of world trade has been substantially transformed since then, following reductions in trade costs and new communications technology (Baldwin, 2016). Global supply chains are a pervasive feature of world trade (Hummels, Ishii and Yi, 2001; Johnson and Noguera, 2017) and the resulting production networks are increasingly complex and fragmented across multiple countries (Antrás, Fort and Tintlenot, 2017; Fort, 2017). Supply chains are a potentially important channel of transmitting the impact of import tariffs to exports because they can amplify shocks to demand and trade costs and demand within firms and across locations (Almunia, Antrás, Lopez-Rodriguez and Morales, 2018; Boehm, Flaaen and Pandalai-Nayar, 2019; Yi, 2003). In this paper, we estimate and quantify the supply chain spillovers to export growth of newly imposed U.S. import tariffs.

The notable weakness in aggregate U.S. exports from mid-2018 through late 2019, especially in products not facing retaliatory export tariffs,underlines the importance of quantifying the supply chain spillovers of import tariffs. Aggregate quarterly U.S. export growth (year-on-year) between 2018Q4 and 2019Q3 was flat on average and turned negative in 2019Q2 and 2019Q3 versus an average of 8 percent a year earlier. The drop in exports extends beyond the major products or countries that were the focus of 2018-2019 trade tensions: export growth remains negative in 2019Q2 and 2019Q3 even after excluding the contribution of exports to China or products facing retaliation.[3] Figure 1 shows the dip in average country by product export growth is large, even when we progressively exclude products that will ultimately face foreign retaliation, all remaining exports to China and NAFTA countries, and finally all remaining trade with Asia and Europe.

Leveraging the detail in confidential U.S. firm-trade linked data, this paper demonstrates that U.S. import tariffs restrained U.S. exports. We employ firm-trade transactions data to measure the incidence of the tariffs by firm characteristics, e.g. employment, industry, export

[1]The dollar value of tariffed imports is calculated on an annual basis using 2017 data, and the average tariff increase is weighted using the same data. For a timeline of tariffs on U.S. imports and foreign retaliatory export tariffs, see Bown and Kolb (2019).

[2]Irwin (1998) documents that the Smoot-Hawley tariffs increased import duties by about 20% on average and set off a wave of worldwide protectionism.

[3]A similar decline in growth appears in country by product averages.

participation. We then identify the set of exporters that are also importing products in the same category on which tariffs are ultimately imposed in 2018-2019, constructing measures of import tariff exposure for disaggregated 6-digit export sectors. Combined with official monthly public-use export data from 2017 through 2019Q3, we estimate the supply chain spillovers of import tariffs. Our results demonstrate that spillovers from new import tariffs dampened U.S. export growth in recent quarters by 2 percentage points for the typical affected export product, even after controlling for the effects of foreign-imposed retaliatory tariffs.

Our findings are consistent with U.S. export growth weakening in response to newly imposed import tariffs that impacted firms' supply chain networks. Faced with higher import tariffs, firms might absorb the input cost increase, reduce imports of affected products, find new domestic and foreign input sources, or exit export markets altogether – all changes that potentially impose large fixed and variable costs on the firm. U.S. tariff increases were disproportionately applied to intermediate goods that are typically inputs in production (Bown and Zhang, 2019). Lovely and Liang (2018) document that the Section 301 import tariffs taxed inputs for U.S. businesses via supply chain trade. Bown (2019a) notes that governments have traditionally avoided tariffs on intermediate goods for this reason. Amiti, Redding and Weinstein (2019) estimate that $165 billion in trade may have been lost when firms redirected trade in their supply chains to avoid tariffs.

The import tariffs may have benefited some industries, but numerous anecdotes from firms line up with the negative impacts we ultimately find in the data. For example, in U.S. Senate testimony, the CEO of Learning Resources wrote: "We have business reasons for the assignment of products to specific factories, whether in the United States or in other countries. [...] We have also made repeated attempts to develop a U.S.-based supply chain but cannot do so on any basis, even inefficiently. We have no known realistic alternative to our current supply chain."(U.S. Committee on Finance, 2018). Caldara, Iacoviello, Molligo, Prestipino and Raffo (2019) find that when firms discussed tariffs and policy uncertainty on earnings calls in recent years, the primary concern cited was their supply chains. Another example is documented in the Federal Reserve Beige Book (November 27, 2019) "[...] firms have reported tariff impacts on sales, either in terms of pricing or in terms of supply chain disruptions slowing their product supply."

The first part of the paper documents tariff incidence within and across firms by linking the publicly available data on tariff lines to data on the operations of firms importing or exporting in 2016 those products that would ultimately receive tariffs.[4] About 33% of all U.S. importers in 2016 traded in product categories that would be exposed to the new tariffs in 2018-2019, and these importers employed 32% of all private, non-farm employees. As for retaliatory foreign tariffs, about 19% of U.S. exporters were directly affected, employing 23% of all private, non-farm employees. The typical affected firm also had a non-trivial share of trade value that would be impacted: on average, 46% of an affected importer's purchases were subject to U.S. import tariffs, and 33% of an affected exporter's sales faced foreign export tariffs.

Next, we document important sources of heterogeneity across firms hit by new import and export tariff increases. It is well established that importers and exporters tend to exhibit higher wages, sales, and employment levels compared to firms that do not participate in international markets. We find that U.S. importers facing new tariffs are even larger - about twice as large in terms of employment compared to the average importing firm and about nine times larger than the average firm. This implies that U.S. import tariffs hit the very largest trading firms in the economy. Similarly, we find that U.S. exporting firms facing retaliatory tariffs are over three times larger than the average exporting firm. In terms of employment, manufacturing and retail sectors are hit the hardest - 65% of employment in manufacturing and 60% of employment in retail is at firms facing higher import tariffs. The tariff costs are non-trivial for affected firms: assuming the tariffs remained in place for a full year and firms did not adjust sourcing strategies, the implied duties paid were $900 per worker overall and about $1,600 per worker in the manufacturing sector.

Interconnections between a firm's import and export activities affect a large fraction of total U.S. trade flows.[5] We find that, based on 2016 trade flows, U.S. exporters exposed to import tariffs in the same broad product category as their exports, i.e. products mostly likely to be part of a supply chain, accounted for 43% of total U.S. exports and 24% of the total number of U.S. exporters. If we use a broader measure, considering U.S. exporters exposed to any import tariff, the share of affected export value nearly doubles, to 84%.

We then estimate the impact of increases in U.S. import tariffs on U.S. export growth in a difference-in-differences framework. Using publicly available trade data from 2016 through June 2019, we regress the 12-month change in exports at the HS6-country level on our sector-specific import tariff exposure measures, controlling for potential retaliatory tariffs

[4] Our exposure measures leverage trade patterns well before the 2016 presidential election outcome was known and prior to the anticipation of new tariffs throughout 2017.

[5] The top 1 percent of U.S. traders account for more than 80 percent of total U.S. trade (Bernard, Jensen, Redding and Schott, 2018).

that those exports may have faced.[6] We find that average bilateral export growth at the country-product level was lower in sectors with a higher share of exporters hit by import tariffs. We further trace out the timing of these effects by interacting the import tariff exposure measure with quarterly indicators. We find that in 2019 Q3, the typical affected export product had a growth rate of about 2 percentage points lower than an unaffected sector using our baseline measure of exposure. This is equivalent to an *ad valorem* tariff on U.S. exports of almost 2% for the average country-product export in our baseline. For sectors with exposure just one standard deviation above the mean, the *ad valorem* equivalent tariff is almost 4%, which is close to the average, statutory MFN tariff rates imposed on trade partners by the U.S. and European Union.

This paper makes three main contributions. First, to our knowledge we are the only paper to use linked firm-trade transactions data to assess the incidence of the 2018-2019 tariffs on firms, jobs, economic sectors, and most importantly, export growth via our measure of supply chain networks. We thus broaden our understanding of the impacts of recent tit-for-tat tariff wars in an era of outsourcing and global production fragmentation. Our contribution is complementary to several recent papers that study the incidence of the 2018-2019 tariffs.[7] Flaaen, Hortaçsu and Tintlenot (2019) estimate that tariff increases caused washing machine prices to rise by 12 percent. Amiti, Redding and Weinstein (2019) and Fajgelbaum, Goldberg, Kennedy and Khandelwal (2020) study the direct impacts of the 2018-2019 U.S. import tariff increases on U.S. import prices and the direct impact of the foreign retaliatory tariff increases on U.S. export prices. Cavallo, Gopinath, Neiman and Tang (2019) also examine the pass-through of U.S. import tariff increases on to U.S. importers and retailers using firm-level data. These studies do not consider spillover effects of increases in U.S. import tariffs on U.S. exports through supply chains. Our estimates suggest accounting for supply chain linkages would likely increase the welfare costs of the 2018-2019 U.S. tariff increases.

Second, our results demonstrate that firms' reliance on global supply chains can complicate the application of traditional mercantilism - trade policy that aims to improve the

[6]HS6 is the most disaggregated product code that is consistent across countries. The retaliatory export tariff data is linked to U.S. export flows at the HS6 level.

[7]There are a few studies examining non-trade outcomes. Waugh (2019) studies the impact of Chinese retaliatory tariffs in 2018 on U.S. consumption to find that counties more exposed to Chinese tariffs experienced 2.5 percentage points lower growth in auto sales compared to counties with lower exposure. Blanchard, Bown and Chor (2019) study the impact of a county's exposure to U.S.-imposed import tariffs and foreign retaliatory export tariffs on the county's Republican vote share in the 2018 U.S. House elections. Flaaen and Pierce (2019) consider the effect of higher input costs from the U.S. tariffs using aggregated input-output tables, but focus on domestic outcomes in the U.S. manufacturing sector.

balance of trade by reducing imports and promoting exports. In a counterfactual exercise, we find the reduction in export growth would have been 60% smaller if the tariffed products were not part of tightly linked supply chains within firms. Blanchard, Bown and Johnson (2016) studied the policy trade-offs in the presence of global supply chains. They show that global supply chains, which increase the foreign content embodied in domestic final goods, should lower a government's incentive to impose tariffs on inputs. Our evidence provides empirical motivation for that incentive, but highlights how designing the optimal tariff policy may be difficult in practice. For example, the first phase of import tariff increases on Chinese products under Section 301 were intended to target specific Chinese products where U.S. consumers and businesses had alternative country sourcing options (U.S. Committee on Finance, 2018). But our findings suggest that firms were unable, at least in the short-term, to reorient sourcing strategies, perhaps because buyer-seller relationships embody relationship specific investments and capital cannot easily be replaced by alternative foreign and domestic sourcing.[8]

Finally, we make a novel methodological contribution. Confidential firm-transaction linked data is available with much longer processing lags (typically two years or more in the U.S.) that prohibits contemporaneous analyses of firm-level impacts of the 2018-2019 tariffs. But the trading status of large firms is persistent. Moreover, even if individual firms enter and exit international markets, moments constructed from the cross-section of firm-level data should be representative of the population of trading firms at an industry level, which provides a sufficient basis for constructing our import tariff exposure measure capturing supply chain linkages. We show that nearly contemporaneous, public-use monthly trade data can be combined with data moments derived from the rich, underlying detail in firm-level micro data to evaluate policy changes. Our approach could be extended to better inform the policy making process in international trade and other economic applications.

The rest of the paper is organized as follows. Section 2 describes our data sources and provides summary statistics on U.S. importers facing import tariffs and U.S. exporters facing retaliatory foreign export tariffs. We describe the empirical approach in Section 3 and present the results in Section 4. Section 5 concludes.

[8]The evidence in Monarch (2016) indicates that even when choosing among different suppliers, switching costs are very high for buyer-supplier relationships in U.S.-China trade.

2 Measuring the Impact of Tariffs with Firm Data

We begin by linking confidential micro data on U.S. trading firms to publicly available lists of product codes subject to newly imposed import and export tariffs. The micro data consists of both trade data - value, quantity, and HS product code for every firm-level trade transaction; and business data - age, employment, payroll, sector. Since the import and export tariff lists and the trade data use the HS classification system, it is possible to determine which firms are being directly affected by import and export tariffs.

2.1 Data Sources

2.1.1 Tariff Data

We construct a database of monthly U.S. import tariffs at the HS 8-digit level from using publicly available tariff schedules published by the U.S. International Trade Commission. For all tariff increases since the beginning of 2018 through August 2019, we keep track of the HS code, the old and new tariff rate, and the date of the change.[9] Import tariffs for affected products increased by an average of about 24 percentage points over 2018-2019.[10] We also construct a database of retaliatory foreign export tariffs at the HS6 level using the detailed timeline from Bown and Zhang (2019). The multiple waves of U.S. tariff increases on different countries and products were often followed by retaliation against U.S. exporters by the affected countries. Export tariffs for affected products increased by an average of about 20 percentage points over 2018-2019.[11]

One key feature of the U.S. tariff increases is that products exposed to tariffs are mainly intermediate goods, rather than consumer or capital goods. Intermediates represent 56.8% of the total value of goods receiving tariffs, compared to 27.3% for capital goods and 15.6% for consumption goods.[12]

[9] Fajgelbaum, Goldberg, Kennedy and Khandelwal (2020) provides the timeline of the waves of tariff increases and the affected products.

[10] This calculation is the value-weighted tariff increase using 2017 annual data.

[11] We do not include either the September 1, 2019 U.S. tariff increases or the subsequent retaliation.

[12] This breakdown uses Broad Economic Category codes for 2017 imports at an annual basis. Bown (2019b) shows that for the Section 301 tariffs imposed on nearly half of Chinese imports, 82% of all intermediate goods imported from China had received tariffs by May 2019. In comparison, the share of new tariffs on capital and final goods were 38% and 29%, respectively.

2.1.2 Firm-Level Trade Data

The Longitudinal Firm Trade Transactions Database (LFTTD) contains transaction-level detail on the universe of imported shipments valued over US$2,000 and exported shipments valued over US$2,500 of merchandise goods. The LFTTD enables us to identify U.S. exporters and importers in 2016 (Bernard, Jensen and Schott, 2009). We link the U.S. import tariff and foreign retaliatory export tariffs to the 2016 LFTTD at the country-product level. We use the more detailed 8 digit tariff line codes to match firms to the 2016 import transactions directly.

Although tariff increases took place in 2018 and 2019, we create the import tariff exposure measure using 2016 trade data for two reasons. First, using pre-tariff data minimizes concerns that our measure may be contaminated by any anticipatory or policy uncertainty induced factors influencing firms' decisions in advance of tariffs actually being imposed. Using 2016 predates the outcomes of the U.S. presidential election for most of that year or any anticipatory affects in 2017. Second, contemporaneous exposure measures may reflect firm responses to the trade policy changes, which are endogenous. These include exit from sourcing in some foreign markets and entry into others induced by the policy. Importing and exporting are also very persistent activities, such that firms we identify as being affected by the tariffs using 2016 data are also very likely to be affected in the years tariffs are actually enacted. This means that the cross-section, population level statistics of 2016 firm characteristics should be representative at the aggregate and industry-aggregate level of import and export *exposure* to future tariffs, even if firms responded to the policy change in 2018, for instance, by stopping importing from a source country.

2.1.3 Firm Characteristics

The Longitudinal Business Database (LBD) tracks U.S. establishments in the non-farm, private sector employer universe over time (Jarmin and Miranda, 2002).[13] It contains information on every establishment's firm affiliation, year of birth (used to construct firm age), industrial activity at six-digit NAICS level, employment, and payroll. We link the LBD to the LFTTD using firm-level identifiers. The most recent available year of the LBD is 2016.

[13]LBD excludes operations with no statutory employees, e.g. self-employed, farms (but not agri-business), and the public sector.

2.2 Characteristics of Affected Importers and Exporters

Table 1 presents a broad picture of how U.S. importers and exporters, as identified in 2016, were affected by the 2018-2019 tariffs. Taking all of the newly imposed U.S. tariffs in 2018 through August 2019, affected imports represented 11.2% of total imports (about $247 billion) and close to one-third of all importing firms. These firms employed 32% of all U.S. non-farm private sector workers. Among affected importers, about 46.5% of their import value on average was subject to the tariff increases. As for retaliatory export tariffs imposed by foreign countries, 7.9% of U.S. exports (about $115 billion) and 18.7% of all exporting firms faced tariffs. These firms employed about 23% of all non-farm private sector employees.[14] The average exporter facing tariffs had one-third of its 2016 exports, by value, subject to foreign tariff increases.

Panel A in Table 2 uses the linked firm-trade data to examine the characteristics of firms, as of 2016, that would face U.S. import tariffs in the 2018-2019 period. Importing firms facing tariffs are at the large end of the firm size distribution. The average importing firm facing tariffs was about twice as large as the average importer, both in terms of employment (430 vs. 212 workers) and the number of establishments (9 vs. 5). Comparing the last two columns illustrates the well-known fact that importers exhibit a significant size premium relative to the average firm, indicating that U.S. import tariffs overwhelmingly impacted the largest firms in the U.S. economy. The age profile of affected importers is very similar to overall importers, and the typical annual pay for workers at firms facing import tariffs is also very similar, about $58,000 per worker.

We carry out a similar decomposition for U.S. firms facing retaliatory tariffs from foreign countries. Panel B in Table 2 shows that these firms are about two to three times as large as the average exporter, using employment or the number of plants, respectively. Retaliatory tariffs are thus also being faced by the largest firms in the U.S. economy. The impacted exporters tend to have higher average earnings and are also older compared to the average exporter.

2.3 Characteristics of Affected Sectors

Linking the trade data to firm-level characteristics also enables an examination of the most affected sectors and workers. We identify which firms in 2016 are trading the products that

[14] Since many firms both import and export, this share is not mutually exclusive from the share of workers affected by import tariffs.

face tariffs in 2018-2019 and aggregate up to broad production sectors, using firm sector and employment information.

We report summary statistics on the share of workers impacted by the increase in U.S. tariffs, and average duties paid per worker overall and across four broad sectors (manufacturing, wholesale, retail, and other).[15] Table 3 displays the share of U.S. workers employed at affected firms. In some of the sectors most affected by U.S. import tariffs, such as manufacturing and retail, upwards of 60% of workers are employed at firms facing tariff increases. This is in contrast to sectors included in "Other" where relatively few workers are employed at affected firms, including firms providing services as well as in agriculture.[16] In the second column, we observe similar sectoral rankings in the share of workers that were most exposed to increases in foreign retaliatory export tariffs.

The third column of Table 3 shows the implied average duty per worker by sector. This measures the total tariff bill of all affected firms in a sector divided by the number of workers in that sector.[17] To the extent that these imputed tariffs can be interpreted as a direct increase in costs, manufacturing firms paid about $1,600 in tariffs for each of their employed workers, while wholesale firms paid closer to $5,000 per worker.[18] The typical affected firm paid about $900 per worker in tariffs. This figure is large in absolute terms, but also in relative comparisons. Using payroll (earnings) per worker from Table 2, the implied duties were equivalent to 1.5% of the average wage bill.

2.4 Import Tariffs and U.S. Exporters

The broad coverage of intermediate goods subject to the 2018 and early 2019 import tariffs means that firm-level supply chains were more likely to be directly affected relative to consumer products. The official Federal Register notice of tariff increases in April 2018

[15]Manufacturing is defined as all sectors within NAICS 31-33; Wholesale is defined as all sectors within NAICS 42; Retail is defined as all sectors within NAICS 44 and 45; and Other includes all other sectors except Public Administration 92.

[16]Some reports indicate that individual farmers may be negatively affected by new tariffs (see Bunge et al. (2019), for example), but the employment data we use from the LBD covers only non-farm employees.

[17]Total tariffs paid are imputed based on total imported value of tariffed products in 2016 times the respective tariff increase as of April 2019. The calculation assumes that the import tariff burden is borne as an additional cost for U.S. firms consistent with evidence of complete pass-through of the tariffs onto American firms (Amiti, Redding and Weinstein, 2019; Fajgelbaum, Goldberg, Kennedy and Khandelwal, 2020; Cavallo, Gopinath, Neiman and Tang, 2019).

[18]Although a large fraction of retail workers were employed at affected firms, the overall per-worker burden on these firms was fairly small because tariffs fell mainly on imported intermediates rather than consumer goods.

indicates that tariffed products were chosen by "selecting products...with lower consumer impact" (Federal Register, April 6, 2018).

Linking import and export activity at the firm level reveals the extent to which firm's supply chain operations were potentially impacted. The last column in Table 4 shows that 84% of total U.S. exports were by firms facing at least one import tariff increase. The share of affected firms is smaller, 24%, but these exporters tend to be larger than average. It is implausible to assume that all of each firm's exports are affected by import tariffs, especially if the affected products are a small share of an exporter's import basket. For this reason, we perform a similar exercise, but only consider a firm's exports that are in the same HS6 product category facing a new import tariff. Column (1) shows that even for these "narrrow" measures, close to one-third of U.S. exports (10% of U.S. exporters) are potentially affected by U.S. import tariffs. The "broad" measure captures an overall increase in input costs at the firm level, while the "narrow" measure more closely captures supply chain linkages due to foreign sourcing or offshoring.[19]

A middle ground between these two definitions is to consider exporters affected only if they face new import tariffs in a product in the same HS4 category as their HS6 product exports. Hummels, Jørgensen, Munch and Xiang (2014) employ this definition to measure firm-level offshoring. The closer the inputs are to the final output product classification, the more likely it is that the U.S. firm could have produced these inputs. Thus, this definition captures the exposure to U.S.-imposed import tariffs on inputs representing integrated supply chains. Using this approach, as can be seen in Column (2) of Table 4, implies that 43% of U.S. exports are subject to the new import tariffs within related product groups, representing 13% of all U.S. exporters.

The linkage between imports and exports that the data reveals provides a straightforward and intuitive way to capture the supply chain sensitivity of exports to import tariffs. This is the motivation for our next exercise: constructing tariff exposure measures at the 6-digit product level of exports.

3 Empirical Framework

We develop a concept of the import tariff exposure for U.S. exporters using the cross-section of all U.S. trading firms in 2016. We first describe the measures and then link them to an

[19]Hummels, Munch and Xiang (2018) define three elements of offshoring as involving (i) intermediate inputs used for production; (ii) imported inputs; and (iii) inputs that could have been produced internally within the same firm.

empirical estimating equation.

3.1 Tariff Exposure

Building on the data described above, we construct a measure of exposure by 6 digit export product codes, conventionally known as the HS6 sub-heading level.[20]

As described in the data section, many exporters are also importers. We start by counting the number of unique exporters in each HS6 product, p, regardless of their import participation. We then count the subset of these exporters that are importing a product in their supply chain subject to a new tariff in 2018-2019. In our preferred measure, we use the 4 digit heading, HS4, to define the set of imports that are part of a firm's export supply chain.[21] Let H be the set of products in an HS4 heading. For each exported HS6 product $p \in H$, we count the total number of exporters in 2016 that import at least one tariffed product in H.

The share of exporters hit by an import tariff in their supply chain forms our baseline measure of import tariff exposure (ITE_p),

$$ITE_p = \frac{ExporterNum_{p,2016}^{T,SameHS4}}{ExporterNum_{p,2016}} \tag{1}$$

where $ExporterNum_{p,2016}^{T,SameHS4}$ is the total number of exporters in 2016 selling HS6 product p that are hit by new import tariffs in their supply chain. The denominator, $ExporterNum_{p,2016}$, is the total number of exporters selling HS6 product p in 2016. This measure closely captures supply chain linkages due to the similarity of exported and imported products. Appendix A lays out a conceptual model of how this measure is consistent with accounting for heterogeneous effects of the tariffs on firm output across firms of different sizes.

We also construct two additional exposure measures: a broad and a narrow measure of import tariff exposure. The broad measure counts an exporting firm as exposed if any of its 2016 imported products are subject to new tariffs in 2018-2019. Specifically,

$$ITE_p^{Broad} = \frac{ExporterNum_{p,2016}^{T,All}}{ExporterNum_{p,2016}} \tag{2}$$

[20]This is not the finest level of detail, but we use HS6 codes because they can be consistently concorded over time for imports and exports and matched to export tariff retaliation reported at the same level. There is a revision to Harmonized System nomenclature in 2017 that affects hundreds of 6 digit codes and thousands of 8 and 10 codes at finer detail.

[21]There are about 1,000 HS4 level heading codes.

where $ExporterNum_{p,2016}^{T,All}$ is the total number of exporters in 2016 selling a HS6 product p with at least one of its imported product categories subject to tariff increases in 2018-2019. The denominator is the same as in equation (1). Thus, ITE_p^{Broad} measures the overall exposure of exporters of a HS6 product to U.S. import tariffs. In this measure, linkages between imported tariffed products and exports are potentially weaker and not necessarily related to supply chains, which we will test below.

The narrow measure of import tariff exposure, in contrast, measures exposure as imports of tariffed products in the exact same HS6 product as the firm's exports. This is defined as,

$$ITE_p^{Narrow} = \frac{ExporterNum_{p,2016}^{T,SameHS6}}{ExporterNum_{p,2016}} \tag{3}$$

where $ExporterNum_{p,2016}^{T,SameHS6}$ measures the total number of exporters in 2016 selling a HS6 product p that also import products in p subject to tariff increases in 2018-2019. This is more restrictive than the baseline measure and may capture very tightly linked products in a firm's supply chain.

An important property of all three measures is that they share the same denominator and the numerators are nested subsets. That is, for any HS6 product p, we know exposure measures must satisfy the inequality

$$ITE_p^{Narrow} \leq ITE_p \leq ITE_p^{Broad}.$$

We will use this property to examine whether the strength of linkages within the supply chain, which is increasing in the narrowness of the measure, are more or less important to explain weaker export growth.

We focus on our count-based ITE measures because exposure of firms that export a product hit by import tariffs in similar products is likely more robust to a variety of measurement error problems that arise with alternatives. A high exposure share demonstrates the existence of supply chains and that the firm is importing a product it could feasibly produce internally. Using this type of share at the product p - instead of a value-based share - level better captures how representative the exposure is for typical firms, even if the value of affected exports is heterogeneous.[22] To see this, consider an alternative measure that uses the share of export value in 2016 affected by tariffs in 2018 forward. There are several sources of potential measurement error. First, value weighting could place undue influence to only

[22]For example, many firms may not import directly under their own account even though their supply chain is global.

a few firms in the 2016 firm-level data, some of which may be extreme outliers. Second, a firm's idiosyncratic response to the trade friction need not be proportional to its export value, e.g. firms small value weights respond more and vice versa. Third, a firm's export destination in one year may be replaced by an alternative buyer in an another country, which would receive zero value weight even though the supply chain friction remained.[23]

We do construct a cost-based exposure measure that considers the implied dollar value increase in duties paid, defined as

$$ITE_{pc}^{Cost} = \frac{ImpliedDuties_{pc,2016}^{T,All}}{ImportValue_{pc,2016}} \tag{4}$$

where $ImpliedDuties_{pc,2016}^{T,All}$ measures the implied value of new duties borne by exporters buying a product p from source country c (tariff rate increase $\times$ value of imports in 2016)[24]; $ImportValue_{pc,2016}$ is the total value of imports in a HS6 product and country pair in 2016. ITE_{pc}^{Cost} is a direct measure of increases in input costs as implied by increases in U.S. import tariffs. The cost measure is interesting in its own right, but it measures only one specific channel through which import tariffs could impact exports - direct increases in input costs that may not fully reflect a variety of other policy induced fixed and switching costs within the supply chain.

Table 5 provides summary statistics of our various exposure measures. The ITE_p measure for the average HS6 product is 0.10, with a standard deviation of 0.13. For the average HS6 exported product, therefore, 10% of exporters import products that (a) face import tariff increases in 2018-2019 and (b) are in the same HS4 category as that exported product. The ITE_p^{Broad} measure has a mean of 0.56 whereas the ITE_p^{Narrow} measure has a mean of 0.04. The cost measure, ITE_{pc}^{Cost}, has a mean of 0.02, which means the implied increase in costs from U.S. import tariffs is around 2% of imports for the average product-country pair.

3.2 Estimating Equation

We now turn to mapping the HS6 sector level measures of supply chain import tariff exposure into our estimation equation.

Our empirical approach combines product level exposure measures with public-use data on monthly U.S. exports at the country and HS6 product level. The data are sourced from

[23]We refer the reader to Appendix A for more detail on these issues.

[24]We use tariff rates as of April 2019, though including rates following the May 2019 increase leaves our results unchanged.

the U.S. Census Bureau and available with lags of 2-3 months. Our outcome of interest is the changes in U.S. exports.

We assume that trade has a standard gravity form that decomposes bilateral exports (in logs) into fixed effects for destination c, time t, and trade frictions as follows

$$\ln Exports_{pct} = \theta_\tau \ln(1+\tau_{pct}) + \gamma_t ITE_p + \alpha_c + \alpha_p + \alpha_t + \epsilon_{pct} \tag{5}$$

where $\ln Exports_{pct}$ is log value of exports for a product p to country c in month t. Tariffs, $\ln(1+\tau_{pct})$, are the *ad valorem* equivalent foreign retaliatory export tariffs and ITE_p measures disruptions to supply chains via exposure to increased import tariffs as defined in equation (1). The α_x terms are fixed effects for country, product and time.

We include ITE_p based on a simple empirical model outlined in Appendix A showing how unobserved firm-level export responses to import tariffs aggregate up to a time-varying export attenuation factor. This factor depends on unobservable, time-varying firm exposure and responses to the several rounds of tariff implementation. In the appendix we show the time-varying export attenuation, if any, is estimated by the coefficient on ITE_p, or $\gamma_t < 0$.

To handle seasonality in high frequency monthly trade flows, we take log differences in exports in equation (5) relative to the previous year to obtain

$$\Delta \ln Exports_{pct} = \theta_\tau \Delta \ln(1+\tau_{pct}) + \Delta\gamma_t ITE_p + \alpha_{ct} + \varepsilon_{pct} \tag{6}$$

where we combine country-time effects α_{ct}. If supply chain linkages reduce export growth, then we predict the coefficient $\Delta\gamma_t < 0$.

The 2018-2019 tariff increases in U.S. imports provides a quasi-natural experiment for evaluating the supply-chain effects on U.S. exports. The import tariff increases were largely unanticipated. The outcomes of the 2016 U.S. presidential election was a surprise to most observers making it unlikely that affected industries could have anticipated the tariff changes.[25] Our exposure measure is fixed by product and time using moments from firm-level trade flows in 2016 and should not be influenced by the 2016 presidential election or anticipation of tariffs in 2017.

Our approach aims to estimate the supply chain impact after the tariff escalation begins relative to the period before the tariff escalation. One straightforward way to do this is via interacting ITE_p with an indicator for post-2017 trade flows, $I(> 2017Q4)$. Our estimation

[25] Fajgelbaum, Goldberg, Kennedy and Khandelwal (2020) also show there is no evidence of differential pre-existing trends in U.S. exports and imports in an event study framework.

strategy is then a simple difference-in-differences equation,

$$\Delta\ln Exports_{pct} = \theta_\tau \Delta\ln(1+\tau_{pct}) + [\Gamma_1 - \Gamma_0] ITE_p \times I(> 2017Q4) + \Gamma_0 ITE_p + \alpha_{ct} + \varepsilon_{pct} \quad (7)$$

where we denote pre-period average of coefficients with subscript 0 and post-period with subscript 1. Thus $\Gamma_0 = \overline{\Delta\gamma}_t$ for $t \leq 2017Q4$ and $\Gamma_1 = \overline{\Delta\gamma}_t$ for $t > 2017Q4$.

The coefficient Γ_0 is the pre-tariff effect of ITE_p on export growth. This could be positive or negative as the measure may be correlated with other unobserved product sector p characteristics that influenced export growth. For example, if nearly all firms in a product p are affected by import tariffs then our measure might capture supply chain intensity unrelated to import tariffs. In our baseline regressions we include α_p fixed effects to control for this concern. We can then identify only the difference $[\Gamma_1 - \Gamma_0]$, which is negative if $\Gamma_1 < \Gamma_0$ such that export growth is lower in the post-period where ITE_p is high.

In our baseline estimating equation, we include several additional sets of fixed effects and write the coefficients and indicators more parsimoniously, as follows:

$$\Delta\ln Exports_{pct} = \theta_\tau \Delta\ln(1+\tau_{pct}) + \Gamma_{Q_t - 0} ITE_p \times Q_t + \alpha_{ct} + \alpha_p + \alpha_{Ic} + \alpha_{It} + \varepsilon_{cpt}. \quad (8)$$

This flexible specification allows us to estimate separate difference-in-difference coefficients on import tariff exposure for each Q_t indicator, which equals one in each quarter from 2018Q1-2019Q3 and zero in 2017Q1-2017Q4. So the coefficient $\Gamma_{Q_t-0} = [\overline{\Delta\gamma}_{t\in Q_t} - \overline{\Delta\gamma}_0]$ and the $Q_t - 0$ subscript is shorthand for the effect in Q_t relative to the omitted group before tariffs were implemented: monthly export growth in 2017. The underlying identifying variation is all country-product exports in the same product p during the three months included in quarter Q_t. The estimated time-variation in $\Gamma_{Q_t-0} = [\overline{\Delta\gamma}_{t\in Q_t} - \overline{\Delta\gamma}_0]$ reflects several characteristics of import tariffs from 2018-2019. First, they are implemented against different countries and products over a period of time. Second, it may take several months for exporters hit by import tariffs to make adjustment to their export behavior.

We control for destination-time unobservable factors (e.g. exchange rate fluctuations, time-varying aggregate trade barriers, and destination specific demand shocks) by including α_{ct} fixed effects. We control for other U.S. supply-side trends and unobservables in α_p and in most regressions also include HS6-calendar quarter fixed effects so Γ_0 is not identified separately. We also include sector×country and sector×time fixed effects in most specifications where we consider sector to be either sections or HS2. A section is a grouping of similar

HS2 categories into 21 groups.[26] The sector×time fixed effects control for shocks to export supply or import demand. We stack twelve-month changes in U.S. exports in 2017, 2018, and the first 9 months of 2019. Because we include HS6-calendar quarter fixed effects the omitted pre-tariff comparison period is monthly export changes in 2017 from the same calendar quarter. Standard errors are clustered at the HS6-level, which is the level of variation for the ITE measure.

4 Results

We begin by estimating the effect of our import tariff exposure measures separately in the pre- and post-tariff escalation periods. We then provide a set of baseline results that are robust to several variations in the specification and measures of exposure.

4.1 Baseline Results

In Tables 6 and 7, we estimate the specification in equation (6) in the pre-tariffs period (2017) and the post-tariffs period (2018-2019), separately.

If the variation in our sectoral measure of import tariff exposure, ITE_p, is only holding back exports once tariffs are actually imposed (and not before), this constitutes further evidence of the importance of the effect of the recent changes in trade policy. In Table 6, we show U.S. export growth was higher, on average, in products with high import tariff exposure before 2018. The dependent variable is the 12-month change in HS6-country exports, beginning in January 2017. One might expect the effect to be zero, but the measure also picks up products that have more integrated supply chains in general. Sectors highly exposed to import tariffs are those that use a relatively large amount of imported inputs overall and the access to foreign imports may have been an important contributor to U.S. export growth in general. Nevertheless, we include α_p effects in our subsequent baseline regression to absorb any unobserved product-specific supply chain characteristics or growth trends. Table 6 also shows the positive effect is largest using the narrow measure, where the import-export linkages are likely stronger, and weakest in the broad measure, where we include any tariffed product in a firm's 2016 import bundle.

Turning to Table 7, we estimate equation (6) during the post-tariff period, using the 12-month change in HS6 exports beginning in January 2018 through September 2019 as the dependent variable. Here we find that the supply chain linkages are a drag on export

[26] The official list of sections is found at World Customs Organization (2019).

growth. The main coefficient of interest is the impact of import tariff exposure, ITE, on export growth. Columns (1) and (2) in the table shows that a one standard deviation increase in the tariff exposure measure, ITE_p, lowers U.S. export growth by about 0.04 percentage points for the typical affected sector. The mean value for the ITE_p measure is 0.10 with a standard deviation of 0.12. Thus, the coefficient implies that a sector at the mean - ITE_p of 0.10 - has export growth about 0.4 percentage points lower than a sector with no exporters affected - ITE_p of 0.[27] The coefficient magnitudes remain fairly similar using ITE_p^{Broad} in columns (3) and (4) of the table, and ITE_p^{Narrow} as shown in columns (5) and (6) of the table. The table also shows that a 1 percentage point increase in foreign retaliatory export tariffs, τ_{pct}, lowers U.S. export growth by about 1.06 percentage points, a result in line with Fajgelbaum et al. (2020).

Next, we stack pre- and post-tariff period data across 2017-2019 and present results in Table 8. We interact ITE_p with an indicator for post-2017Q4 time periods as in equation (7) to estimate the average effect on exports during the entirety of the tariff escalation. In this specification we also control for HS6-calendar quarter fixed effects, which was not possible when splitting the sample in Tables 6 and 7.[28] The HS6 effects sweep out any unobserved product level growth trends in either U.S. export supply or global demand.[29] We also add sector-time effects to control for shocks to export supply or import demand.

We find a negative and statistically significant coefficient on the interaction term between ITE_p and the 2017Q4 indicator. Sectors more exposed to U.S. import tariff increases experienced lower growth compared to less exposed sectors after 2017. Table 9 additionally provides estimates for the broad and narrow exposure measures. All three exposure measures point in the same direction—U.S. export growth was weakened by increases in U.S. import tariffs.

4.2 Timing, Mechanism, and Quantification

While the above results indicate that import tariff exposure dampened exports over this time period, the majority of U.S. imposed import tariffs did not come into place until late 2018, with another major ratcheting up of tariffs on imported intermediates from China occurring in May 2019. We thus explore time variation in the supply chain impacts of changes in U.S. import tariffs by using quarterly interaction terms in conjunction with our ITE measures,

[27] We calculate (-0.04*0.10)=0.4 percent.

[28] "Calendar quarter" refers to Q1, Q2, Q3, or Q4.

[29] We interact by calendar quarter so that comparison in the pre versus post-tariff period is to months in the same quarter of 2017, in case there is additional seasonality in export growth.

as in specification (8). This allows the impact of ITE_p to vary across quarters. We interact the import tariff exposure measure with quarters beginning in 2018, using all the 12-month change data from January 2017 to September 2019.

Table 10 presents the results using ITE_p. As columns (1) and (2) show, simply including a post-2018Q3 indicator interacted with the measure generates significant negative effects. When splitting the timing out in more detail, there is strong evidence of significant, negative effects for the typical affected export sector in 2019Q2 and 2019Q3, as well as some signs of negative effects in earlier quarters depending on the specification. The larger impacts later in the sample are consistent additional tariffs being added or increased throughout 2018 and 2019. We should expect a smaller initial effect since our ITE measure uses all the newly-imposed tariffs regardless of timing. Moreover, our results are consistent with exporters taking time to react due to existing inventories, adjustment costs, and uncertainty about how long the tariff increases would remain in place.

The quantitative implications of these estimates are large, especially in 2019. Again considering a movement from unaffected to the mean value of the ITE_p measure to assess the magnitude of these coefficients and focusing on $\Gamma_{2019Q3-0} = -0.18$, the typical affected HS6 product has a 12-month change in exports that is about 2 percentage points lower than the typical less affected sector ($-0.18 \times 0.10 \approx -0.02$). This quantitative magnitude is robust to all three exposure measures, as indicated by the results in Table 11 for the ITE_p^{Broad} measure and the results in Table 12 for the narrow HS6-based measure. Regardless of the exposure measure, foreign export tariffs had a large and negative impact on U.S. export growth through supply chains.

To compare the effects of the import tariff exposure with the foreign retaliatory export tariffs, we calculate the *ad valorem* tariff equivalent of the U.S. import tariffs, using the estimated coefficient on the import tariff exposure measures (Γ_{Q_t-0}), distribution of the exposure measures (ITE_p), and the coefficient on the elasticity of the retaliatory tariff effects (θ_τ). The *ad valorem* equivalent, AVE, of import tariffs friction on supply chains can be expressed as

$$\tau^{AVE} = \exp\left(\frac{\Gamma_{Q_t-0} \times ITE_p}{\theta_\tau}\right) - 1. \tag{9}$$

The AVE of import tariffs measures the equivalent change in foreign export tariffs that would generate the same change in export growth as the exposure to import tariffs do.[30] At the mean of the $ITE_p = 0.10$, using the coefficients in column (3), the AVE of the supply

[30]Handley and Limao (2017) undertake a similar exercise to compare effects of trade policy uncertainty with other policies.

chain effect is between 0.8% and 1.7% from 2018Q4-2019Q3, respectively. Table 13 shows the estimated AVE of import tariffs in 2019Q3 for all three exposure measures evaluated at the mean and mean plus one standard deviation of ITE. Γ_{Q_t-0} and θ_τ are obtained from Tables 10, 11, and 12 for the baseline, broad, and narrow exposure measures, respectively, for the specifications with *country* × *time*, *country* × *section*, *section* × *time* and $HS6$-calendar quarter fixed effects. For product sectors at the mean plus one standard deviation of the baseline exposure measure, $ITE_p = 0.10 + 0.13 = 0.23$, the τ^{AVE} is almost 4%. This is about the same as the average U.S. statutory MFN tariff on all countries without a free trade agreement. Using the broad and narrow measures, τ^{AVE} is 10% and 2.6%, respectively.

The magnitude of the estimated effects may seem large compared to what appears to be a fairly small cost shock in the aggregate - total customs duties collected in 2018 was $53.3 billion or about 2% of total merchandise imports (U.S. Bureau of Economic Analysis, 2019). However, our import tariff exposure measure is meant to capture not just the effect of actually paying the tariffs, but rather the comprehensive set of activities that need to be undertaken to re-optimize supply chains in response to the tariffs and accompanying uncertainty. Anecdotally, U.S. firms have described these effects as significant to their operations, perhaps even more important than the actual direct increase in costs from the tariffs themselves. If exporters choose to drop out of importing and exporting altogether in response to new tariffs on intermediate inputs, our measure would still capture the effects of that decision on total export growth. We identify only the reduced form of the impact, but do not take a position on precisely how the increase in costs transmits through the supply chains of affected firms.

4.2.1 Decomposition

Although the coefficients for the different ITE_p measures have similar magnitudes, the measures are nested and allow us to decompose the importance of each channel. The baseline exposure measure captures the supply chain effects of import tariffs. In contrast, the broad measure reflects an overall sensitivity of exports to any import tariffs, even in unrelated categories; while the narrow measure reflects only the HS6 products with the closest characteristics to those products receiving import tariffs.

We test the relative importance of each linkage by computing the residual differences of broader measures relative to more narrow measure. For example, $ITE_p^{Broad} - ITE_p$ reflects the residual share of product p exporters in the broad measure exposed to any tariff that were **not** exposed to import tariffs on a product in the same group of HS4 products. The nesting means the following identities will hold

$$ITE_p^{Broad} = [ITE_p^{Broad} - ITE_p] + ITE_p \tag{10a}$$

$$ITE_p^{Broad} = [ITE_p^{Broad} - ITE_p^{Narrow}] + ITE_p^{Narrow} \tag{10b}$$

$$ITE_p \quad = [ITE_p - ITE_p^{Narrow}] + ITE_p^{Narrow} \tag{10c}$$

$$ITE_p^{Broad} = [ITE_p^{Broad} - ITE_p] + [ITE_p - ITE_p^{Narrow}] + ITE_p^{Narrow} \tag{10d}$$

Table 14 illustrates the results from this exercise. Columns (1) and (2) include the baseline exposure measure, ITE_p, with an indicator for the post-2018Q3 period, as well as, for each product, p, the difference between ITE_p^{Broad} and ITE_p from the RHS of equation (10a). The baseline measure remains negative and significant, while the difference measure is statistically insignificant, indicating that it is mainly variation at the HS4 level of supply chain linkages driving the results. Columns (3) and (4) repeat the exercise, but using the narrow measure combined with the difference between ITE_p^{Broad} and ITE_p^{Narrow} from (10b). The difference between the broad and narrow measure is negative and significant alongside the narrow measure, but this is because the residual still includes the residual variation in baseline ITE_p measure. In columns (5) and (6), we use the exhaustive breakdown in the RHS of equation (10d). The coefficient on the broad measure net of the baseline is now statistically insignificant, but narrow and baseline ITE coefficients are both negative and significant.

The results in Table 14 permit a simple counterfactual exercise. How much higher would export growth have been if the import tariffs were on products less important to firms' supply chains? The mean of the broad measure is 0.56. Of this, the fraction 0.04 is from exporters with narrow exposure (same HS6) and an additional 0.06 is exporters with only baseline exposure (same HS4). Using column (6) of Table 14, the effect at the mean from the narrow and baseline net of narrow are $-0.142 \times 0.04 - .123 \times 0.06 = 0.013$, or about 1.3 log points per quarter from 2018Q3-2019Q4. If we assume, counterfactually, that the tariffed products were not part of the exporters supply chains, i.e. shift those products into the residual broad measure, then the impact falls to only -0.5 log points (-0.052×0.1), which reduces the impact by over 60%. So conservatively, the exporters in this counterfactual continue to pay tariffs on imports, but the export growth is substantially dampened when the products are less likely to be part of a supply chain.[31]

[31] A similar attenuation of 60% is found by simply taking the ratio of the coefficients on ITE_p and the broad residual in column 2 of Table 14, e.g. $1 - 0.052/0.131 = 60\%$.

4.3 Cost Shares

Thus far we have been agnostic about how exactly the increase in import tariffs is affecting exporters - all that matters for the above specifications is whether an exporter was potentially subject to tariffs, not the tariff rate. That said, research has found that the tariff burden is falling directly on U.S. businesses rather than foreign companies, so there is the possibility that our results are stemming from the direct increase in input costs.[32] To check this, we consider our other import tariff exposure measure, ITE_{pc}^{Cost}, as defined in equation 4. This measures the share of implied value of duties exporters paid as a share of their total imports within a HS6-country pair.

The results are shown in Table 15. Columns (1) and (2) show, using the ITE_{pc}^{Cost} measure together with a post-2018Q3 indicator, that there is a strong, negative impact on U.S. export growth. Column (3) indicates that the quarterly interactions do not present as clear a picture as the earlier results - much of the weakness appears to be coming in 2019Q1, without significant results in later quarters.

Although the broad picture of the results is consistent with increased costs affecting tariffs, there are numerous ways in which firms could be affected that are not related to the direct input costs. For example, Monarch (2016) finds that changing suppliers is surprisingly uncommon in international trade, and that switching costs can be quite large, in part due to the non-monetary component of switching. This is consistent with accounts of firms trying to find new suppliers in other countries following the rise in trade tensions. There are businesses that are certainly affected negatively by the change in trade policy, but may not be paying duties directly. Thus, although the cost share results are instructive, it is not surprising that the results are muted compared to using ITE_p which allows for a more varied set of firm responses.

4.4 Robustness Checks

Our main finding is that U.S. exports have been adversely affected by the imposition of U.S. import tariffs, using our preferred baseline measure of exposure (where affected exports are those in the same HS4 category as the import tariff being assessed) and also robust to other exposure measures. In this section, we address three main concerns that may be driving our results and establish the robustness of the baseline result to alternative samples and specifications.

[32]See Amiti et al. (2019) and Cavallo et al. (2019).

First, U.S. exports to China declined substantially in the wake of trade tensions flaring in 2018, a decline that may be causing our results to appear stronger than they would otherwise be. Furthermore, since U.S. import tariffs were mostly assessed on imports from China, there may be a particular relationship between U.S. imports from China and U.S. exports to China that is driving our results. This is ruled out in part by the evidence in Figure 1 showing no particular set of countries or products explains weak export growth. Our inclusion of country-time and country-industry fixed effects already addresses these concerns, but some spurious correlations between our measure of particular country groups or products may remain.

Table 16 shows our results are robust to exluding China and major geographic regions of the world. Column (1) of Table 16 presents regression results after excluding U.S. exports to China. As can be seen, the ITE_p measure interacted with post-2018Q3 indicator gives very similar results to the overall result from Table 10 even after excluding exports from China. This suggests many tariffed imports from China were inputs to output exported to the rest of the world. The remaining columns, (2) through (8), exclude U.S. exports to North America, Central America, South America, Europe, Asia, Australia and Oceania, and Africa, respectively. The results are all in line with the baseline result, indicating that there is no single region driving our main finding. That said, it is interesting to note that eliminating exports to Europe (column 5) results in a coefficient estimate about 30% more negative than other specifications, suggesting that import tariffs are having an outsize impact on U.S. exports to Europe relative to other regions.

Second, the timing of the various waves of retaliation over the 2018-2019 period may be driving the overall decline in exports and causing our results to be stronger. The actual amount of the retaliatory tariff may also matter in a non-linear manner such that our current control for retaliatory tariffs may not reflect their full impact on exports. Thus, in columns (1) and (2) of Table 17, we exclude all export products that faced any retaliation whatsoever over our time period.[33] Removing these categories does little to alter our overall result.

Finally, our time period encompasses a switch in HS nomenclature in 2017. Throughout the analysis above, we used only those HS6 export codes that did not change over time. Restricting to those codes may have biased our results, so we also include a robustness check where we use the officially released concordance to match export codes. As can be seen from

[33] We continue to not include either the September 1, 2019 U.S. tariff increases or the subsequent retaliation in this analysis.

the results in columns (3) and (4) in Table 17, the baseline results are again very similar.[34]

5 Concluding Remarks

We provide new empirical evidence that new U.S. import tariffs in 2018-2019 significantly dampened U.S. export growth. Using detailed firm-level micro-data to assess the incidence of tariffs on firms in 2016, before the onset of the tariff war, we find that almost one fourth of U.S. exporters imported products subject to new import tariffs. Moreover, these firms account for more than 80% of U.S. exports by value. Affected firms were disproportionaely larger than the average exporter in term of total exports, employment, and number of plants. The incidence of these tariffs is non-trivial for U.S. firms in general. Over 30% of U.S. firms and employment in the non-farm private sector are subject to new import tariffs. The implied duties per worker, based on 2016 import bundles, are $900 per worker overall and about $1,600 in the manufacturing sector.

Using our identification of U.S. exporters that imported newly tariffed goods, we construct supply chain import tariff exposure measures for over 5,000 detailed, product level export sectors. Our difference-in-differences estimates imply that export growth was about 2% lower from 2018Q4-2019Q3 for the average country-product trade flow affected by U.S. import tariffs. This is equivalent to an *ad valorem* tariff of almost 2 percentage points on U.S. exports for mean exposure and almost 4% for product sectors one standard deviation above the mean. Moreover, the export growth reductions would have been 60% smaller if the new import tariffs were not on product likely to be part of the average firm's supply chain.

More broadly, our approach provides a novel means to combine detailed firm-level trade transactions data with higher frequency public-use trade data to estimate near contemporaneous impacts of trade policy. We show that, in practice, trade policy designed to avoid tariffs on consumer goods may disproportionately impact imported inputs, spilling over to affect exports of other products to third countries. Moreover, research estimating the direct trade, price and welfare impacts of U.S. import tariffs and subsequent retaliation by trade partners, omits the indirect the supply chain spillovers and may understate the total effect on firms and their workers.

[34] For import tariff codes assessed at the HS8, we simply merged HS codes over time, neither restricting to HS6 codes that were unchanged nor concording. The results from restricting only to unchanged import codes are not appreciably different from the baseline.

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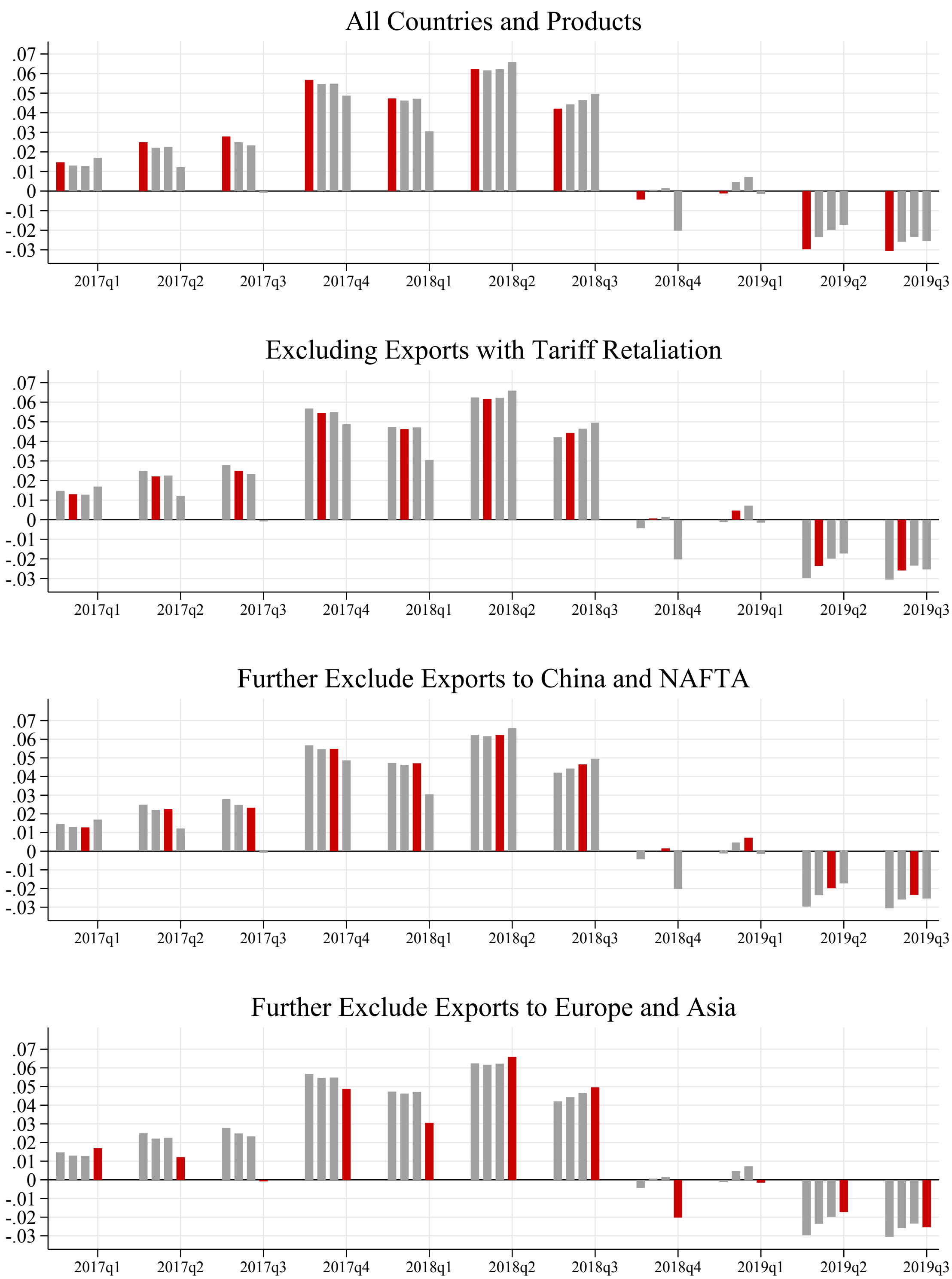
Figure 1. Average Quarterly Country-Product Export Growth 2017Q1-2019Q3 (year-on-year): Total Growth and Progressively Excluding Groups



Notes: Bars are average monthly (ln) export growth (year-on-year) within each quarter from 2017Q1-2019Q3. Observations are at the country-product (HS6) level. The top graph highlights averages in red for the entire sample of country-product U.S. export growth. Subsequent graphs progressively drop observations from the sample, as denoted in the sub-titles, and highlight resulting averages in red.

Table 1. 2018 Tariff Incidence by 2016 Trade Patterns

	Imports	Exports
Share of Value	11.5	7.9
Share of Firms	32.9	18.7
Share of Employees	31.8	23.2
Tariffed Share at Affected Firms	46.5	32.5

Notes: "Imports" ("Exports") show statistics for all importers (exporters) impacted by U.S.-imposed import (foreign retaliatory export) tariffs. "Value" is the share of trade impacted by tariffs; "Firms" is the share of firms affected by tariffs; "Share of Employees" is the share of private, non-farm employees working at affected firms, and "Tariffed Share at Affected Firms" is average trade value at affected firms that face tariffs.
Source: Authors' calculations using 2016 LFTTD.

Table 2. Characteristics (2016 basis) of firms affected by new tariffs in 2018

Panel A: Importers

	Tariffed Importers	All Importers	All Firms
Employment	430.9	212	24.0
Establishments	9.3	4.8	1.3
Age	17.6	18.0	14.1
Pay/Worker	57.8	57.5	29.5

Panel B: Exporters

	Tariffed Exporters	All Exporters	All Firms
Employment	720.3	241.7	24.0
Establishments	14.8	5.8	1.3
Age	22.5	18.8	14.1
Pay/Worker	64.2	57.1	29.6

Notes: This table displays average firm characteristics with standard deviations in parentheses. Annual pay per worker in thousands of dollars.
Source: Authors' calculations using 2016 LFTTD and LBD.

Table 3. Tariff Incidence by Affected Sectors (2016 Basis)

	Importers Employment Share	Exporters Employment Share	Implied Duties per Worker
Manufacturing	0.65	0.63	$1,595
Wholesale	0.51	0.38	$5,049
Retail	0.60	0.44	$364
Other	0.21	0.13	$314
Total	0.32	0.23	$893

Notes: Manufacturing is defined as all sectors within NAICS 31-33; Wholesale is defined as all sectors within NAICS 42; Retail is defined as all sectors within NAICS 44 and 45; and Other includes all other sectors except 92. Duty-per-worker weighted by sectoral employment.
Source: Authors' calculations using 2016 LFTTD and LBD.

Table 4. Exporters Paying Import Tariffs: Supply Chain Incidence

Firm exports with at least one new tariff on firm-level imported product within same:			
	6 digit sub-heading (HS6) Narrow	4 digit heading (HS4) Baseline	Any Product Broad
	(1)	(2)	(3)
Share of Exports	30%	43%	84%
Share of Exporters	11%	13%	24%

Notes: "Narrow" considers only those exports in the same HS6 category as the import tariff. "Baseline" considers firm exports in a HS6 category that shares the same HS4 as firm imports subject to import tariffs. "Broad" considers all firm exports to be subject to import tariffs. Measures are nested from left to right.
Source: Authors' calculations using 2016 LFTTD.

Table 5. Summary Statistics: Import Tariff Exposure and U.S. Export Growth

	Mean	St.Dev.
Import Tariff Exposure		
ITE_p	0.10	0.13
ITE_p^{Broad}	0.56	0.16
ITE_p^{Narrow}	0.04	0.07
ITE_{pc}^{Cost}	0.02	0.03
$\Delta lnExports_{pct}$		
All Periods	0.02	1.27
2017Q1-2018Q3	0.04	1.27
2018Q4-2019Q3	-0.02	1.27

Notes: ITE measures described in Section 3. Source: Authors' calculations using 2016 LFTTD and public-use Census Bureau data on U.S. monthly exports.

Table 6. Export Growth and Import Tariff Exposure: Pre-Tariffs Period (2017)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(1+\tau_{pct})$	-	-	-	-	-	-
ITE_p	0.077***	0.077***				
	(0.024)	(0.024)				
ITE_p^{Broad}			0.058**	0.058**		
			(0.026)	(0.026)		
ITE_p^{Narrow}					0.087**	0.087**
					(0.037)	(0.037)
Fixed Effects	*ct*, *cI*	*ct*, *cI*, *It*	*ct*,*cI*	*ct*, *cI*, *It*	*ct*,*cI*	*ct*, *cI*, *It*
Observations[a]	1,034,000	1,034,000	1,034,000	1,034,000	1,034,000	1,034,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. *I* refers to section category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 7. Export Growth and Import Tariff Exposure: Post-Tariffs Period (2018-2019Q3)

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(1+\tau_{pct})$	-1.053***	-1.059***	-1.061***	-1.067***	-1.053***	-1.059***
	(0.143)	(0.142)	(0.143)	(0.142)	(0.142)	(0.142)
ITE_p	-0.035*	-0.035*				
	(0.018)	(0.018)				
ITE_p^{Broad}			-0.044**	-0.044**		
			(0.019)	(0.019)		
ITE_p^{Narrow}					-0.053*	-0.053*
					(0.030)	(0.030)
Fixed Effects	*ct*, *cI*	*ct*, *cI*, *It*	*ct*,*cI*	*ct*, *cI*, *It*	*ct*,*cI*	*ct*, *cI*, *It*
Observations[a]	1,830,000	1,830,000	1,830,000	1,830,000	1,830,000	1,830,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. *I* refers to section category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 8. Export Growth and Import Tariff Exposure, 2017-2019Q3

	(1)	(2)	(3)
$\Delta \ln(1+\tau_{pct})$	-1.091***	-1.065***	-1.084***
	(0.142)	(0.143)	(0.140)
$ITE_p \times (> 2017Q4)$	-0.085***	-0.085***	-0.117***
	(0.028)	(0.028)	(0.030)
Fixed Effects	ct	ct, cI	ct, It, cI
Observations[a]	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. I refers to section category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 9. Export Growth and Import Tariff Exposure, Compare Exposure Measures 2017-2019Q3

	(1)	(2)	(3)
$\Delta \ln(1+\tau_{pct})$	-1.084***	-1.095***	-1.086***
	(0.140)	(0.140)	(0.140)
$ITE_p \times (> 2017Q4)$	-0.117***		
	(0.030)		
$ITE_p^{Broad} \times (> 2017Q4)$		-0.114***	
		(0.033)	
$ITE_p^{Narrow} \times (> 2017Q4)$			-0.132***
			(0.047)
Fixed Effects	ct, cI, It	ct, cI, It	ct, cI, It
Observations[a]	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. I refers to section category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 10. Export Growth and Import Tariff Exposure, Quarterly Effects
Baseline Exposure Measure

	(1)	(2)	(3)	(4)
$\Delta \ln(1+\tau_{pct})$	-1.085***	-1.042***	-1.085***	-1.056***
	(0.140)	(0.142)	(0.140)	(0.146)
$ITE_p \times (> 2018Q3)$	-0.111***	-0.105***		
	(0.033)	(0.040)		
ITE_p				
$\times 2018Q1$			-0.090*	-0.02
			(0.054)	(0.049)
$\times 2018Q2$			-0.108**	-0.052
			(0.053)	(0.048)
$\times 2018Q3$			-0.062	-0.034
			(0.053)	(0.047)
$\times 2018Q4$			-0.09	-0.102**
			(0.055)	(0.049)
$\times 2019Q1$			-0.108**	-0.039
			(0.052)	(0.048)
$\times 2019Q2$			-0.194***	-0.157***
			(0.049)	(0.046)
$\times 2019Q3$			-0.180***	-0.149***
			(0.050)	(0.045)
Fixed Effects	ct, It, cI	ct, it, ci	ct, It, cI	ct, it, ci
Observations[a]	2,865,000	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 11. Export Growth and Import Tariff Exposure, Quarterly Effects
Broad Exposure Measure

	(1)	(2)	(3)	(4)
$\Delta \ln(1+\tau_{pct})$	-1.069***	-1.093***	-1.061***	-1.047***
	(0.143)	(0.141)	(0.146)	(0.143)
ITE_p^{Broad}				
$\times 2018Q1$	-0.055	-0.088*	-0.053	-0.097
	(0.046)	(0.053)	(0.046)	(0.060)
$\times 2018Q2$	-0.099**	-0.135**	-0.097**	-0.187***
	(0.046)	(0.054)	(0.046)	(0.061)
$\times 2018Q3$	-0.029	-0.081	-0.028	-0.087
	(0.049)	(0.057)	(0.049)	(0.066)
$\times 2018Q4$	-0.043	-0.056	-0.041	-0.064
	(0.049)	(0.058)	(0.049)	(0.069)
$\times 2019Q1$	-0.034	-0.124**	-0.032	-0.112**
	(0.040)	(0.051)	(0.040)	(0.056)
$\times 2019Q2$	-0.165***	-0.184***	-0.162***	-0.209***
	(0.043)	(0.051)	(0.043)	(0.058)
$\times 2019Q3$	-0.124***	-0.163***	-0.121***	-0.139**
	(0.041)	(0.051)	(0.041)	(0.058)
Fixed Effects	ct, cI	ct, It, cI	ct, ci	ct, it, ci
Observations[a]	2,865,000	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 12. Export Growth and Import Tariff Exposure, Quarterly Effects Narrow Exposure Measure

	(1)	(2)	(3)	(4)
$\Delta \ln(1+\tau_{pct})$	-1.064***	-1.086***	-1.055***	-1.041***
	(0.143)	(0.140)	(0.145)	(0.142)
ITE_p^{Narrow}				
$\times 2018Q1$	-0.007	-0.082	-0.007	-0.074
	(0.076)	(0.080)	(0.077)	(0.091)
$\times 2018Q2$	-0.02	-0.068	-0.016	-0.037
	(0.076)	(0.078)	(0.076)	(0.087)
$\times 2018Q3$	-0.057	-0.088	-0.053	-0.086
	(0.075)	(0.080)	(0.075)	(0.091)
$\times 2018Q4$	-0.178**	-0.145*	-0.174**	-0.145
	(0.078)	(0.082)	(0.078)	(0.094)
$\times 2019Q1$	-0.039	-0.111	-0.037	-0.09
	(0.076)	(0.081)	(0.076)	(0.091)
$\times 2019Q2$	-0.197***	-0.202**	-0.189**	-0.164*
	(0.076)	(0.079)	(0.076)	(0.090)
$\times 2019Q3$	-0.210***	-0.222***	-0.199***	-0.175**
	(0.072)	(0.075)	(0.072)	(0.086)
Fixed Effects	ct, cI	ct, It, cI	ct, ci	ct, it, ci
Observations[a]	2,865,000	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) category.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 13. *Ad Valorem* Equivalent Tariff of Supply Chain Import Tariff Exposure, 2019Q3

	Mean	Mean + S.D.
ITE_p^{Broad}	-8.01	-10.18
ITE_p	-1.65	-3.74
ITE_p^{Narrow}	-0.81	-2.62

Notes: ITE measures described in Section 3. This table displays the *ad valorem* equivalent of the import tariffs on export growth in 2019Q3 using equation 9. We use the coefficients on ITE_p and $\Delta \ln(1+\tau_{pct})$ from 2019Q3 in column 3 of Tables 10,11, and 12. The first (second) column evaluates τ^{AVE} at the mean (mean plus 1 standard deviation) of ITE.

Table 14. Export Growth and Import Tariff Exposure: Decomposition of Supply Chain Margins

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(1+\tau_{pct})$	-1.087***	-1.043***	-1.089***	-1.043***	-1.087***	-1.042***
	(0.140)	(0.143)	(0.140)	(0.143)	(0.140)	(0.142)
$ITE_p \times (> 2018Q3)$	-0.138***	-0.131***				
	(0.040)	(0.048)				
$ITE_p^{Narrow} \times (> 2018Q3)$			-0.166***	-0.151**	-0.145***	-0.142**
			(0.055)	(0.063)	(0.055)	(0.062)
Broad Exposure Net of Baseline						
$[ITE_p^{Broad} - ITE_p] \times (> 2018Q3)$	-0.056	-0.052			-0.055	-0.052
	(0.036)	(0.039)			(0.036)	(0.039)
Broad Exposure Net of Narrow						
$[ITE_p^{Broad} - ITE_p^{Narrow}] \times (> 2018Q3)$			-0.074**	-0.070*		
			(0.035)	(0.038)		
Baseline Exposure Net of Narrow						
$[ITE_p - ITE_p^{Narrow}] \times (> 2018Q3)$					-0.132***	-0.123**
					(0.049)	(0.056)
Fixed Effects	ct, cI, It	ct, ci, it	ct, cI, It	ct, ci, it	ct, cI, It	ct, ci, it
Observations[a]	2,865,000	2,865,000	2,865,000	2,865,000	2,865,000	2,865,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) category.

[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 15. Export Growth and Import Tariff Exposure, Cost Share

	(1)	(2)	(3)
$\Delta \ln(1+\tau_{pct})$	-1.125***	-1.079***	-1.124***
	(0.141)	(0.143)	
$ITE_{pc}^{Cost} \times (> 2018Q3)$	-0.227**	-0.199*	
	(0.113)	(0.113)	
ITE_{pc}^{Cost}			
$\times 2018Q1$			0.02
			(0.181)
$\times 2018Q2$			0.283
			(0.176)
$\times 2018Q3$			-0.189
			(0.182)
$\times 2018Q4$			-0.330*
			(0.190)
$\times 2019Q1$			-0.357**
			(0.179)
$\times 2019Q2$			-0.078
			(0.173)
$\times 2019Q3$			-0.116
			(0.185)
Fixed Effects	ct, cI, It	ct, ci, it	ct, cI, It
Observations[a]	2,811,000	2,811,000	2,810,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) product category.

[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 16. Export Growth and Import Tariff Exposure: Regional Sensitivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Excluding	China	N. America	C. America	S. America	Europe	Asia	Aus./Oce.	Africa
$\Delta \ln(1+\tau_{pct})$	-1.142***	-0.824***	-1.047***	-1.086***	-1.623***	-1.174***	-1.091***	-1.085***
	(0.156)	(0.154)	(0.144)	(0.139)	(0.174)	(0.160)	(0.140)	(0.141)
$ITE_p \times (> 2018Q3)$	-0.110***	-0.115***	-0.118***	-0.115***	-0.073**	-0.121***	-0.111***	-0.118***
	(0.033)	(0.035)	(0.037)	(0.035)	(0.033)	(0.036)	(0.033)	(0.033)
Observations[a]	2,786,000	2,726,000	2,273,000	2,550,000	2,109,000	2,025,000	2,754,000	2,751,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include country by section, section by time, and HS6-calendar quarter fixed effects. Each column excludes one region at a time in the following order: North America, Central America, South America, Europe, Asia, Australia and Oceania, Africa, and China. The regions are defined by the Census Bureau (https://www.census.gov/foreign-trade/schedules/c/countrycode.html).
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

Table 17. Export Growth and Import Tariff Exposure: Product Group Sensitivity

	(1)	(2)	(3)	(4)
	No Retaliation	No Retaliation	Concorded	Concorded
$\Delta \ln(1+\tau_{pct})$			-1.085***	-1.041***
			(0.139)	(0.141)
$ITE_p \times (> 2018Q3)$	-0.092***	-0.097***	-0.106***	-0.087**
	(0.030)	(0.033)	(0.033)	(0.040)
Fixed Effects	ct	ct, cI, It	ct, cI, It	ct, ci, it
Observations[a]	2,763,000	2,763,000	2,953,000	2,953,000

Notes: * p<10%; ** p<5%; *** p<1%. Robust standard errors in parentheses, clustered by HS6 product. All regressions include HS6-calendar quarter fixed effects. $I(i)$ refers to section (HS2) product category. "No Retaliation" considers only export product-country pairs that did not face foreign retaliatory export tariffs in 2018-2019; "Concorded" includes export product codes that were merged or split through a concordance between 2016 and 2018 due to revisions in the HS classification.
[a] Observation counts rounded to comply with Census Bureau disclosure avoidance rules.

A Empirical Aggregation to Export Growth

To fix ideas, we write down a simple empirical model where exporters may have been affected by import tariffs. We index firms by i and products by p. Exporters with positive trade to country c in product p are in the set Ω_{pc}. Firm level export sales in product code p to country c in the absence of import tariffs are given by $\tilde{r}_{ipct}$. We define an indicator variable $D_{it} = 1$ if any imports of firm i are hit by a new tariff and zero otherwise. We assume that the impact of the import tariff on a firm's *export* output is potentially heterogeneous and adjusts output by $1 - \delta_{ip} \leq 1$. We can interpret $\delta_{ip} \in [0, 1]$ as a firm-product specific export trade friction induced by tariffs on its own imports.[35]

For clarity, we drop the product subscript and write observed exports r_{ict} of any firm to country c as,

$$r_{ict} = \left[(1 - D_{it}) + D_{it}(1 - \delta_i)\right] \tilde{r}_{ict} = \tilde{r}_{ict}\left[1 - D\delta_i\right].$$

Note that unobserved firm-level exports in the absence of the tariff are $\tilde{r}_{ict}$. We aggregate over all exporters to obtain the equation for observable aggregate exports to country c

$$\begin{aligned}
R_{ct} &= \sum_{i \in \Omega_c} \left[1 - D_{it}\delta_i\right] \tilde{r}_{ict} \\
&= \tilde{R}_{ct} - \sum_{i \in \Omega_c} D_{it}\delta_i \tilde{r}_{ict} \\
&= \tilde{R}_{ct}\left[1 - \frac{\sum_{i \in \Omega_c} D_{it}\delta_i \tilde{r}_{ict}}{\tilde{R}_{ct}}\right] \\
&= \tilde{R}_{ict}\left[1 - \tilde{\delta}\right]
\end{aligned}$$

The last line uses that $\left[1 - \tilde{\delta}\right]$ is a trade weighted average of the heterogeneous export effect of import tariffs on affected firms.

We predict $\delta_i \in [0, 1]$ so that exports are possibly lower if firms imports are hit by new tariffs, i.e. $\left[1 - \tilde{\delta}\right] < 1$. We cannot do this directly because of unobserved heterogeneity of impact across firms and because exports without the presence of tariffs $\tilde{r}_{ict}$ in the weights implied above are unobserved. Instead, we use trade participation measures from 2016, before the new tariffs were likely anticipated or implemented, to construct a set of exposure measures that can identify the effect on exports without knowledge of the trade weights

[35] The restriction to $[0, 1]$ is a testable assumption. It is feasible that firms hit by an import tariff increase their output.

above.

Firm level trade flows can be decomposed into the average exports per firm and deviations from average exports relative to the population of all firms that export to c, i.e $r_{ict} = \bar{r}_{ct} + (r_{ict} - \bar{r}_{ct})$. Note that $R_{ct} = N_{ct} \times \bar{r}_{ct}$, so that total exports is the number of exporters times average exports per firm. Moreover, the number of firms hit by a tariff is given by $N^D_{ct} = \sum_{i\in\Omega_c} D_{it}$. So we can write total exports of firms hit by an import tariff as $R^D_{ct} = N^D_{ct} \times \bar{r}^D_{ct}$ where superscript D indicates the total exports, the count of firms, or average export per firm for the set of firms hit by a new tariff.

We obtain an expression for $\tilde{\delta}$ in terms of firm level sub-components as follows

$$
\begin{aligned}
\tilde{\delta} &= \frac{\sum_{i\in\Omega_c} D_{it}\delta_i r_{ict}}{N_{ct} \times \bar{r}_{ct}} \\
&= \frac{\sum_{i\in\Omega_c} D_{it}\delta_i r_{ict}}{N^D_{ct} \times \bar{r}_{ct}} \frac{N^D_{ct}}{N_{ct}} \\
&= \frac{\sum_{i\in\Omega_c} D_{it}\delta_i (\bar{r}_{ct} + (r_{ict} - \bar{r}_{ct})]}{N^D_{ct} \times \bar{r}_{ct}} \frac{N^D_{ct}}{N_{ct}} \\
&= \left[\frac{\sum_{i\in\Omega_c} D_{it}\delta_i}{N^D_{ct}} + \frac{\sum_{i\in\Omega_c} D_{it}\delta_i (r_{ict} - \bar{r}_{ct})}{N^D_{ct} \times \bar{r}_{ct}}\right] \frac{N^D_{ct}}{N_{ct}} \\
&= \left[\bar{\delta} + \frac{1}{N^D_{ct}} \sum_{i\in\Omega_c} D_{it}\left[\delta_i \left(r_{ict}/\bar{r}_{ct} - 1\right)\right]\right] \frac{N^D_{ct}}{N_{ct}} \qquad (11) \\
&= B_t \frac{N^D_{ct}}{N_{ct}} \qquad (12)
\end{aligned}
$$

The first four lines are algebra. Then we have the first term in equation (11), where we denote the simple average of the supply chain friction for affected firms by $\bar{\delta} = \frac{\sum_{i\in\Omega_c} D_{it}\delta_i}{N^D_{ct}}$. The second term in (11) is the total effect on average firm sales, δ_i times a measure of how much higher or lower export sales are at each affected firm relative to the average firm's sales.

The coefficient B_t on the share of firms affected by tariffs, $\frac{N^D_{ct}}{N_{ct}}$, is the simple average effect $\bar{\delta}$ plus an adjustment factor for the ratio of the affected firms' exports, r_{ict} in the absence of the friction, relative to the average sales of all firms $\bar{r}_{ct}$. In short, effects of tariffs can be amplified by the second term if the incidence of the tariff is on exporters that are larger than average. As we document in the main text, affected firms were indeed larger than average in multiple dimensions, including exports, for the tariffs of 2018-19.[36]

[36] Alternatively, the adjustment could be close to zero if $r_{ict} \approx \bar{r}_{ct}$ and there was little heterogeneity across firms.

To handle seasonality in high frequency monthly trade flows, we take log differences in exports relative to the previous year. We assume that in the absence of frictions on a firm's import, trade has a standard gravity form where $\ln R_{pct} = \alpha_c + \alpha_p + \alpha_t + \theta \ln \tau_{pct}$. That is, aggregate bilateral export flows, $\ln R_{pct}$, can be decomposed into fixed effects for destination c, time t, and product specific bilateral trade frictions, τ_{pct}, such as retaliatory export tariffs.

If exporters are responding to tariffs on their import bundles, then exports will be reduced by a factor $\tilde{\delta}_t \in [0, 1]$. We do not observe the contemporaneous and endogenously determined share of affected firms, $\frac{N^D_{pct}}{N_{pct}}$, or the relative average sales ratios of affected firms, $\frac{\bar{r}^D_{pc}}{\bar{r}_{pc}}$, to all firms. Instead, we employ lagged values that are fixed over time at 2016 levels as described in the main text. We assume that the number of exporter in any particular product p does not change much over time such that $N_{pct} \approx N_{p,2016}$. The number of affected firms at any point in time from 2018-2019 does change over time such that $N^D_{pct} = \phi_t N^D_p$. Thus we have $\frac{N^D_{pct}}{N_{pct}} = \phi_t \frac{N^D_p}{N_{2016}}$. Using these expressions and log differences relative to the same month at $t - 12$ we obtain

$$
\begin{aligned}
\Delta \ln R_{pct} &= \theta \Delta \ln \tau_{pct} + \ln \left[1 - \tilde{\delta}_t\right] - \ln \left[1 - \tilde{\delta}_{t-12}\right] + \alpha_{ct} + \alpha_p \\
&\approx \theta \Delta \ln \tau_{pct} - \tilde{\delta}_t + \tilde{\delta}_{t-12} + \alpha_{ct} + \alpha_p + \varepsilon_{pct} \\
&= \theta \Delta \ln \tau_{pct} - \left(B_{pct} \frac{N^D_{pct}}{N_{pct}} - B_{pc,t-12} \frac{N^D_{pc,t-12}}{N_{pc,t-12}} \right) + \alpha_{ct} + \alpha_p + \varepsilon_{pct} \\
&\approx \theta \Delta \ln \tau_{pct} - \Delta B_{pct} \phi_t \frac{N^D_p}{N_{p,2016}} + \alpha_{ct} + \alpha_p + \varepsilon_{pct}. \qquad (13)
\end{aligned}
$$

We use a log approximation in line 2 and replace the unobserved firm shares with the approximate values described above.

In the main text, we estimate a difference-in-difference. As the expression above shows, the term $\Delta B_{pct} \phi_t$ has country, product and time-heterogeneity. Our estimated coefficients average over the country and product heterogeneity. We use discrete pre- and post-tariff period indicators or quarterly interaction terms to capture two things. First, time indicators account for changing share of affected firms relative to 2016 trade patterns as tariffs are phased in ϕ_t. Second, they allow endogenously determined average exports of affected and unaffected firms included in B_{pct} to be reflected in changes in the estimated coefficient.