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Abstract

During the U.S.-China trade war, the U.S. punitive tariffs were almost entirely borne by U.S. importers. In contrast, only 68% of China's retaliatory tariffs were paid by Chinese importers. The puzzling difference between the U.S. and China is mainly driven by their different import structures and product heterogeneity in tariff pass-through. China mainly imported products with lower tariff pass-through from the U.S., such as agricultural products and aircraft, while the U.S. primarily imported products with higher tariff pass-through from China, such as electronics. Furthermore, we decompose the product-level tariff pass-through and show that a higher ratio of import demand elasticity over export supply elasticity leads to lower tariff pass-through under perfect competition.

JEL Classifications: F13, F14, F61

Keywords: trade war, tariff pass-through, import structure, product heterogeneity, demand elasticity, supply elasticity

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1 Introduction

The unprecedented tariff increases during the U.S.-China trade war have fueled extensive discussions on the economic consequences of trade protectionism. One of the central topics is who pays for the tariffs, as tariff pass-through is a central parameter for the inference of tariff incidence and distributional equity. While the U.S. tariffs were almost entirely borne by the U.S. importers (e.g., Amiti et al., 2019; Fajgelbaum et al., 2020; Cavallo et al., 2021; Jiao et al., 2021), we find that the pass-through of Chinese retaliatory tariffs was only 68%. The findings are surprising for two reasons. First, the average pass-through in China was considerably lower than that in the U.S. for the same event. Second, complete tariff pass-through is uncommon in the pass-through literature (Fajgelbaum and Khandelwal, 2021), particularly for the U.S., a large economy with significant market power to influence the terms of trade.

In this paper, we study how tariffs are shared between importers and exporters during the trade war and seek to understand the underlying determinants of the U.S.-China difference in average tariff pass-through. We find that the U.S. tariffs mostly fell on the U.S. importers, while Chinese importers only paid about two-thirds of the Chinese retaliatory tariffs. The difference in the average tariff pass-through can mainly be attributed to their different import structures and product heterogeneity in tariff pass-through. The tariff pass-through was higher for the U.S. because the U.S. imported more products with higher pass-through from China, such as electronics. In contrast, China imported more products with lower tariff pass-through from the U.S., such as agricultural products. Regarding the product heterogeneity in tariff pass-through, a higher ratio of import demand elasticity over export supply elasticity leads to lower tariff pass-through under perfect competition.

We start our analysis by estimating the average tariff pass-through in the U.S. and China using monthly panel data on tariffs and trade flows. We investigate the impact of tariffs on tariff-inclusive import prices and weigh regressions with product-exporter-level imports in 2017. We find that 93% of the U.S. punitive tariffs were borne by U.S. importers. In contrast, only 68% of China's retaliatory tariffs were passed on to Chinese importers. The difference in tariff pass-through persists under various empirical settings, such as different sets of fixed effects and different weights. The estimation of pass-through requires precisely measuring the changes in tariffs. During the trade war, China lowered the Most-Favored-Nation (MFN) tariffs to boost imports from other countries and had several regional trade agreements that granted preferential tariffs to some trade partners, who accounted for 43% of China's total imports in 2017. To account for these changes, we hand-collected the daily announcement of Chinese tariff schedules by HS-8 instead of using the annual MFN tariffs by HS-6, apart from collecting data on punitive tariffs. Based on the pass-through estimation, Chinese retaliatory tariffs were costing Chinese importers \$0.18 (\$0.51) billion per month in 2018 (2019), while U.S. tariffs were costing U.S. importers \$1.21 (\$2.47) billion per month in 2018 (2019).

The U.S.-China difference in average tariff pass-through can mainly be explained by the two countries' different import structures and different tariff pass-through rates across products. The average tariff pass-through was higher in the U.S. because the U.S. mostly imported products with high tariff pass-through. In contrast, China's tariff pass-through was lower because China imported more products with low tariff pass-through. In the presence of substantial product heterogeneity in tariff pass-through and a highly skewed import distribution, it is critical to weigh the regressions (Solon et al., 2015). The intuition is similar to using expenditure shares to construct price indices, such as the CPI. We compare the results with and without weights and verify that it is especially important to use weights when calculating the average pass-through for China, which gives an estimate of 68% as compared to 89% without weights. For the U.S., the estimation results are similar when we use weights (93%) or not (98%). This is because the correlation between import value and tariff pass-through is negative for China but close to zero for the U.S.

Apart from import structure and product heterogeneity, the remaining unexplained differences can be attributed to the two countries' different tariff regimes. Based on our econometric decomposition, we learn that tariff regimes, such as when each product is taxed and what is the tariff rate, also affect the estimation of average tariff pass-through. By documenting the key features of the trade policies implemented by China and the U.S. between 2018 and 2019, we show that the two countries indeed adopted different strategies during the trade war. The Trump government's priority was not to reduce trade deficits or manipulate the terms of trade as it claimed. The primary target was to hurt Chinese high-tech sectors. As the tariff data suggests, the U.S. government's target in the first few rounds of the trade war was high-end manufacturing products rather than the major products imported from China. This implies that the U.S. government was more concerned about competition in high-tech sectors in the long run than reducing trade deficit and minimizing welfare loss in the short run. In contrast, China chose to set tariffs in sectors where it has market power as a large importer. The Chinese government enacted retaliatory tariffs on China's primary imports from the U.S. This implies that the goal of the Chinese government was to hit the U.S. heavily and end the trade war as swiftly as possible. The different strategies adopted by the Chinese and U.S. governments also contribute to the different average tariff pass-through in the two countries.

To understand the determinants of tariff pass-through, we decompose tariff pass-through into demand and supply elasticity. Tariff pass-through is determined by import demand and export supply elasticity under perfect competition (Weyl and Fabinger, 2013). Following Zoutman et al. (2018), we estimate the elasticity using import tariffs as instruments. The U.S.-China trade war provides a perfect setting to identify the underlying determinants of tariff pass-through using tariff changes. The trade dispute was an unanticipated event, where the punitive tariffs increased unexpectedly and substantially for a wide range of products within a very short time. In comparison, free trade agreements, such as the Uruguay and Doha rounds, usually involve lengthy negotiations, which are susceptible to corporate lobbying and leave the firms sufficient time to adjust before the agreements take effect. As a quasi-natural experiment, we explore the different import price responses across countries and products and the underlying corresponding determinants in the context of the trade war. Based on our calculation, the import demand elasticity and export supply elasticity for China are 2.4 and 5, respectively. For the U.S., the import demand elasticity and export supply elasticity are 1.5 and 20, respectively. The U.S. tariff pass-through is higher because its demand elasticity to supply elasticity ratio is lower than that of China.

To further explore product heterogeneity, we decompose product-level tariff pass-through. Take the major import products as examples. For the electronics products imported by the U.S., the import demand elasticity is 1.6 and the export supply elasticity is 25. The low demand-to-supply elasticity ratio leads to a higher tariff pass-through of 93%. In contrast, the import demand elasticity and export supply elasticity of animal products imported by China are 0.6 and 0.9, respectively. A higher demand-to-supply elasticity ratio leads to a lower tariff pass-through of 68%.

This paper complements the nascent and growing literature on the U.S.-China trade war. Most of the existing works investigate the effect of U.S. tariffs, such as tariff pass-through and U.S. imports (Amiti et al., 2019; Fajgelbaum et al., 2020; Alviarez et al., 2021; Cavallo et al., 2021), employment (Flaaen and Pierce, 2019), trade diversion (Fajgelbaum et al., 2021), politics (Blanchard et al., 2019), consumption (Waugh, 2019), stock return (Huang et al., 2018; Amiti et al., 2021), and China's exports (Jiao et al., 2021; Jiang et al., 2023). In comparison, less is known about the impact of the Chinese retaliatory tariffs or non-tariff barriers (Chor and Li, 2021; Ma et al., 2021; Chen et al., 2022; Tian et al., 2022; Feng et al., 2023). Our research links the trade war literature on the U.S. and China by documenting the puzzling U.S.-China difference in average tariff pass-through. We show that the difference can mainly be attributed to the different import structures and product heterogeneity in pass-through. It is important to use weights, especially for China.

This paper contributes to the pass-through literature by exploring product heterogeneity in pass-through, which plays a central role in the estimation of economic incidence. There is a large literature on exchange rate pass-through (e.g., Feenstra, 1989; Goldberg and Knetter, 1997; Amiti et al., 2014). Most papers find incomplete exchange rate pass-through, where depreciation of the exporter's currency decreases the export price and increases the import price measured in this currency. Similarly, there is also a large body of evidence on tariff pass-through prior to the U.S.-China trade war (e.g., Feenstra, 1989; Irwin, 2014; De Loecker et al., 2016) and during the trade war (e.g., Amiti et al., 2019; Fajgelbaum et al., 2020; Cavallo et al., 2021; Jiao et al., 2021). However, less attention has been paid to product heterogeneity in pass-through and the underlying determinants despite their academic value and policy relevance. Our research contributes to the literature by estimating product-level pass-through. Furthermore, we decompose tariff pass-through into demand and supply elasticity building on the pioneer works of Weyl and Fabinger (2013) and verify that a higher import demand elasticity and lower export supply elasticity lead to a lower tariff pass-through.

This paper is also broadly related to the literature on the economic consequences of trade protectionism. Trade protectionism and decoupling have recently gained more salience. It is important to understand the economic consequences of punitive tariffs as they provide guidance for policymakers when determining trade policies. Whereas there has been a large literature estimating tariff pass-through during trade liberalization, these results do not necessarily apply to trade protection. One plausible reason is the asymmetric response of demand, where demand falls upon a tariff increase but does not rise after a tariff reduction (Irwin, 2014).[1] Our estimation is aligned with the existing works on trade liberalization and complements the literature on trade policy evaluation from the perspective of trade protectionism. Using the U.S.-China trade war as a quasi-natural experiment, our research investigates product heterogeneity in tariff pass-through and provides policy implications for understanding the economic consequences of trade protectionism policies.

The rest of the paper is organized as follows. Section 2 introduces the trade war and highlights key data patterns. Section 3 describes the data and variable construction. Section 4 illustrates the econometric specification and estimates the average tariff pass-through in China and the U.S. Section 5 seeks to understand the U.S.-China difference in the average tariff pass-through. Section 6 explores the determinants of tariff pass-through from the perspective of demand elasticity and supply elasticity. Section 7 concludes.

2 The U.S.-China trade war

In this section, we document the U.S.-China trade war, present the key empirical patterns, and summarize the different strategies adopted by China and the U.S.

In early 2018, the Trump administration launched several waves of punitive tariffs on imports from trade partners, which we refer to as the U.S. tariffs or the Trump tariffs interchangeably. The investigation under Section 201 concluded that imports of washing machines and solar panels had hurt these two U.S. industries. The U.S. government imposed global safeguard tariffs on $8.5 billion of solar panel imports and $1.8 billion of washing machine imports at rates of 20% and 30% starting on February 7. Korea and China then filed WTO disputes against these punitive tariffs. Two further investigations under Section 232 found that steel and aluminum imports had threatened national security. As a result, the U.S. issued additional tariffs on steel (25%) and aluminum (10%) imported from all countries, temporarily exempting seven trade partners on March 23, 2018, and extending to Canada, Mexico, and the European Union on June 1, 2018.[2][3] The European Union, Canada, Turkey, India, Mexico, and China imposed retaliatory tariffs in response. Specifically, China imposed additional 15% or 25% tariffs on $2.4 billion of imports from the U.S., including pork, fruits, and nuts, starting on April 2. From July 2018, the U.S. shifted its focus to China and sparked a tit-for-tat trade war between the two countries.[4] Table A1 describes the events in detail. Figure A1 shows the

[1] Irwin (2014) finds a striking asymmetry of tariff pass-through where a tariff reduction is completely passed through to consumer prices, whereas only 40% of a tariff increase is passed through to consumer prices.

[2] The seven partners are Argentina, Australia, Brazil, Canada, Mexico, the European Union, and South Korea.

[3] Around $2.8 billion in Chinese steel and aluminum exports to the U.S. were covered.

[4] The first two waves of tariff escalations were imposed on all countries. Starting from wave 1, the U.S. shifted its main target to China rather than imposing punitive tariffs on the rest of the world. On June 16, the U.S. released a list of $50 billion of imports from China to be targeted at the rate of 25%. From July 6, punitive tariffs were imposed

share of products affected by punitive tariffs for China and the U.S.

2.1 U.S. strategy

In this subsection, we compare the U.S. import structure in 2017 with its trade policy implemented in 2018. We infer that the Trump administration was primarily concerned about future competition from China in high-tech sectors. The main intentions went beyond short-run economic interests, such as manipulating the terms of trade and reducing the trade deficit.

We start the analysis by exploring the U.S. import structure. Figure 1 and Figure A2 display the U.S. import structure before the outbreak of the trade war. The red bars show U.S. import shares from China in 2017 by broadly defined product categories.[5] In 2017, U.S. imports from China accounted for 23% of its total imports. Major imports were labor-intensive products, including plastics, leathers, textiles, footwear, toys, furniture, and electronics. Specifically, the U.S. imported $150 billion of electronics from China, accounting for about 42% of total global electronics imports by the U.S. in 2017. For textiles, footwear, toys, and furniture-related products, 39% of U.S. imports in 2017 were from China.

We then turn to the trade policy implemented by the U.S. government during the trade war. It is challenging to identify the products most valued by the U.S. government because it increased tariffs on most imported goods. Figure A1 shows the share of HS-10 products affected by U.S. punitive tariffs. By the end of 2019, the U.S. government imposed punitive tariffs on 86% of the HS-10 products imported from China in 2017, about 54% of the total import value from China.[6] Furthermore, tariff rates at the HS-10 level were similar across products, either 15% or 25%. Therefore, we focus on analyzing tariffs imposed during the first few waves in 2018, as goods that were subjected to earlier tariffs were the U.S. government's main targets. As shown in Figure A1, the share of HS-10 products affected by Trump tariffs has experienced a huge rise since Wave 3. From mid-2018, the U.S. government shifted its focus to China and imposed punitive tariffs on high-end manufacturing goods in the first few rounds rather than labor-intensive products that the U.S. imported heavily

on imports worth approximately $34 billion (wave 1). The remaining $16 billion were taxed from August 23 (wave 2). In response, China issued retaliation lists for U.S. imports worth $50 billion (25% punitive tariffs) to be enforced on July 6 (wave 1) and August 23 (wave 2).

[5] Product categories are classified as follows: Animal Products (HS-2 codes: 01-05), Vegetables Products (HS-2 codes: 06-14), Food (HS-2 codes: 15-24), Plastics (HS-2 codes: 39-43, 44-49), Raw Materials (HS-2 codes: 25-38), Textiles (HS-2 codes: 50-67, 71, 94-97), Metals and Nonmetals (HS-2 codes: 68-70, 72-83), Machinery (HS-2 codes: 84), Electronics (HS-2 codes: 85), Vehicles (HS-2 codes: 87, 89), Aircraft (HS-2 codes: 86, 88, 93), Optical Instruments (HS-2 codes: 90-92). Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refer to chemicals, crude oil, and mineral products. Textiles refer to textiles, footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refer to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.

[6] If we ignore tariff exemption, the U.S. government imposed punitive tariffs on 90% of the HS-10 products imported from China in 2017, about 67% of the total import value from China. At the HS-6 level, the U.S. government imposed punitive tariffs on 91% of the HS-6 products imported from China in 2017. If we ignore tariff exemption, the U.S. government imposed punitive tariffs on 93% of the HS-6 products imported from China in 2017.

from China. As shown in Panel B of Figure 2, the first few waves of punitive tariffs were targeted at high-tech products from China, such as aircraft, railways, optical instruments, and machinery, most of which were listed in China's five-year plan "Made in China 2025" (Ju et al., 2020).[7]. The import values of major targeted products in the first few waves (e.g., aircraft, railways, optical instruments) did not make up a large proportion of the total imports. By the end of 2019, products that had not been subject to punitive tariffs were mainly labor-intensive goods, including textiles, footwear, toys, furniture, and electronics. These patterns could also be observed in Panel B of Figure A3, which shows the average tariffs for each broad product category over time. As shown in Panel B of Figure A4, the U.S. tariffs on Chinese goods were negatively correlated with its imports from China, implying that manipulating the terms of trade and reducing the trade deficit was not U.S.'s primary target. Meanwhile, the Bureau of Industry and Security (BIS) of the U.S. Department of Commerce added a number of high-tech Chinese firms to its Entity List and imposed trade restrictions. Putting several pieces of evidence together, we infer that the U.S. government was more concerned about future competition in high-tech sectors than about reducing the trade deficit. Apart from high-tech sectors, the U.S. government was also preoccupied with product substitutability and the economic interest of U.S. importers and consumers in the first few rounds, as the U.S. avoided imposing higher tariffs on major imported products from China. Fajgelbaum et al. (2020) show that political election was another concern of the Trump administration.

2.2 China's strategy

By comparing China's import structure in 2017 with its trade policy implemented in 2018, we show that China adopted a different strategy. While the U.S. government targeted high-tech products that the U.S. did not import heavily from China in the first few waves, the Chinese government imposed tariffs on its major imported goods from the U.S., such as soybeans and vehicles and excluded aircraft-related products due to their low sustainability.

Figure 1 and A2 display the Chinese import structure. In 2017, China's imports from the U.S. accounted for 9% of its total imports. The green bars show that China imported mostly agricultural products and high-tech products from the U.S., such as aircraft and vehicles. Specifically, China imported $16 billion of vegetable products, such as soybeans, from the U.S., accounting for about 27% of China's total global imports of vegetable products in 2017. In the field of aircraft and railways, 53% of China's imports were from the U.S.

Following the same logic as our analysis of the U.S. trade policy, we analyze the patterns of the first few waves of Chinese tariffs in 2018. As shown in Figure A1, the share of HS-8 products

[7] Later waves covered nearly all listed products. More detailed descriptions are displayed in Panel A of Table A1. Except for labor-intensive products that the U.S. imported heavily from China, the cumulative tariff rates for all other products reached more than 20%. The import shares of affected products in 2017 in each wave are plotted in Panel B of Figure A5. It shows that around 55% (34%) of U.S. imports of aircraft (optical instruments) were affected by the Trump tariffs in Wave 1. In contrast, major products that the U.S. imported from China, such as labor-intensive products, were mostly unaffected in Wave 1 and Wave 2.

affected by China's retaliatory tariffs was above 70% after Wave 3. By the end of 2019, 84% of HS-8 products were subject to retaliatory tariffs, about 60% of China's total imports from the U.S.[8] In contrast, the Chinese government enacted tariff increases on its major imports from the U.S. that were more substitutable in 2018, such as agricultural products and vehicles. Meanwhile, China avoided imposing higher tariffs on its major imports from the U.S. that were less substitutable, such as aircraft and spacecraft. As shown in Panel A of Figure 2, the first two waves (prelude 1 and wave 1) targeted animal products, vegetable products, and transportation equipment, such as vehicles, which occupied a relatively sizable share of China's imports from the U.S. (Figure 1). Wave 2 added plastics, leathers, and raw materials (e.g., mineral fuels) to the list, while waves 3, 4, and 5 covered almost all remaining goods. The retaliatory tariffs varied significantly across product categories, as shown in Panel A of Figure A3. The tariff retaliation disproportionately focused on agricultural products, with animal products rising by 43% and vegetable products by 30%. In contrast, goods relating to aircraft, railways, and optical instruments suffered the least (i.e., below 10%).[9] Almost all agricultural products and vehicles from the U.S. were subject to retaliatory tariffs in the first few waves, while imports of aircraft and railway products (less substitutable) remained mostly unaffected by the end of 2019. The data pattern implies that China adopted a different strategy during the trade war. The goal was to hit U.S. exporters as hard as possible in order to end the trade war at the earliest opportunity. The positive correlation between the Chinese retaliatory tariffs and the Chinese import share from the U.S. in Panel A of Figure A4 further confirms our conjecture.

3 Data and variable construction

This section describes the data and variable construction. We use tariff and trade data from 2017 through 2019 for our primary empirical analysis.

3.1 Tariff data

We build granular panel data with information on the U.S. and Chinese tariffs. For the U.S. import tariffs, we obtain (i) the annual baseline tariff schedule imposed by the U.S., which was released in January and revised mid-year by the United States International Trade Commission (USITC), available at the country-HS-8 product level; (ii) U.S. punitive tariffs imposed on goods imported from China and other countries based on announcements by the United States Trade Representative

[8]If we ignore tariff exemption, 85% of the products were subject to retaliatory tariffs by the end of 2019, about 70% of China's total imports from the U.S. in 2017. At the HS-6 level, 89% of the products had been imposed retaliatory tariffs. If we ignore tariff exemption, 90% of the products were subject to retaliatory tariffs by the end of 2019.

[9]The import shares of affected products in 2017 in each wave are plotted in Panel A of Figure A5. It shows that for animal products (vegetable products), around 96% (99%) of Chinese imports were affected by the Chinese retaliatory tariffs in Prelude 1 and Wave 1. For vehicles, 86% of imports were affected in Wave 1. In contrast, only 2% of Chinese imports on aircraft were imposed punitive tariffs by the end of 2019.

(USTR), available at the country-HS-10 product level; and (iii) tariff exemptions, available at the country-HS-10 product level.[10] For China's import tariffs, we obtain (i) the annual baseline tariff schedule imposed by China, which was released in January by the Customs General Administration of China, available at the country-HS-10 product level; (ii) retaliatory tariffs imposed by China on U.S. goods based on official documents released by the Ministry of Finance of China, available at the HS-8 level; (iii) tariff exemptions, available at the HS-8 product level; and (iv) adjustments in MFN tariff schedule and Free Trade Agreement (FTA) preferential rates released by the Ministry of Finance of China, available at the country-HS-8 product level.[11] It is worth noting that we do not use the conventional 6-digit HS annual MFN tariffs when measuring the applied tariffs. Instead, we use the monthly MFN tariff schedules at the 8-digit HS level because China lowered its MFN tariffs during the trade war to alleviate the adverse effect of U.S. punitive tariffs. We also consider the FTA preferential rates that vary by trade partners and products. Because it is essential to measure the applied tariffs accurately, we hand-collect the country-HS-8 product level tariff adjustment data.[12] In the calculation, we scale the punitive tariffs by the number of days of the month in effect and then aggregate the tariffs by the month, following Fajgelbaum et al. (2020). Table A2 displays the summary statistics.

Figure 3 plots the dynamics of U.S. tariffs imposed on China (solid green line) and the rest of the world (ROW, dashed green line), as well as Chinese tariffs on the U.S. (solid red line) and the rest of the world (dashed red line) from January 1, 2018, to December 31, 2019.[13] With the increases in punitive tariff rates and more products included in the lists, the import-weighted average tariff rates increased rapidly over time during the U.S.-China trade war. Specifically, U.S. tariffs on Chinese products rose from 2.7% in January 2018 to 13.8% in December 2019, and Chinese tariffs on U.S. products increased from 5.3% to 16.2% during the same period. It is worth noting that the tariffs occasionally experienced some slight declines. There are two reasons for this. One reason is that China lowered its MFN tariffs and preferential tariffs several times. For instance, China cut the MFN tariff rates on daily consumption goods, automobiles, and information technology products on July 1, 2018, which is also reflected in the dashed lines. Meanwhile, China also cut the tariff rates for its FTA partners. The second reason is that the U.S. and Chinese governments issued a series of tariff exemptions and a 90-day truce after the G20 meeting on December 1, 2018. The U.S. tariffs on imports from other countries changed from 1.2% in January 2018 to 1.5% in December

[10]One source of information on the Trump tariffs is Bown (2021). To double-check the data, we compare our measures of punitive tariffs with the data published by Amiti et al. (2020) and Fajgelbaum et al. (2020).

[11]We drop products with specific duties, namely a levy of duty per unit, products with mixed duties, namely products with both ad valorem equivalent tariffs and specific duties, and products without ad valorem equivalent MFN tariffs, as their imports accounted for only 0.58% of China's total imports in 2017. For products with import quotas, we assume the imports of these products are within the quota restriction and use the lowest tariff rates (e.g., MFN, FTA) to measure their applied tariffs.

[12]The correlation coefficients between our measures of tariff rates and annual MFN tariff rates are 0.6 and 0.5 for China and the U.S., respectively.

[13]Bown (2021) has provided a detailed and up-to-date timeline for the U.S.-China trade war and our summary statistics are comparable.

2019.[14] Chinese tariffs on imports from other countries changed from 2.6% in January 2018 to 2.1% in December 2019. The summary statistics in Section 2 and Section 3 show that there are enough variations for Chinese and U.S. punitive tariffs across products, across trade partners, and over time, which allows us to empirically identify the impact of tariffs on imports during the trade war.

3.2 Trade data

For the U.S., we obtain monthly U.S. import values (in USD) and quantities at the country-HS-10 product level from the U.S. Census Bureau. Our sample has over 17,000 HS-10 products and covers more than 200 countries from January 2017 to December 2019. For China, we use publicly available monthly import data from the Customs General Administration of China that records import values (in USD) and quantities at the country-HS-8 product level. Our sample period ranges from January 2017 to December 2019 and contains over 7,000 HS-8 products and over 200 supply countries. We also observe the customs regime (e.g., ordinary trade, processing, and assembling). The unit value is calculated as the ratio of import value over quantity. The tariff-inclusive unit value is the unit value multiplied by (1 plus) the import tariff rate.

4 Average tariff pass-through

In this section, we seek to answer the first research question by estimating the average tariff pass-through in China and the U.S. To this end, we examine the responses of import values, import quantities, and import prices to tariff changes over the period of January 2017 to December 2019. To compare the average tariff pass-through in the two countries, we estimate and compare the tariff pass-through of China and the U.S. using comparable data under comparable empirical frameworks.

4.1 Baseline results

We explore the impact of the tariffs on imports (i.e. import values, quantities, and prices) at the source country i, product g, month t level. We regress the month-to-month log change of the Chinese or U.S. import value $\Delta lnp_{igt}q_{igt}$, import quantity Δlnq_{igt}, tariff-exclusive import price Δlnp^*_{igt}, or tariff-inclusive import price Δlnp_{igt} on the log change of tariffs, where $\Delta ln(1+\tau_{igt})$ denotes the log change of tariffs between month t and the last month $t-1$. As both the dependent variables and the tariffs are measured in logs, the coefficient β measures the trade elasticity. The econometric specification is shown as follows in Equation (1):

[14] The U.S. imposed Section 232 tariffs on steel and aluminum imported from all countries, temporarily exempting seven countries on March 23, 2018, and later extended to Canada, Mexico, and European Union on June 1, 2018. The seven countries are Argentina, Australia, Brazil, Canada, Mexico, the European Union, and South Korea. The dashed green line shows that the U.S. tariffs on imports from the ROW slightly increased twice during the early part of 2018. Tariff exemptions for other countries other than China lowered the average tariff (green dashed line).

$$\Delta lny_{igt} = \beta \Delta ln(1+\tau_{igt}) + \eta_g + \eta_{Gt} + \eta_{it} + \varepsilon_{igt}. \quad (1)$$

We include country-year-month fixed effects η_{it} to control for country-specific time-varying factors affecting imports, such as exchange rate fluctuations. To account for time-invariant and time-variant product heterogeneity, we include HS-8 (HS-10) product fixed effects η_g and HS-6-product-year-month fixed effects η_{Gt} for China (the U.S.).[15] The changes in punitive tariffs, MFN tariffs, and preferential tariffs are considered. The standard errors are clustered at the HS-6 product level and country level. This allows the residual term ε_{igt} to be correlated over time and across HS-8 (HS-10) products within each HS-6 product and country pair in China (the U.S.). All regressions are weighed using the import value in 2017 by the source country i and product g. In Section 5, we will elaborate on why we run weighted regressions instead of simple average regressions.

The above specification allows us to identify the within-product changes in Chinese (U.S.) imports from the U.S. (China) relative to other source countries. The coefficient of interest β measures the tariff pass-through when the dependent variable is the log change of tariff-inclusive import price. Table 1 reports the baseline estimation results. Panel A shows the results using the Chinese import data. There is a sharp decline in import values when the tariffs rise. Column (1) indicates that a 1% increase in tariffs leads to a 1.9% decrease in the import values. We further decompose the changes in import values into two components, namely, the changes in import quantities (Column 2) and the changes in unit values (tariff-exclusive prices, Column 3). As shown in Column (2), a 1% increase in tariffs is associated with a 1.6% decrease in import quantities. The estimated effect could be underestimated because of zero imports. The impact of tariffs on the number of varieties will be analyzed in Section 6.2. To address this concern, we use the inverse hyperbolic sine transformation in Column (1) of Table A3. After correcting for zeros, we find that a 1% increase in tariffs results in a 7.8% decrease in import values.[16] This estimate of trade elasticity is similar to the estimates in the literature (e.g., Broda and Weinstein, 2006), which usually ranges from 3 to 8. As a comparison, Panel B shows the results using the U.S. import data. A 1% increase in tariffs leads to a 1.5% decrease in import values and a 1.4% decrease in import quantities. After we adjust for zeros and use the inverse hyperbolic sine transformation, the effect of tariffs on import values changes to -1.3%.

Columns (3) and (4) show our key findings on how the prices faced by exporters and importers move in response to a tariff increase. We regress the changes in the log import unit values, namely the log tariff-exclusive import prices, on the changes in tariffs in Column (3). The estimate of the impact of tariffs on unit values is -0.32% for China (Panel A), suggesting that foreign exporters paid one-third of the Chinese retaliatory tariffs. In contrast, the impact of the U.S. tariffs is noisily estimated. It is not statistically different from zero for the U.S. (Panel B), implying an absence of the terms-of-trade effect. In Column (4), we regress the changes in log tariff-inclusive import prices on the changes in

[15] The trade data and tariff data are measured at the HS-8 level for China and are measured at the HS-10 level for the U.S.

[16] When the import values are positive in t and zero in $t-1$ or $t+1$, we use the inverse hyperbolic sine transformation.

tariffs. We obtain an estimate of 68% in Panel A and an estimate of 93% in Panel B. The estimate in Panel B is not statistically significantly different from 100%, so we can not reject the hypothesis of complete pass-through in the U.S.[17] The key results in Columns (3) and (4) imply that two-thirds of the Chinese import tariffs were borne by Chinese importers, and the rest were paid by foreign exporters. In comparison, the burden of the U.S. import tariffs has been entirely borne by U.S. importers, consistent with the previous findings (e.g., Amiti et al., 2019; Fajgelbaum et al., 2020; Cavallo et al., 2021).

While our findings on the pass-through of U.S. punitive tariffs are consistent with the literature, our estimation of the impact of Chinese retaliatory tariffs is different from the literature. While we find an incomplete pass-through of Chinese tariffs, the previous findings indicate a complete pass-through for retaliatory tariffs. Different research objects, data, and weights can explain the different findings. First, we focus on the retaliatory tariffs imposed only by China, while Amiti et al. (2019) and Fajgelbaum et al. (2020) study the average effect of retaliatory tariffs imposed by several U.S. trading partners, including China. Second, we use Chinese import data to estimate the effects on Chinese importers and foreign exporters. In contrast, Amiti et al. (2019) and Fajgelbaum et al. (2020) use U.S. export data to estimate the effects of retaliatory tariffs on U.S. exporters. It usually takes several weeks to a few months for exported products to be shipped from the U.S. to China, especially for goods exported from the eastern coast.[18] In terms of the timing of tariff implementation, import data can better match the punitive tariff data. Third, we use imports as weights in the analysis. In Section 5, we will compare the results with and without weights and show that it is important to use weights in the presence of product heterogeneity and skewed import distribution.

With the estimated tariff pass-through, we now seek to measure the welfare effect of punitive tariffs under the assumption of perfect competition. In the first-order approximation, the change in consumer surplus depends on three components, namely the import-weighted average of the tariff changes for targeted varieties, tariff pass-through, and import value for targeted varieties in 2017. We calculate China's imported-weighted average tariff change for targeted varieties as 9.78% in 2018 and 19.31% in 2019, respectively. Combined with the average monthly import value for targeted varieties in 2017 ($8.98 billion) and pass-through (68%), we conclude that Chinese importers lost $0.18 billion per month in 2018 and $0.51 billion per month in 2019 (or $2.16 billion in 2018 and $6.12 billion in 2019) from Chinese retaliatory tariffs. Similarly, the U.S. imported-weighted average tariff change for

[17]In order to make the data structure more comparable for the two countries, we aggregate the HS-10 U.S. import data to HS-8 and re-run the regressions. As shown in Table A4, the results are robust.

[18]To study the overall effect of retaliatory tariffs on U.S. exporters, using U.S. export data is a more feasible choice compared to collecting import data across importers. However, there is a caveat to using export data. The month in which the retaliatory tariffs were imposed, i.e. the month the shipment arrived at the foreign ports, can be different from the month the shipment left the U.S. ports. This is especially the case when foreign countries are geographically distant from the U.S., such as China and the EU countries. Because retaliatory tariffs changed frequently, i.e. were imposed, excluded, and increased again intensively in the adjacent months, it is important to match the tariff data with the corresponding correct trade data. To support this hypothesis, we empirically find a strong negative relationship between bilateral distance and the import-export discrepancy, which is the correlation of country A's monthly import from country B with country B's monthly export to country A.

targeted varieties was 3.78% in 2018 and 7.73% in 2019, respectively. Based on the information on the average monthly import value for targeted varieties in 2017 ($319.25 billion) and pass-through (100%), we conclude that U.S. importers lost $1.21 billion per month in 2018 and $2.47 billion per month in 2019 (or $14.52 billion in 2018 and $29.64 billion in 2019) from the U.S. tariffs. The welfare losses we calculate are consistent with those calculated in previous studies. Amiti et al. (2019) estimate that the U.S. total deadweight losses reached $8.2 billion throughout 2018 based on a partial equilibrium model where the import market is perfectly competitive. In Fajgelbaum et al. (2020)'s estimation, importers lost $50.8 billion from January 2018 to April 2019.

4.2 Threats to identification

Addressing the potential endogeneity of tariff increases is a key challenge. In this subsection, we address several threats to empirical identification by controlling for confounding factors. To further alleviate the concern about different preexisting trends and the anticipation effect, we adopt an event study specification and provide several pieces of supporting evidence on the exogeneity of punitive tariffs.

There are three main concerns when estimating tariff pass-through. First, the tariffs imposed by the U.S. and Chinese governments might be correlated with unobserved domestic import demand or foreign export supply shocks. For example, firms in certain sectors are more likely to lobby for trade protection. Besides, if governments strategically impose higher tariffs on products with low (high) pass-through, there will be a downward (upward) bias. This is because our measured tariff rates might be correlated with some unobserved product features, such as skill intensity and tech intensity. For instance, the Trump tariffs targeted high-tech products from China, which were listed in China's five-year plan "Made in China 2025" (Ju et al., 2020). To mitigate this concern on the omitted variable bias, we estimate the tariff elasticities in Table 1 by taking the first difference and controlling for HS-10 (HS-8) product fixed effects and HS-6 product-year-month fixed effects for the U.S. (Chinese) import regressions. The HS-10 (HS-8) product fixed effects capture time-invariant product characteristics. The HS-6 product-year-month fixed effects control for time-varying factors (e.g., global technological change, lobbies) that affect imports from all countries.

Second, tariff changes may coincide with other events which affect tariff pass-through. One major concern is fluctuations in exchange rates. As suggested in Figure A6, the RMB depreciated against the USD during the trade war, partly offsetting the Trump tariffs and alleviating the tariff burdens on Chinese exporters. The co-movement of tariffs and exchange rates complicates the estimates of tariff elasticities. To mitigate this concern, in Table 1 we estimate tariff elasticities using first-difference equations and include country-year-month fixed effects. The country-year-month fixed effects allow for time-varying and country-specific forces that affect imports (e.g., exchange rates).

Moreover, we adopt an event-study specification following Fajgelbaum et al. (2020) to certify the identifying assumption with the parallel trends between treated and untreated groups before the trade war. In the event study (Equation 2), we regress log duty-inclusive unit values (lnp_{igt}) on interactions between treatment time dummies ($I\left(event_{igt}=j\right)$) and targeted variety dummies ($target_{ig}$) for Chinese and U.S. imports:

$$\begin{aligned} lnp_{igt} = \alpha_{ig} + \alpha_{gt} + \alpha_{it} + \sum_{j=-12}^{12} \beta_{0j} I\left(event_{igt}=j\right) \\ + \sum_{j=-12}^{12} \beta_{1j} I\left(event_{igt}=j\right) \times target_{ig} + \epsilon_{igt} \end{aligned} \tag{2}$$

where the reference month is the last untreated month (i.e. $\beta_{10}=0$). We include country-product (defined as variety) fixed effects (α_{ig}), product-year-month fixed effects (α_{gt}), and country-year-month fixed effects (α_{it}) in the specification. For China and the U.S., products are defined at the HS-8 level and HS-10 level, respectively. Standard errors are clustered by HS-6 product and exporter, allowing the ϵ_{igt} to be correlated across products and over time within every HS-6 product and exporter. We assign the event month of targeted varieties to be the nearest month when the punitive tariffs were first implemented. In the control group, non-targeted varieties within the same HS-6 product category are assigned with the earliest event date of targeted varieties within that HS-6 product. The event dates of other non-targeted varieties are assigned sequentially based on the earliest month of targeted varieties within the same HS-4 product. We delete the remaining HS-4 products unaffected by punitive tariffs.

Both the duty-inclusive unit values and tariffs are measured in logs. The estimated coefficient β_{1j} measures tariff elasticity for a given time horizon j. With the inclusion of the product-year-month fixed effects (α_{gt}), we obtain β_{1j} using variations between targeted and non-targeted varieties for a given product-year-month pair. Figure 4 reports the impact on log duty-inclusive unit values by month for the 12 months before and after the treatment, where observations with treatment periods longer than 12 months are combined into the final 12-month category. The results suggest that the estimated coefficients for the months before the treatment are statistically indistinguishable from zero for most periods. Table A5 displays the results on pre-trends, where we regress imports before the trade war on tariff changes during the trade war. The results confirm the event study findings that there is no clear pattern of pre-trends for either China or the U.S.

Third, if importers had anticipated punitive tariffs before implementation and shifted their imports in advance, it would induce a mismatch between the timing of tariff changes and imports, which complicates the tariff elasticity estimation. The event study plot in Figure 4 indicates that anticipatory effects are quantitatively small and, therefore, negligible. Hence, the concern that importers shift their imports in advance to avoid paying punitive tariffs is mild.

4.3 Robustness checks

In this subsection, we conduct a set of tests to examine the robustness of the results. We adopt different sets of fixed effects, deal with outliers, and examine the pass-through using different subsamples and different levels of aggregation.

Alternative fixed effects. In our baseline setting, we control for HS-10 (HS-8) product fixed effects, HS-6 product-year-month fixed effects, and country-year-month fixed effects for the U.S. (China). On the one hand, these fixed effects may absorb tariff pass-through effects that are common across trade partners or products. For example, the U.S. tariffs may lower the overall wage level in China and thus lower the export price of all Chinese goods shipped to the U.S. It is also possible that the price stickiness and selection effects may vary across products. On the other hand, these fixed effects may not capture unobserved confounding factors, such as import demand and export supply shocks varying at the country-HS-6-product level. In the robustness checks, we regress tariff-inclusive unit values on tariff changes with different sets of fixed effects to explore the above possibilities. We first relax the fixed effect controls in Columns (2) of Table A3. The coefficients become much smaller for both countries, suggesting that it is important to control for product-time fixed effects. In Column (3), we remove HS-8 fixed effects. The coefficients are similar relative to baseline results, suggesting that the product heterogeneity within HS-6 is limited and therefore controlling for HS-6 fixed effects is sufficient. We then add additional controls relative to baseline analysis in Column (4) to control for country-HS-6-product fixed effects. In Column (5), we additionally allow bilateral exchange rate fluctuations to exert different impacts on different products. From Columns (3) to (5), we obtain very robust estimates. In Panel A, the average tariff pass-through for China range from 65% to 68%, similar to our baseline estimation of 68%. In Panel B, the U.S. tariff pass-through range from 93% to 95%, which are also close to our baseline estimation of 93%.

Outliers. The interference of outliers could bias the estimate of trade elasticity. To alleviate this concern, we tried different ways of dealing with outliers. Table A6 presents the results. In Panel A, we winsorize variables at a fraction of 2.5% in each tail. In Panel B, we calculate the ratio of the unit value in t relative to that in $t-12$ and drop observations with a ratio greater than 3 or less than 1/3. We obtain consistent results compared with our baseline regressions.

Different horizons. In our baseline regressions in Table 1, we take the month-to-month differences for both imports and tariffs, which estimates the short-run impact. We now assess the tariff incidence at a different time horizon by switching to a year-to-year specification. More explicitly, we regress the changes in year-to-year log import values and log tariff-inclusive prices on the changes in tariffs. As shown in Column (6) and Column (7) of Table A3, the impacts of tariffs on imports and duty-inclusive prices both become slightly greater at the medium-term frequency compared to our baseline results in Column (1) and Column (4) of Table A3, respectively.

Levels of aggregation: HS-8 vs. HS-10. The U.S. monthly import data vary by HS-10 product and trade partner, while the Chinese data vary by HS-8 product and trade partner. To make sure the data are comparable, we aggregate the U.S. import data to the country-HS-8-product-year-month level and rerun the regressions. The results in Columns (5) and (6) in Table A4 are similar to those in the baseline regressions, implying that the different levels of aggregation are not the main contributor to the difference in pass-through between the two countries.

Different trade regimes. One key feature of China's import pattern is the large share of processing imports. Processing imports refer to duty-free inputs, which are processed in China and then exported. These imports are exempted from import tariffs. It is worth stating that the Chinese retaliatory tariffs imposed during the trade war also applied to processing imports when the inputs were imported. This is because the government wanted to prevent illegal tariff avoidance through processing trade. In the robustness check, we divide the total sample into ordinary imports, processing imports, and other imports based on the information on customs regimes in our data. Their corresponding import shares in 2017 were 61.15%, 21.52%, and 17.34%, respectively.[19] The time trends of Chinese imports from the U.S. by customs regime in Figure A7 show that only ordinary imports experienced a sharp decline during the trade war. The effects of tariffs on import outcomes may vary due to different import structures by customs regime (e.g., processing imports include more labor-intensive products). We then set baseline tariff rates to zero for processing and other imports and regress by customs regime. We find a 70%, 86%, and 103% pass-through of the Chinese tariffs in ordinary, processing imports, and other imports in Table A8.

5 Decomposing tariff pass-through: import structure, product heterogeneity, and tariff regime

5.1 Decomposition

The main results in Column 4 of Table 1 are surprising as the tariff pass-through was quite different in the two countries for the same event. Whereas the Chinese import tariffs were shared among Chinese importers and foreign exporters, the U.S. tariffs were completely passed on to U.S. domestic importers. It is also surprising that the impact of Trump tariffs on U.S. import prices was one-for-one, which was in contrast to the terms-of-trade effect proposed in the literature prior to the trade war. The complete pass-through phenomenon is especially puzzling for the U.S. because the U.S. should be large enough to affect export prices. As summarized by Fajgelbaum and Khandelwal (2021), most papers estimating the tariff or exchange rate pass-through find incomplete pass-through (e.g., Feenstra, 1989; Amiti et al., 2014; Irwin, 2014; De Loecker et al., 2016). The existence of the

[19] Processing imports include pure assembly processing import and import and assembly. Other imports include aid or donation, compensation trade, goods on consignment, border trade, equipment for processing trade, contracting projects, goods on a lease, equipment or materials imported as investment by foreign-invested enterprises, outward processing, barter trade, duty-free commodities on payment of foreign currency, customs warehousing trade, entrepot trade by bonded area, equipment imported into logistics goods by customs special control area, other, duty-free goods, which are also duty-free.

terms-of-trade effect and incomplete pass-through can also be inferred from papers on the estimation of tariff elasticities, namely import demand elasticities and export supply elasticities (e.g., Broda and Weinstein, 2006; Romalis, 2007). In the literature on the exchange rate pass-through, most of the works find incomplete exchange rate pass-through (e.g., Feenstra, 1989; Goldberg and Knetter, 1997).

In this section, we seek to interpret the puzzling findings by decomposing the average tariff pass-through from the econometrics perspective. In the Appendix, we provide detailed proofs. We have

$$Y_i = X_i' \sum_{g=1}^{K} \left[\beta_g \mathbb{I}\left(i \in G_g\right)\right] + Z_i'\alpha + \varepsilon_i,$$

where Y_i refers to the tariff-inclusive import price of a certain HS-8 (HS-10) product imported from a given country in a given month, g refers to a specific group, $Z_i = \left(\mathbb{I}\left(i \in G_1\right), \mathbb{I}\left(i \in G_2\right), \ldots, \mathbb{I}\left(i \in G_K\right)\right)'$ and $\alpha = \left(\alpha_1, \ldots, \alpha_K\right)'$. This model is in accordance with the setting in our paper

$$\underbrace{\Delta \ln y_{igt}}_{Y_{igt}} = \underbrace{\beta \Delta \ln\left(1 + \tau_{igt}\right)}_{X_{igt}'\beta_g} + \underbrace{\eta_g + \eta_{Gt} + \eta_{it}}_{Z_i'\alpha} + \varepsilon_{igt},$$

where t, g, and G together forms a group system. In this note, this group system is denoted by $G_{1:K}$. Now let $\mathbf{Z}$ be the $n \times K$ matrix of dummy variables for groups. Since we have a full set of dummy variables, we don't need an intercept. We have

$$\hat{\beta} \rightarrow \left(\sum_{g=1}^{K} \left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]\right)^{-1} \left[\sum_{g=1}^{K} s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right) \beta_g\right],$$

and the weight for β_g is

$$\left(\sum_{g=1}^{K} \left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]\right)^{-1} \left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]$$

The above decomposition suggests that the average tariff pass-through is jointly determined by product-specific tariff pass-through β_g, sample weights, and tariff regimes X_i. It is important to weigh the regressions in the presence of a skewed import distribution and product heterogeneity in tariff pass-through. The intuition is similar to using expenditure share as weights when we calculate prices indexes, such as the CPI. To illustrate the idea on calculating the average pass-through, suppose there are only two products for simplicity ($K = 2$). As the import data suggests, China imported base metals or silver (HS code: 7109) worth \$10,954 from the U.S. in 2017, whose tariff pass-through is 1.38. Meanwhile, China imported grain sorghum (HS code: 1007) worth \$956.97 million from the U.S. in 2017, whose tariff pass-through is 0.5. If we calculate the average pass-through for these two products, the import cost share weighted pass-through (0.5) would be much lower than the simple average pass-through (0.94). Similarly, the U.S. imported telephone sets (HS code: 8517) worth $71,703 million from China in 2017, whose tariff pass-through is 1.4. Meanwhile, the U.S. imported lax yarn (HS code: 5306) worth $105,557 from China in 2017, whose tariff pass-through is 0.47. The import cost share weighted pass-through (1.4) is higher than the simple average pass-through (0.95). From the above two examples, we learn the importance of using weights.

To identify average partial effects in the presence of unmodeled heterogeneity, we follow the empirical practices recommended by Solon et al. (2015). We start by exploring the heterogeneous tariff pass-through across products and then show the skewness of import distribution.[20] We then compare weighted and unweighted estimates, which can serve as a test for misspecification. In addition, we also show that the two countries have adopted different tariff regimes during the trade war, which also contributes to the U.S.-China difference in average tariff pass-through.

5.2 Product heterogeneity and import structure

Guided by the econometric decomposition, we start by exploring product heterogeneity and estimating tariff pass-through across products. In Equation 3, we regress the changes in log tariff-inclusive import prices on the changes in tariffs and the interactions with product category dummies $I\left(product_g = c\right)$, where product categories c are defined based on HS-2 codes classifications in Section 2.[21] As shown in Figure 5 and Table 4, pass-through differs across products. Agricultural goods, such as vegetables and animal products, and high-tech manufactured products, such as aircraft, tend to have low tariff pass-through.[22] Moreover, the tariff pass-through for the same products in the two countries can be different. Figure 5 ranks products by their tariff pass-through. While the pass-through rates for aircraft, vehicles, and plastics are similar in the two countries, the pass-through rates are very different for textiles, food, and machinery.[23] In section 6, we will discuss why tariff pass-through differs across products.[24]

$$\Delta lny_{igt} = \sum_c \beta_c I\left(product_g = c\right) \times \Delta ln(1+\tau_{igt}) + \eta_g + \eta_{Gt} + \eta_{it} + \varepsilon_{igt}. \tag{3}$$

[20] According to Solon et al. (2015), we should use weights when the following two conditions are satisfied, namely a highly skewed distribution of imports across products and a substantial heterogeneity in tariff pass-through across products.

[21] Consistent with baseline estimation (Equation 1), the regression is weighed using the import value in 2017 by the source country i and product g. Standard errors are clustered at the HS-6 product and country levels.

[22] Han et al. (2023) analyze the heterogeneous impact of tariff changes on stock returns across industries.

[23] The tariff pass-through of aircraft is negative. One likely cause is the change in import composition. As we only have product-level data not brand-level data, it is hard to alleviate the concern on the composition effect. In Table 2, we exclude products with negative pass-through to examine if the US-China difference is driven by aircraft imports.

[24] To explore the role of weights, we conduct another experiment by applying the U.S. (Chinese) import weights in the Chinese (U.S.) regressions. Consistent with our conjecture, the estimates differ significantly from our baseline estimates, showing the important role of weights. One caveat to this exercise is that China and the U.S. adopt different product coding systems at the HS-8 level, so we have to aggregate the data at the HS-6 level. Another caveat is that due to different import structures, namely zero import values for many products, we lose one-third of our samples.

We then explore the skewness of the import distribution. Figure 6 shows that the import distributions were highly right-skewed for both countries. Figure 7 shows that the average tariff pass-through was lower in China because China disproportionately imported more products with lower tariff pass-through from the U.S. Figure 1 and A2 show the import structures of China and the U.S. by broad product category. Primary Chinese imports from the U.S. included agricultural products such as soybeans and corn and high-end manufacturing goods such as aircraft and vehicles. In contrast, the U.S. mainly imported labor-intensive products from China, such as electronics, with higher tariff pass-through. Because of the different import structures, the estimation of the average tariff pass-through will be severely biased if we treat each country-product pair equally and do not weigh the regressions with import values.

The above two stylized facts on the product heterogeneity in tariff pass-through and skewness of the import distribution suggest that we need to use weights when estimating the average tariff pass-through. In Table 2, we compare the weighted and unweighted estimates of tariff pass-through. The top panel reports results for China, while the bottom panel reports results for the U.S. Column (1) of each panel reports the corresponding baseline estimates to facilitate comparisons. In Column (2), we replicate the baseline regressions without using import values as weights. China's tariff pass-through increases drastically from 68% to 89%, while the U.S. tariff pass-through remains stable. Without weights, the magnitudes of the estimated tariff pass-through for both countries are similar and close to 1 (Column 2). Comparing the findings in Column 1 and Column 2, we learn that the results for the U.S. remain robust with and without weights, but this is not the case for China. This is because the correlation between import value and tariff pass-through should be close to 0 for the U.S. but negative for China, as shown in Figure 7. While China imported disproportionately more products with lower tariff pass-through, this is not the case for the U.S.

To determine whether the above findings are robust, we try alternative weights. In Column (3), we use as weights the country-product-level import value from 12 months before. pass-through is similar to the results using the import value in 2017 (Column 1). The comparisons (Columns 1 vs 2, Columns 1 vs 3) suggest that the estimates for China remain robust with different sets of weights but vary significantly without using weights. The results in Table 2 imply that different import structures in the two countries are the main reason for the different average tariff pass-through. As shown in Figure 5 and Figure 1, the tariff pass-through of aircraft is negative and China's import value of aircraft is high. To examine whether the U.S.-China difference in average tariff pass-through is driven by aircraft imports, we exclude aircraft imports in Column (4) of Table 2. The results are similar to baseline results in Column (1).[25]

Apart from obtaining the average tariff pass-through from the OLS regressions, we directly calculate it by weighing the product-level tariff pass-through with total product-level imports in 2017. We obtain a tariff pass-through of 0.52 for China and 0.90 for the U.S., which are similar to the baseline

[25] Figure A8 shows the year-to-year log change of tariff-inclusive unit value across HS-8 products in aircraft products (HS-2 code: 88).

results in Table 1.

5.3 Tariff regime

Apart from import structure and product heterogeneity in pass-through, the tariff regime also contributes to the U.S.-China difference in average tariff pass-through. The two countries adopted contrasting strategies during the trade war and imposed punitive tariffs on different products. As we discussed in the background section (Figures 1 and 2), The U.S. mainly imported labor-intensive products from China, such as electronics and textiles, footwear, toys, and furniture-related goods (Figure 1). However, the first few waves of Trump tariffs didn't target the above major imported products but rather high-tech products, such as aircraft, railways, optical instruments, and machinery (Panel B of Figure 2). Panel B of Figure A5 shows that around 55% of U.S. aircraft imports were affected by the Trump tariffs in Wave 1 and 34% U.S. imports of optical instruments were on the lists in Wave 1. In contrast, major products that the U.S. imported from China, such as labor-intensive products, were not on the lists of Wave 1 and Wave 2. The pass-through of electronics, optical instruments, and machinery in the U.S. are nearly complete (0.93, 1.09, and 1.28, respectively). Considering the U.S. import structure and trade policy, we expect a high average pass-through, which is consistent with our finding that a complete pass-through for the U.S. (Table 1). As discussed in Section 2.2, the Chinese government imposed punitive tariffs on major imported goods from the U.S., such as animal products, vegetable products, and high-tech products. Panel A of Figure A5 shows that around 96% of Chinese imports of animal products were affected by the Chinese retaliatory tariffs in Prelude 1 and Wave 1, and 99% of Chinese imports of vegetable products were on the lists in Prelude 1 and Wave 1. For vehicles, 86% of imports were affected in Wave 1. In contrast, China avoided imposing higher tariffs on aircraft, and only 2% of Chinese imports were imposed punitive tariffs by the end of 2019. The pass-through rates of animal products, vegetable products, and high-tech products are 0.63, 0.81, and -1.45. As discussed in Section 4.2, we address this concern that the tariffs are not randomly imposed by controlling for HS-6-product-year-month fixed effects.

We then estimate tariff pass-through for products in different waves separately following Equation 4:

$$\Delta lnp_{igt} = \beta_0 \Delta ln(1+\tau_{igt}) + \sum_{w} \beta_{1w} I\left(\text{product}_g = w\right) \times \Delta ln(1+\tau_{igt}) + \eta_g + \eta_{Gt} + \eta_{it} + \varepsilon_{igt}. \quad (4)$$

Consistent with the baseline estimation in Equation 1, the regression is weighted using the import value in 2017 by the source country i and product g. Standard errors are clustered at the HS-6 product and country levels. Relative to Equation 1, we map products to different waves and include the interactions between wave dummies and tariffs in Equation 4.[26] β_{1w} denotes the pass-through of

[26]Here, we assign the targeted varieties to the wave when the punitive tariffs were initially implemented. For unaffected products, non-targeted varieties within the same HS-6 product category are assigned to the earliest wave of targeted varieties within that HS-6 product. Then other non-targeted varieties are assigned sequentially based on the earliest wave of targeted varieties within the same HS-4 and HS-2 product. Otherwise, we assign the products to

wave w.

The results are shown in Table A7. In Columns (1) and (4), we estimate tariff pass-through for products in wave 1, wave 2, and waves 3-5. We put products that imposed punitive tariffs in waves 3, 4, and 5 together because they involved almost all product categories. Wave 3 and wave 4 have the same product list. We find incomplete pass-through in all waves for China, complete pass-through in early waves, and incomplete pass-through in subsequent waves for the U.S. The reason is that the U.S. administration targeted high-tech products with high pass-through from China in the first several waves. Alternatively, we divide the sample into two groups based on the sample period, namely before and after the end of 2018. In this case, the impacts of wave 3 and wave 4 on prices can be estimated separately. The results are similar to that of the full sample.

To sum up, China has a lower average tariff pass-through rate mainly because China imported disproportionately more products with lower tariff pass-through. It is important to weigh the regressions with imports. Without weights, the average tariff pass-through in China and the U.S. are more similar. The remaining unexplained differences can be attributed to the two countries' different trade policies.

6 Determinants of tariff pass-through: demand elasticity and supply elasticity

6.1 Import demand elasticity and export supply elasticity

In this section, we investigate why different products have different tariff pass-through and how product heterogeneity explains the difference in average tariff pass-through between China and the U.S. The tariff pass-through ρ is determined by the elasticity of demand ϵ_D and the elasticity of supply ϵ_S under perfect competition (Weyl and Fabinger, 2013):

$$\rho = 1/\left[1 + (\epsilon_D/\epsilon_S)\right] \tag{5}$$

where the estimated coefficient β in Equation (1) is ρ when the dependent variable is the log change of tariff-inclusive import price. According to Weyl and Fabinger (2013), the tariff pass-through ρ is defined as the change in the price paid by the consumer in response to the change in tariffs. In our econometric specification, the tariff pass-through β is defined as the percent change in the import price faced by importers in response to the percent change in tariff. In the appendix, we provide proofs to verify that Equation 5 still holds. Following Zoutman et al. (2018), We identify the two elasticities by using the tariff changes as instruments:

prelude 1.

$$\Delta lnq_{igt} = -\epsilon_D \Delta lnp_{igt} + \eta_g^q + \eta_{Gt}^q + \eta_{it}^q + \varepsilon_{igt}^q \tag{6}$$

$$\Delta lnp_{igt}^* = 1/\epsilon_S \Delta lnq_{igt} + \eta_g^{p^*} + \eta_{Gt}^{p^*} + \eta_{it}^{p^*} + \varepsilon_{igt}^{p^*} \tag{7}$$

where the dependent variables are import quantities Δlnq_{igt} in Equation 6 and tariff-exclusive import prices Δlnp_{igt}^* in Equation 7, respectively. ϵ_D and ϵ_S denote the import demand elasticity and export supply elasticity, respectively. Consistent with the baseline estimation in Table 1 , the two regressions include HS-8 (HS-10) product fixed effects (η_g^q, $\eta_g^{p^*}$), HS-6-product-year-month fixed effects (η_{Gt}^q, $\eta_{Gt}^{p^*}$) and country-year-month fixed effects (η_{it}^q, $\eta_{it}^{p^*}$) for China (the U.S.). The regressions are weighed using the import value in 2017 by the source country i and product g. Standard errors are clustered at the HS-6 product and country levels. Import demand elasticity ϵ_D in Equation (6) is identified using the tariff change $\Delta ln(1 + \tau_{igt})$ as the instrument for the tariff-inclusive import price change Δlnp_{igt}. Similarly, the export supply of elasticity ϵ_S in Equation (7) is identified using the tariff change $\Delta ln(1 + \tau_{igt})$ as the instrument for the import quantity change Δlnq_{igt}. In Section 4.2, we have addressed the concern that tariffs might be correlated with unobserved factors in the residuals (ε_{igt}^q, $\varepsilon_{igt}^{p^*}$). Furthermore, the approach requires that the punitive tariff is shared between the importers and exporters. If all incidence falls on the supply (demand) side, the demand (supply) elasticity is not identified.

The estimation results are reported in Table 3. For the U.S., the import demand elasticity ϵ_D is 1.51, and the export supply elasticity ϵ_S is 20 (1/0.05). According to Equation 7, the pass-through ρ is 0.93 (1/(1+1.51/20)). For China, the import demand elasticity ϵ_D is 2.36, and the export supply elasticity ϵ_S is 5 (1/0.2). The pass-through ρ is 0.68 (1/(1+2.36/5)). When supply is more elastic than demand, the tariff pass-through is higher. Because the U.S. has a less elastic import demand elasticity and a more elastic export supply elasticity, U.S. importers bear a larger share of the tariff burdens than Chinese importers.[27]

6.2 Product heterogeneity

To explore product heterogeneity, we then estimate the import demand and export elasticities for different products. The econometric specifications are as follows:

$$\Delta lnq_{igt} = \sum_c -\epsilon_{Dc} I\left(product_g = c\right) \times \Delta lnp_{igt} + \eta_g^q + \eta_{Gt}^q + \eta_{it}^q + \varepsilon_{igt}^q \tag{8}$$

$$\Delta lnp_{igt}^* = \sum_c 1/\epsilon_{Sc} I\left(product_g = c\right) \times \Delta lnq_{igt} + \eta_g^{p^*} + \eta_{Gt}^{p^*} + \eta_{it}^{p^*} + \varepsilon_{igt}^{p^*} \tag{9}$$

[27] Li et al. (2023) investigate how firms with different market power respond to punitive tariffs under oligopoly.

Relative to Equation 6 and 7, we map HS-8 or HS-10 products to broad categories and include the interactions between product category dummies $I\left(product_g = c\right)$ and tariff-inclusive import prices Δlnp_{igt} (import quantities Δlnq_{igt}) in Equation 8 (Equation 9). ϵ_{Dc} and ϵ_{Sc} denote the import demand elasticity and export supply elasticity of product category c, respectively.

The estimation results are reported in Table 4. For electronics in the U.S., the import demand elasticity ϵ_{Dc} is 1.63, and the export supply elasticity ϵ_{Sc} is 25 (=1/0.04). Accordingly, the pass-through ρ is 0.93 (=1/(1+1.63/25)). For products whose supply elasticity is higher than its demand elasticity, such as electronics, optical instruments, and machinery in the U.S., their tariff pass-through are higher and importers bear most of the tariff burdens. On the contrary, when demand is more elastic than supply, the tariff pass-through is lower. As a result, the exporters bear most of the tariff increases. Examples include agricultural products and high-tech products. For the animal products imported by China, the import demand elasticity ϵ_{Dc} is 0.56, and the export supply elasticity ϵ_{Sc} is 0.94 (=1/1.06). The pass-through ρ is 0.63 (=1/(1+0.56/0.94)). Moreover, we find that the pass-through in the two countries can be different for the same product. This is because the import demand elasticity and export supply elasticity are different. For instance, consumers in the two countries have different preferences.

6.3 Alternative determinants of tariff pass-through

Apart from demand and supply elasticities, there are other plausible determinants for tariff pass-through. In this subsection, we speculate on these possible explanations.

Sticky prices and expectations. Sticky prices can result in high tariff pass-through. Because the trade war was an unexpected event, firms would not have been able to adjust their contracts in advance. The sticky price hypothesis could therefore explain the complete pass-through for the Trump tariffs early on. Jiao et al. (2021) conducted a firm survey for 600 Chinese exporters and found that 21% of the firms could not flexibly adjust their prices due to contractual agreements, which provides solid evidence of sticky prices. Meanwhile, the finding also suggests that the sticky price theory is probably not the dominant force, as only 21% firms cannot adjust their prices. In this paper, we provide some supportive evidence to support the argument. First, our baseline result in Table 1 and the event study in Figure 4 suggest that import prices increased instantaneously with the tariff increases, consistent with the findings of Jiao et al. (2021) that contracts signed prior to the event were not overly binding. Amiti et al. (2019), Fajgelbaum et al. (2020), and Cavallo et al. (2021) have also documented similar findings. Second, new contracts signed during the trade war should have already reflected the impact of punitive tariffs. However, as shown in Figure 4, the tariff pass-through did not experience a significant decline as time goes by. Though the sticky price is not a dominant force that affects tariff pass-through, it is still important to control for product-time fixed effects to address this concern (Table A3).

Regarding expectations, if importers believe that the punitive tariffs are meant to be temporary, they may be willing to pay for the tariffs. However, we have shown that even in the short run, tariff pass-through are lower for some products while higher for others. This implies that this hypothesis is also not the major contributing factor.

Composition effect. Tariff hikes may trigger a change in import structure. When there is an increase in trade costs, countries tend to trade more products with higher unit values. The composition effect may lead to an upward bias in the pass-through estimation and mask the decline in tariff-exclusive import prices. In the baseline analysis, we use country-product-level imports in 2017 as weights, which deals with the adjustment on the intensive margin. It is possible, however, that the composition effect operates on an extensive margin, which cannot be addressed using the pre-trade war weights.

We begin our analysis of the composition effect by plotting the changes in import varieties in each wave. A variety refers to an origin-by-HS-8 and origin-by-HS-10 dyad for China and the U.S., respectively. We assume that countries export differentiated varieties for a given product. We calculate the product scope of each wave, namely the number of imported varieties, and normalize the product scope relative to that number in the month prior to the tariffs' implementation. For the untreated group, the treatment month is the same month as the earliest wave. Figure 8 presents suggestive evidence of the reduction in import varieties for treatment groups. There were upward trends in the number of varieties before the punitive tariffs were imposed. When the punitive tariffs came into effect, the product scope declined for treatment groups except prelude 1, which covered a small number of products (washing machines and solar panels for the U.S. or 128 HS-8 products for China). In contrast, the product scope kept rising steadily for untreated groups.

We then explore the entry and exit dynamics of HS-8 (HS-10) products by broad product category for China (the U.S.). As shown in Panel A of Figure A9, relative to 2017, about 85% - 95% of the products that China imported from the U.S. continued to be imported during the trade war. A few exceptions include agricultural products, food, and vehicles, which have a small number of varieties. Panel B of Figure A9 shows the product scope pattern for the U.S., which has a similar pattern.

To explore to what extent the composition effect biases the estimates of tariff pass-through, we re-regress the baseline specification using the sub-sample of continuous products. The estimates of tariff pass-through in Panel C of Table A6 are robust, implying that tariff-triggered changes on the extensive margin are not sufficiently large enough to bias our estimations of the average tariff pass-through in the baseline regressions. Furthermore, we study the impact of the trade war on the adjustment of the extensive margin. We define product scope (num_{iGt}) as the number of imported products in a broader product category G (HS-6) from country i at time t. Based on the unit value, we divide HS-8 (HS-10) products in each origin-product-category pair into two groups using the Chinese (U.S.) import data in 2017. The product scopes in the high and low unit price groups are labeled as num_highuv_{iGt} and num_lowuv_{iGt}, respectively. As shown in Equation 10, the weighted-average tariffs are computed at the country-HS-6 product level. We include product category (φ_G) and country-year-month (φ_{it}) fixed effects to control unobserved time-invariant product-specific factors and time-variant country-specific shocks. The regressions on tariffs and product scopes are weighed by import values at the country-HS-6 product level in 2017.

$$ln\left(y_{iGt}\right) = \beta ln\left(1+\tau_{iGt}\right) + \varphi_G + \varphi_{it} + \varepsilon_{iGt} \tag{10}$$

Columns (1) - (3) of Table A9 present the results. After controlling for HS-6-product fixed effects and country-year-month fixed effects, the increase in Chinese retaliatory tariffs (Trump tariffs) has no effect on the total number of imported products for a given country of origin in Column (1). We get similar results for the two subgroups, as shown in Columns (2) and (3). The insignificant results suggest that there is no clear evidence for substitution across varieties and the tariff-triggered composition effect is negligible within country-product pairs.

We then investigate the composition effect at a more aggregate level. We re-define product scope (num_{Gt}) as the number of origin-by-HS-8 (origin-by-HS-10) pairs within a given product category G (HS-6) at time t for China (the U.S.). Columns (4) - (6) of Table A9 present the results on the effect of tariffs on the newly defined product scopes.[28] As shown in Column (6) of Panel A, the increase in Chinese retaliatory tariffs leads to an increase in the product scope for the low unit value group. Trump tariffs lead to a decrease in the product scope for both high unit value and low unit value groups. There is no significant difference between the high and low groups in terms of magnitude. Considering the results in Columns (1) - (3), we learn that there are some marginal composition changes across different trade partners within products, but few adjustments within country-product pairs.

Aggregation

The tariff pass-through estimated by comparing different varieties of a product can be very different from that estimated by comparing different products.[29] We aggregate the import values to the country-HS-4 product level and weigh the regressions at the same level. Table A4 reports the elasticities of import values and duty-inclusive unit values against the tariff changes. Column (4) shows no major change in the pass-through: 63% for China and 104% for the U.S., which is similar to our baseline estimation. The results imply that various levels of aggregation do not generate very different estimates of pass-through.

[28] Compared to Columns (1) - (3), we adjust the variable constructions and weights accordingly in Columns (4) - (6). More explicitly, the dependent variables are the weighted-average tariffs at the HS-6 level. We include product category (φ_G) and year-month (φ_t) fixed effects and use HS-6-product-level import data as weights in the regressions.

[29] Cavallo et al. (2021) find that the tariff pass-through in the U.S. is 92.1% without controlling for exchange rates and sectoral fixed effects, while the tariff pass-through is complete with controls. We relax the controls of product-time fixed effects in Column (2) of Table A3 to explore the above possibilities. The average tariff pass-through for China is 55%, lower than our baseline estimation of 68%, while the U.S. tariff pass-through is 78%, which is also lower than our baseline estimation of 93%.

7 Conclusion

Between 2018 and 2019, the U.S. government implemented a series of protective tariffs, which provoked a cascade of retaliatory tariffs from China and other trade partners. With mounting tensions among countries and growing concerns for decoupling, it is particularly important to understand the determinants of tariff pass-through, which can provide policy guidance. The U.S.-China trade war provides a perfect setting to study this topic.

In this paper, we use the trade war as a quasi-natural experiment to understand the tariff incidence and explore the underlying determinants of tariff pass-through. We start by estimating the economic consequences of trade protectionism and examine how increases in tariff burdens are shared among importers and exporters. While the Trump tariffs were almost entirely borne by U.S. importers, Chinese importers only paid 68% of China's retaliatory tariffs. The findings are surprising because the average pass-through for the same event differs a lot in the two countries. Furthermore, the impact of the U.S. tariffs on U.S. import prices was almost one-for-one. Multiple research groups, using different data and at various time horizons, have reached the same conclusion that U.S. punitive tariffs were almost entirely borne by U.S. importers (e.g., Amiti et al., 2019; Fajgelbaum et al., 2020; Cavallo et al., 2021). The puzzling finding has spurred a great deal of interest among economists.

To understand the two puzzling findings, we seek to understand the determinants of the average tariff pass-through in China and the U.S. from two different perspectives. We first show that the puzzling U.S.-China difference is mainly due to the two countries' contrasting import structures, trade policies, and tariff pass-through across products. China imported more products with lower tariff pass-through and chose to set higher punitive tariffs on products with lower tariff pass-through, such as agricultural products. In contrast, the U.S. tariffs had higher average pass-through because the U.S. imported more products with higher pass-through, such as textiles and electronics, and imposed higher tariffs on products with higher pass-through, such as machinery and optical instruments. Because the U.S. import values are not correlated with tariff pass-through, the results are similar for the U.S. with or without weights. However, the difference was significant for China as its product-level imports negatively correlate with tariff pass-through. Apart from the econometric perspective, we decompose the average tariff pass-through as well as product-level tariff pass-through into demand elasticity and supply elasticity. A country or a product's higher tariff pass-through is mainly due to the lower import demand elasticity and higher export supply elasticity.

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Table 1: **Tariff pass-through rates**

(1) = (2) + (3)	(1) $\Delta lnp^*_{igt}q_{igt}$	(2) Δlnq_{igt}	(3) Δlnp^*_{igt}	(4) Δlnp_{igt}
Panel A. China				
$\Delta ln(1+\tau_{igt})$	-1.92***	-1.60***	-0.32***	0.68***
	(0.40)	(0.39)	(0.10)	(0.10)
Observations	2,127,210	2,127,210	2,127,210	2,127,210
R-squared	0.35	0.33	0.17	0.17
HS-8 Product FE	YES	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES
Panel B. United States				
$\Delta ln(1+\tau_{igt})$	-1.47***	-1.40***	-0.07	0.93***
	(0.28)	(0.22)	(0.11)	(0.11)
Observations	3,318,350	3,318,350	3,318,350	3,318,350
R-squared	0.26	0.23	0.17	0.17
HS-10 Product FE	YES	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES

Notes. Columns (1) - (4) report import values, quantities, tariff-exclusive unit values, and tariff-inclusive unit values regressed on the import tariff rates. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns in Panel A include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns in Panel B include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Sample in Panel A: China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Panel B: U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors *** p<0.01, ** p<0.05, * p<0.1.

Table 2: **Tariff pass-through rates: different weights**

	(1)	(2)	(3)	(4)
			Δlnp_{igt}	
Sample	Full Sample	Full Sample	Full Sample	Samples excluding aircraft
Weight	Import in 2017	No weight	Import in the last year	Import in 2017
Panel A. China				
$\Delta ln(1+\tau_{igt})$	0.68***	0.89***	0.69***	0.72***
	(0.10)	(0.23)	(0.10)	(0.10)
Observations	2,127,210	2,134,017	1,461,376	2,121,591
R-squared	0.35	0.17	0.17	0.17
HS-8 Product FE	YES	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES
Panel B. United States				
$\Delta ln(1+\tau_{igt})$	0.93***	0.98***	0.93***	0.94***
	(0.11)	(0.05)	(0.10)	(0.11)
Observations	3,318,350	3,339,459	2,196,152	3,299,072
R-squared	0.26	0.17	0.17	0.17
HS-10 Product FE	YES	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES

Notes. Columns (1) - (4) report tariff-inclusive unit values regressed on the import tariff rates using different weights. Regressions in Columns (1) and (4) are weighted by the country-product-level import value in 2017. Regressions in Column (3) are weighted by the country-product-level import value in the last year. Column (2) does not use sample weights. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns in Panel A include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns in Panel B include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Sample of Columns (1) - (3) in Panel A: China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample of Columns (1) - (3) in Panel B: U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Sample of Column (4) in Panel A and Panel B: excluding the aircraft (HS-2 codes: 86, 88, 93). Standard errors are clustered by HS-6 product and country. Standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Table 3: **Average import demand and export supply elasticities**

	(1)	(2)	(3)	(4)
	China		United States	
	Δlnp^*_{igt} Inverse export supply elasticity $1/\epsilon_S$	Δln_{igt} Import demand elasticity $-\epsilon_D$	Δlnp^*_{igt} Inverse export supply elasticity $1/\epsilon_S$	Δln_{igt} Import demand elasticity $-\epsilon_D$
Δlnq_{igt}	0.20**		0.05	
	(0.08)		(0.07)	
Δlnp_{igt}		-2.36***		-1.51***
		(0.67)		(0.35)
Observations	2,127,210	2,127,210	3,318,350	3,318,350
R-squared	-0.42	-0.69	-0.08	-0.08
HS-8 Product FE	YES	YES	NO	NO
HS-10 Product FE	NO	NO	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES

Notes. Columns (1) and (3) report the foreign export supply curve IV regression, $1/\epsilon_S$, from Equation 6; the first stage is Column (2) in Table 1. Columns (2) and (4) report the import demand curve IV regression, $-\epsilon_D$, from Equation 7; the first stage is Column (4) in Table 1. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns (1) - (2) include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns (3) - (4) include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Sample in Columns (1) - (2): China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Columns (3) - (4): U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors *** p<0.01, ** p<0.05, * p<0.1.

Table 4: **Import demand and Export supply elasticities**

	(1)	(2)	(3)	(4)	(5)	(6)
		China			United States	
	Δlnp_{igt}	Δlnp^*_{igt}	$\Delta ln\left(q_{igt}\right)$	Δlnp_{igt}	Δlnp^*_{igt}	$\Delta ln\left(q_{igt}\right)$
	Pass through ρ	Inverse export supply elasticity $1/\epsilon_{Sc}$	Import demand elasticity $-\epsilon_{Dc}$	Pass through ρ	Inverse export supply elasticity $1/\epsilon_{Sc}$	Import demand elasticity $-\epsilon_{Dc}$
X: ×	X: $\Delta ln\left(1+\tau_{igt}\right)$	X: $\Delta ln\left(q_{igt}\right)$	X: $\Delta ln\left(p_{igt}\right)$	X: $\Delta ln\left(1+\tau_{igt}\right)$	X: $\Delta ln\left(q_{igt}\right)$	X: $\Delta ln\left(p_{igt}\right)$
01 Animal Products	0.63***	1.06***	-0.56	0.26	0.17***	-16.20***
	(0.12)	(0.34)	(1.28)	(0.23)	(0.05)	(5.30)
02 Vegetables Products	0.81***	0.46**	-0.50	0.04	0.41*	-59.50**
	(0.09)	(0.22)	(1.94)	(0.55)	(0.23)	(24.62)
03 Food	0.98***	0.05	-0.53	0.35	0.66***	-2.82*
	(0.23)	(0.44)	(0.68)	(0.22)	(0.22)	(1.60)
04 Plastics	0.92***	0.16	-0.55	0.97***	0.04	-0.83***
	(0.15)	(0.29)	(0.49)	(0.10)	(0.13)	(0.19)
05 Raw Materials	0.46***	0.33***	-3.56***	1.39***	-0.22**	-1.29***
	(0.15)	(0.09)	(1.33)	(0.18)	(0.10)	(0.38)
06 Textiles	1.22***	-0.01	-12.27***	0.58***	0.40**	-1.80**
	(0.24)	(0.02)	(3.37)	(0.19)	(0.18)	(0.71)
07 Metals and Nonmetals	0.97***	-0.02	2.30**	0.79***	0.24***	-1.12**
	(0.20)	(0.09)	(0.93)	(0.08)	(0.09)	(0.52)
08 Machinery	0.44*	1.83**	-0.69	1.28***	-0.12	-1.88***
	(0.26)	(0.87)	(2.51)	(0.24)	(0.10)	(0.36)
09 Electronics	0.85	3.26	-0.06	0.93***	0.04	-1.63***
	(0.52)	(10.98)	(1.11)	(0.13)	(0.09)	(0.42)
10 Vehicles	0.83***	0.12	-1.69**	0.87***	0.34	-0.42*
	(0.11)	(0.08)	(0.81)	(0.11)	(0.29)	(0.24)
11 Aircraft	-1.45	-36.70	-0.05	-0.47***	-5.53***	-0.56
	(2.04)	(30.58)	(2.00)	(0.12)	(0.40)	(0.39)
12 Optical Instruments	-2.36***	-7.16***	-0.20	1.09***	-0.07	-1.31***
	(0.73)	(1.56)	(0.36)	(0.22)	(0.15)	(0.28)
Observations	2,127,210	2,127,210	2,127,210	3,317,071	3,317,071	3,317,071
R-squared	0.17	0.17	0.34	0.17	0.17	0.23
HS-8 Product FE	YES	YES	YES	NO	NO	NO
HS-10 Product FE	NO	NO	NO	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES	YES	YES

Notes. Columns (1) and (4) report tariff-inclusive unit values regressed on the import tariff rates and the interactions of import tariff rates and product category dummies. Columns (2) and (5) report the foreign export supply curve IV regression, $1/\epsilon_{Sc}$, from Equation 8. Columns (3) and (6) report the import demand curve IV regression, $-\epsilon_{Dc}$, from Equation 9. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns (1) - (3) include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns (4) - (6) include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Sample in Columns (1) - (23): China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Columns (34) - (46): U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors *** p<0.01, ** p<0.05, * p<0.1.

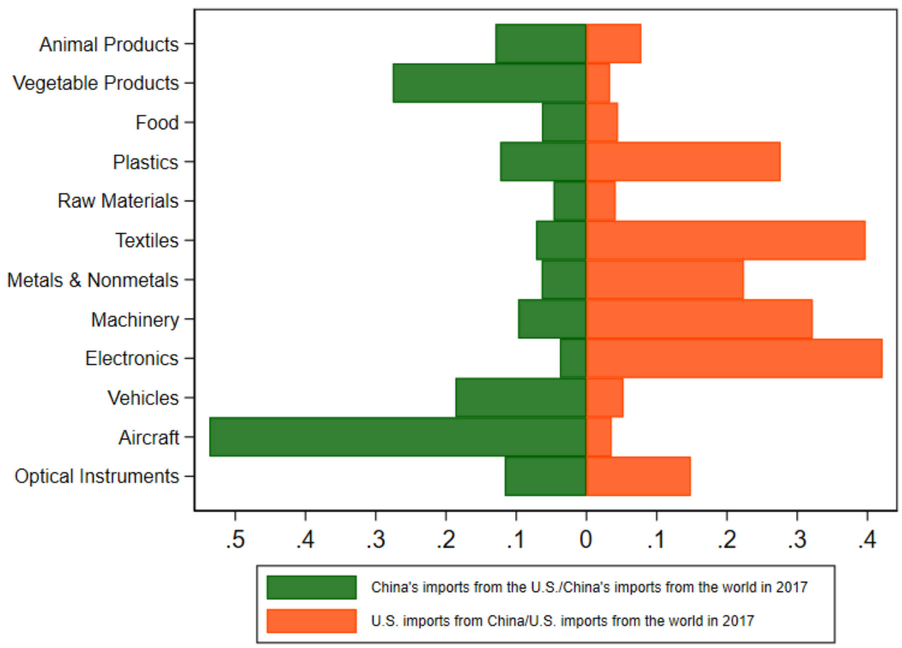
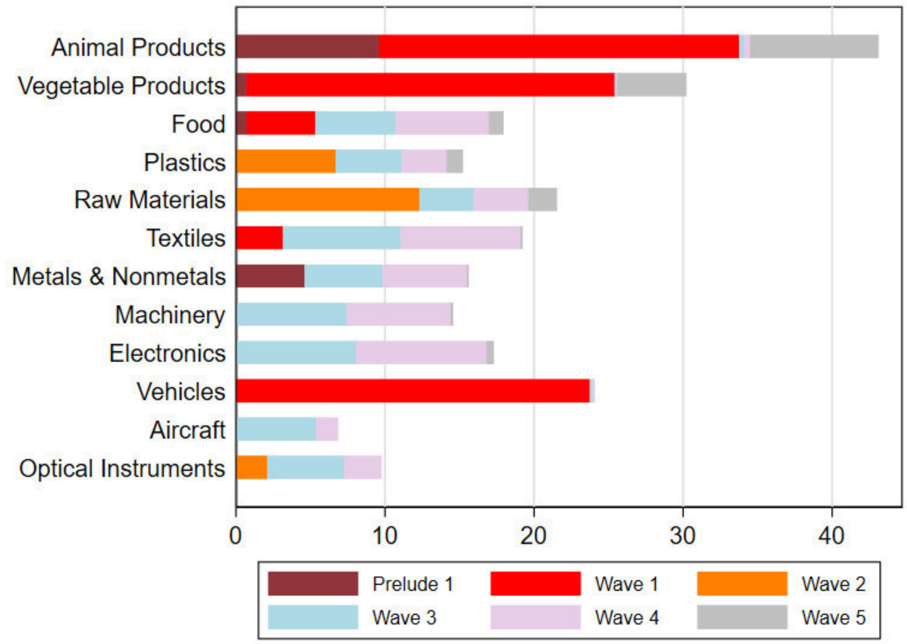
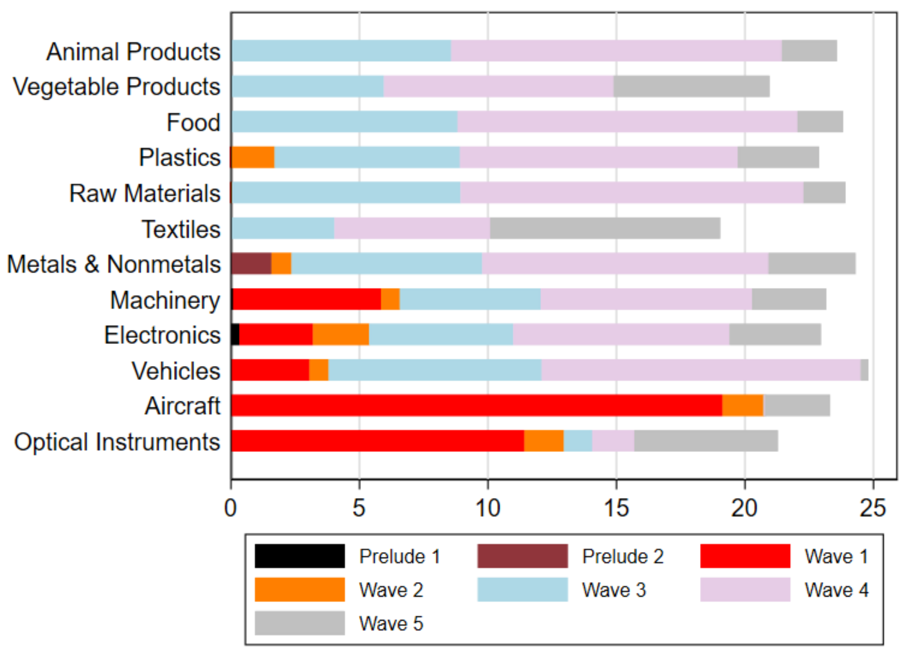


Figure 1: Share of import value in 2017 by product category

Note: The figure presents the share of China's imports from the U.S. (green box) and the share of U.S. imports from China in 2017 (red box) by product category. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from UN Comtrade.



(a) Chinese retaliatory tariff(%)



(b) U.S. tariff (%)

Figure 2: Punitive import tariffs imposed by China and the U.S.

Note: China's retaliatory tariffs by product category are computed as the weighted average using China's imports from the U.S. in 2017. U.S. import tariffs by product category are weighed by U.S. imports from China in 2017. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).

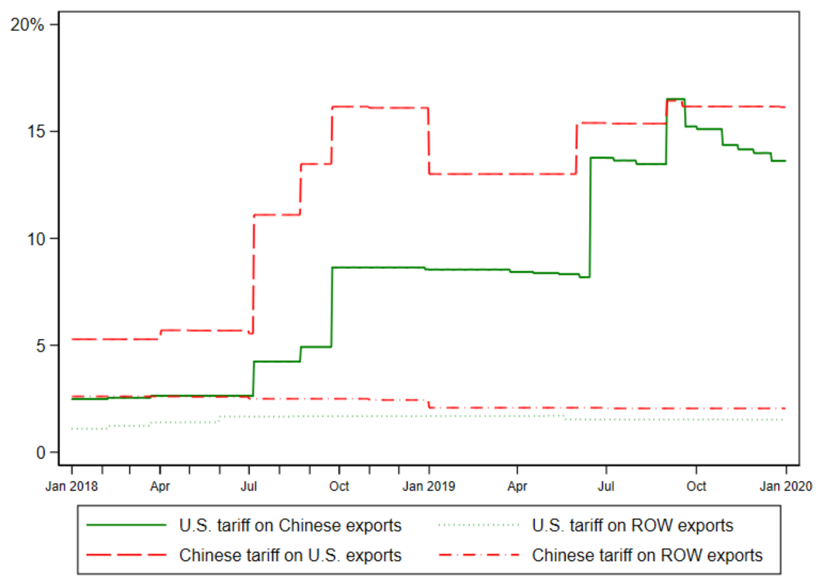
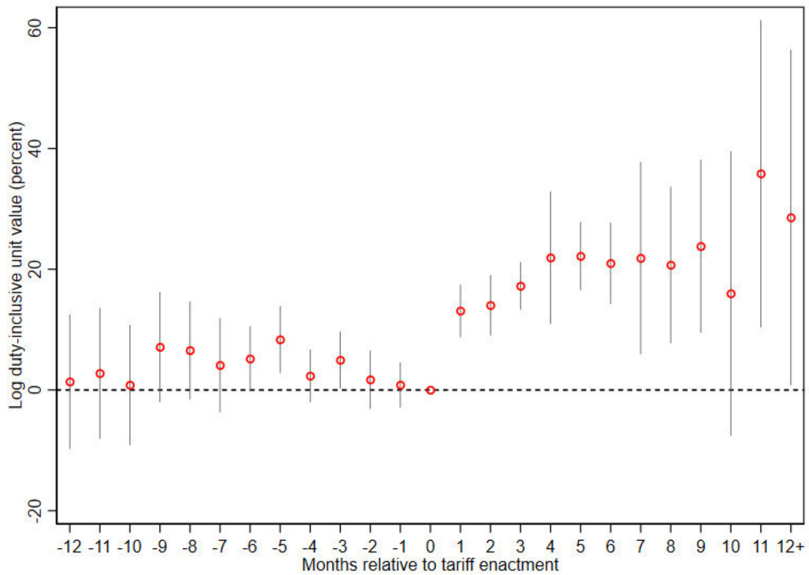
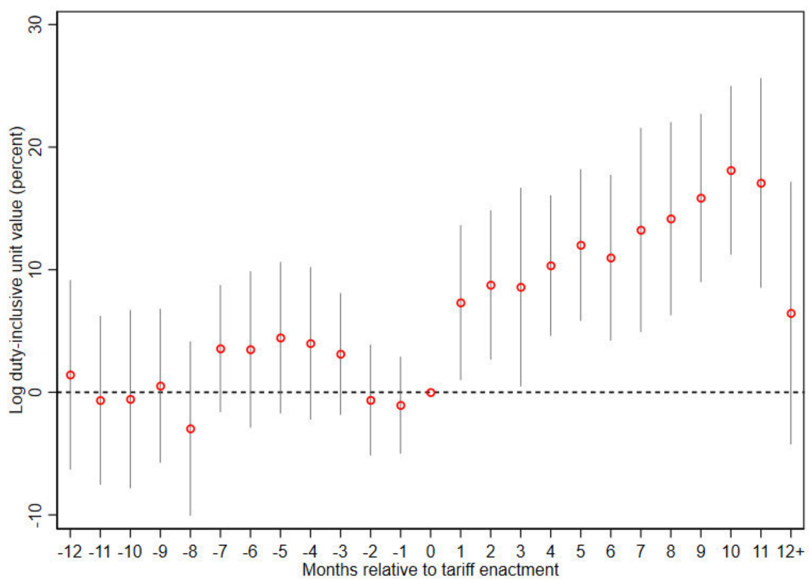


Figure 3: China and U.S. tariffs during the trade war

Note: The figure presents the import-weighted average Chinese tariff rates on U.S. products (solid red line) and the rest of the world (dashed red line), as well as U.S. tariffs on Chinese products (solid green line) and the rest of the world (ROW, dashed green line). Chinese tariffs are weighed by China's country-HS-8-product-level imports in 2017. U.S. tariffs are weighed by the U.S. country-HS-10-product-level imports in 2017.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, United States Trade Representative (USTR), and United States International Trade Commission.



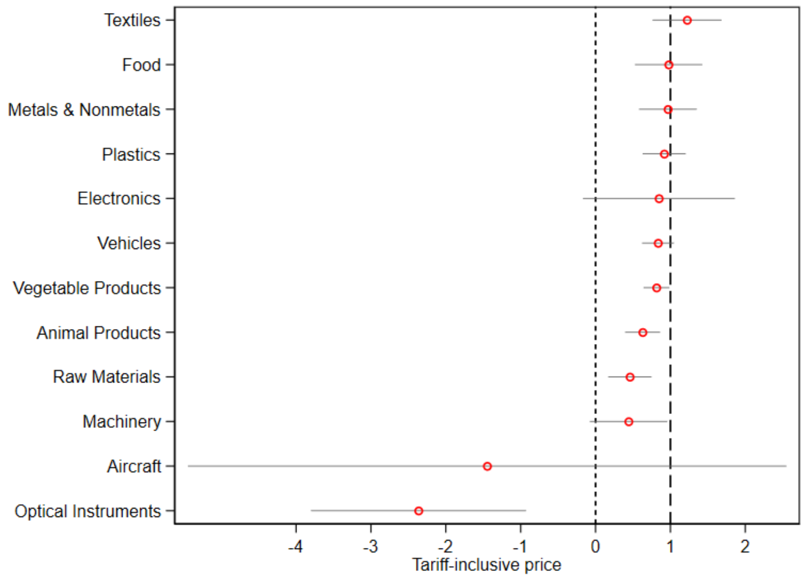
(a) China



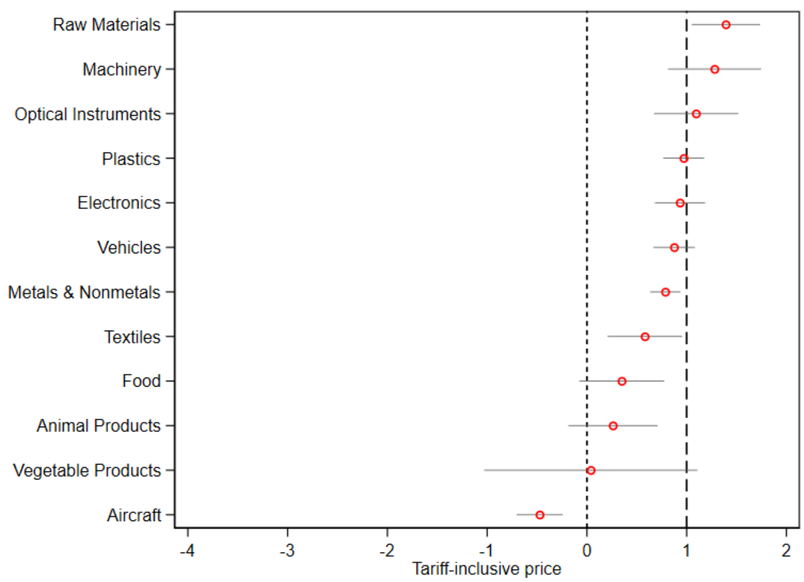
(b) U.S.

Figure 4: Event study

Note: In Panel A (Panel B), we use China's monthly country-HS-8-product (U.S. monthly country-HS-10-product)-level import data from 2017:1 to 2019:12. In Panel A (Panel B), all regressions include country-HS-8-product (country-HS-10-product) fixed effects, HS-8-year-month fixed effects (HS-10-year-month fixed effects), and country-year-month fixed effects. In both panels, we drop all HS-4 products that were never subject to punitive tariffs during the sample period. The baseline month is the last untreated month (i.e. $\beta_{10} = 0$). Standard errors are clustered by HS-6 product and country. Error bars show 95% confidence intervals.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China



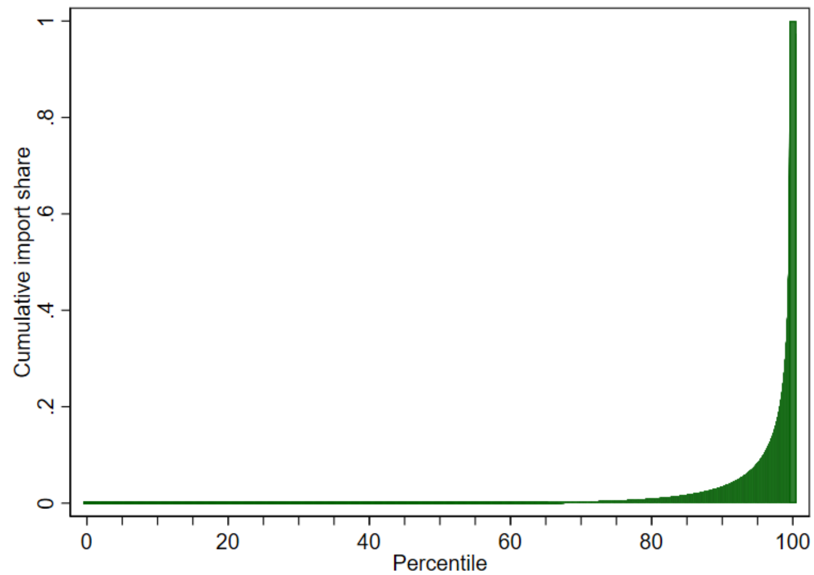
(a) Pass-through of Chinese retaliatory tariffs



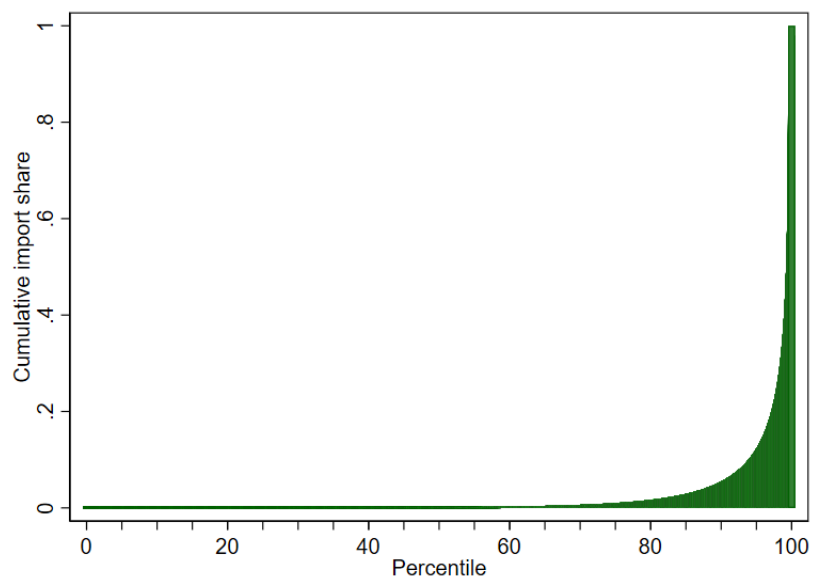
(b) Pass-through of U.S. import tariffs

Figure 5: Tariff pass-through by product category

Note: Panel A displays China's import tariff pass-through by product category, and Panel B displays U.S. import tariff pass-through by product category. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission.



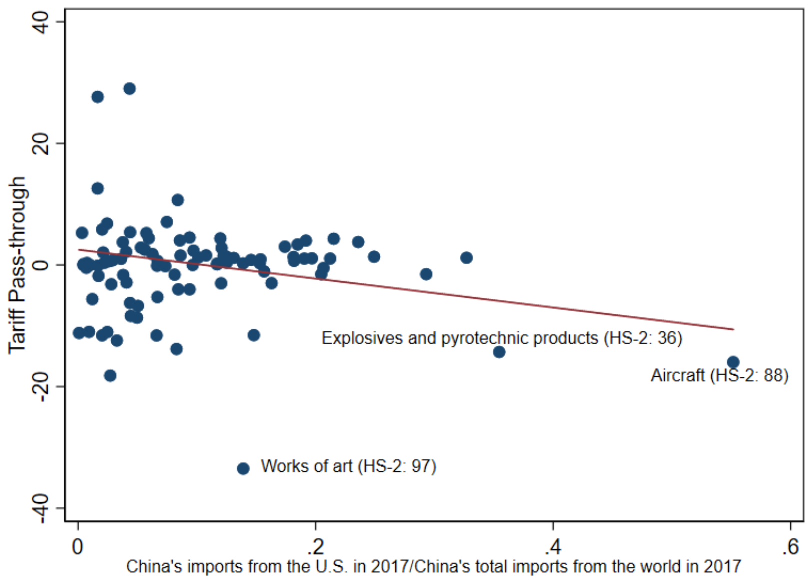
(a) China



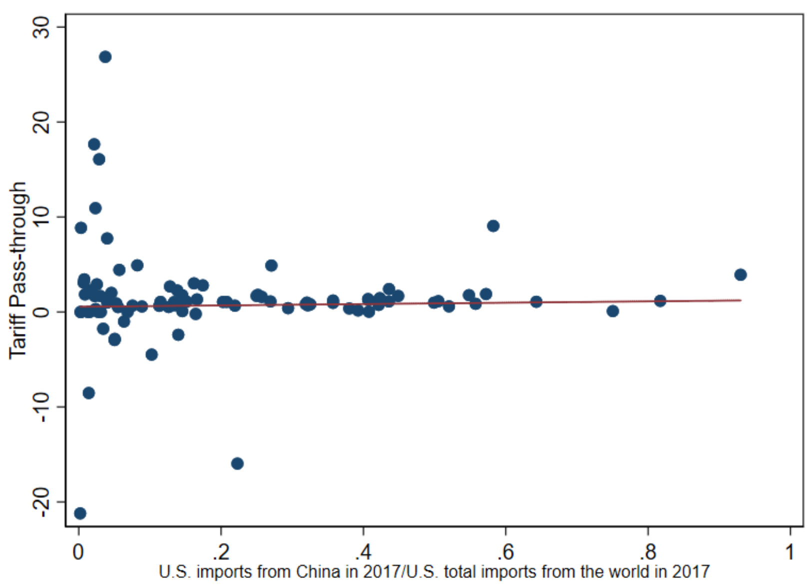
(b) U.S.

Figure 6: Import Distribution

Note: Sample in Panel A: country-HS-8-product observations in 2017, Sample in Panel B: country-HS-10-product observations in 2017.
Source: Authors' calculations based on data from the Customs General Administration of China and the United States Census Bureau.



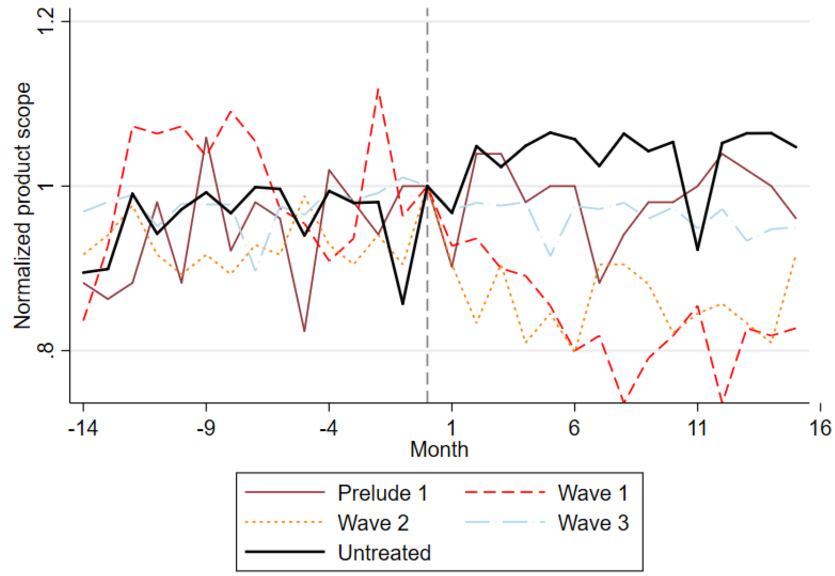
(a) China



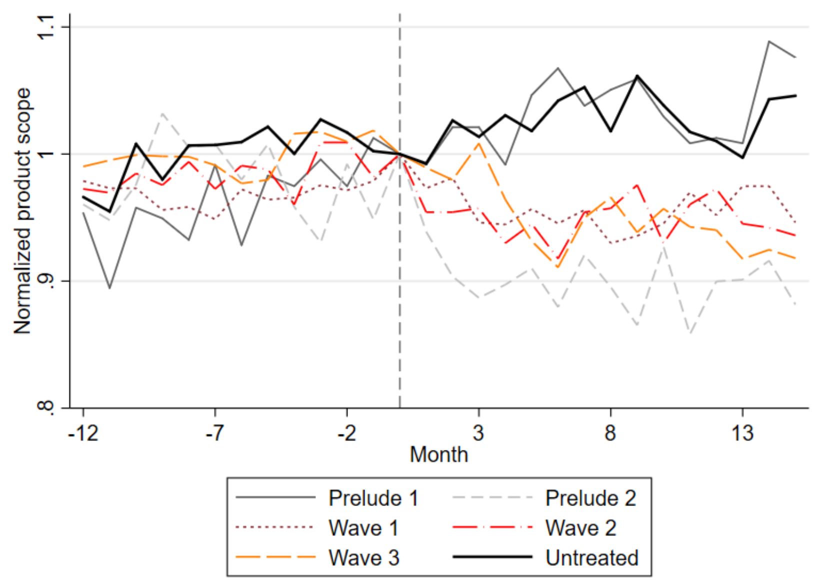
(b) U.S.

Figure 7: Import share and tariff pass-through

Note: This scatter plot shows the relationship between the pass-through and import share at the HS-2 level. We estimate the tariff pass-through for each HS-2 product category by regressing the month-to-month log change of tariff-inclusive unit value on the log change of import tariff following Equation 1. Panel A: China's monthly country-HS-8-product-level import from the U.S. from 2017:1 to 2019:12. Panel B: U.S. monthly country-HS-10-product-level import from China from 2017:1 to 2019:12. Regressions in Panel A (B) are weighed by the country-HS-8 (HS-10)-product-level import value in 2017. Standard errors are clustered by HS-6 product. We drop outliers with pass-through greater than 40 or less than -40. There are four outliers (HS-2 codes: 6, 45, 51, 53) for China and eight outliers (HS-2 codes: 4, 10, 12, 13, 23, 43, 68, 78) for the U.S.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission.



(a) China



(b) U.S.

Figure 8: Number of varieties by tariff wave

Note: An import variety is defined at country-HS-8 for China and country-HS-10 for the U.S. The normalized number of varieties is the number of import varieties relative to that in the month prior to the tariffs' implementation. For the untreated group, the treatment month is the same month as for the earliest wave. All the waves are defined in Table A1.

Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).

A Appendix: Tables

Table A1: **Timeline**

Wave	Date of implementation	Event
Panel A. United States		
Prelude 1	2018-02-07	The US imposes 30% tariffs on solar panels and 20% on washing machines under two Section 201 cases.
Prelude 2	2018-03-23	The US imposes 25 % Section 232 tariffs on steel and 10 % Section 232 tariffs on aluminum imported from China and other countries, temporarily exempting Argentina, Australia, Brazil, Canada, Mexico, the European Union, and South Korea.
Wave 1	2018-07-06	The US imposes 25% Section 301 tariffs on $34 billion of imports from China.
Wave 2	2018-08-23	The US imposes 25% Section 301 tariffs on $16 billion of imports from China.
Wave 3	2018-09-24	The US imposes 10% Section 301 tariffs on $200 billion of imports from China.
Wave 4	2019-06-15	The US raises Section 301 tariffs from 10% to 25% on $200 billion of imports from China.
Wave 5	2019-09-01	The US imposes 15% tariffs on $101 billion of imports from China.
Panel B. China		
Prelude 1	2018-04-02	China imposes 15% or 25% retaliatory tariffs on $2.4 billion of imports from the US in response to US Section 232 tariffs on steel and aluminum tariffs.
Wave 1	2018-07-06	China imposes 25% retaliatory tariffs on $34 billion of imports from the US in response to US Section 301 tariffs imposed on July 6, 2018.
Wave 2	2018-08-23	China imposes 25% retaliatory tariffs on $16 billion of imports from the US in response to US Section 301 tariffs imposed on August 23, 2018.
Wave 3	2018-09-24	China imposes 5% or 10% retaliatory tariffs on $60 billion of imports from the US in response to US Section 301 tariffs imposed on September 24, 2018.
Wave 4	2019-06-01	China imposes an additional 5%, 10%, or 15% tariffs on a subset of the existing product list implemented on September 24, 2018, in response to the US Section 301 tariff increase imposed on June 15, 2019.
Wave 5	2019-09-01	China imposes an additional 5% or 10% tariffs on $75 billion of imports from the US in response to the US Section 301 tariff increase imposed on September 1, 2019.

Notes. From Bown (2021).

Table A2: **Summary statistics**

	Obs	Mean	SD	Min	Max	P1	P5	P10	P25	P75	P90	P95	P99
Panel A. China													
$\Delta lnp^*_{igt}q_{igt}$	2,127,210	0.00	0.71	-14.89	14.81	-1.86	-0.82	-0.50	-0.19	0.20	0.50	0.82	1.87
Δlnq_{igt}	2,127,210	0.00	0.76	-18.66	18.73	-1.91	-0.83	-0.52	-0.19	0.20	0.51	0.83	1.90
Δlnp^*_{igt}	2,127,210	0.00	0.39	-17.39	16.11	-1.14	-0.34	-0.17	-0.05	0.06	0.17	0.33	1.13
Δlnp_{igt}	2,127,210	0.00	0.39	-17.39	16.11	-1.14	-0.34	-0.17	-0.05	0.06	0.17	0.33	1.13
$\Delta ln(1+\tau_{igt})$	2,127,210	0.00	0.01	-0.37	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Panel B. United States													
$\Delta lnp^*_{igt}q_{igt}$	3,318,350	-0.00	0.66	-11.04	11.57	-1.96	-0.78	-0.48	-0.19	0.19	0.46	0.76	1.93
Δlnq_{igt}	3,318,350	-0.00	0.73	-16.75	16.61	-2.24	-0.86	-0.52	-0.20	0.19	0.50	0.83	2.20
Δlnp^*_{igt}	3,318,350	0.00	0.52	-15.60	15.47	-1.60	-0.47	-0.22	-0.06	0.07	0.23	0.46	1.62
Δlnp_{igt}	3,318,350	0.00	0.52	-15.60	15.47	-1.60	-0.46	-0.22	-0.06	0.07	0.24	0.46	1.63
$\Delta ln(1+\tau_{igt})$	3,318,350	0.00	0.01	-0.44	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06

Notes. All the statistics are weighted by the country-product-level import data in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Sample in Panel A: China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Panel B: U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12.

Table A3: **Robustness checks: alternative specifications**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Month-to-month difference				Year-to-year difference	
	$\Delta IHS\,(p^*_{igt}q_{igt})$		Δlnp_{igt}			$\Delta 12lnp^*_{igt}q_{igt}$	$\Delta 12lnp_{igt}$
Panel A. China							
$\Delta ln(1+\tau_{igt})$	-7.84***	0.59***	0.68***	0.66***	0.65***		
	(2.54)	(0.11)	(0.10)	(0.11)	(0.11)		
$\Delta 12ln(1+\tau_{igt})$						-2.64***	0.84***
						(0.47)	(0.10)
Observations	5,164,933	2,140,897	2,127,329	2,115,792	2,091,953	1,398,713	1,398,713
HS-8 Product FE	YES	YES	NO	NO	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES	YES	YES	YES
HS-4 Product × Year-month FE	NO	YES	NO	NO	NO	NO	NO
Country × HS-6 Product FE	NO	NO	NO	YES	NO	NO	NO
HS-6 Product × Year-month FE	YES	NO	YES	YES	YES	YES	YES
Exchange Rate × HS-8 Product FE	NO	NO	NO	NO	YES	NO	NO
Panel B. United States							
$\Delta ln(1+\tau_{igt})$	-1.31***	0.86***	0.94***	0.95***	0.93***		
	(0.46)	(0.08)	(0.11)	(0.11)	(0.11)		
$\Delta 12ln(1+\tau_{igt})$						-2.14***	0.99***
						(0.27)	(0.08)
Observations	10,913,547	3,330,104	3,318,708	3,306,358	3,194,767	2,128,457	2,128,457
HS-10 Product FE	YES	YES	NO	NO	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES	YES	YES	YES
HS-4 Product × Year-month FE	NO	YES	NO	NO	NO	NO	NO
Country × HS-6 Product FE	NO	NO	NO	YES	NO	NO	NO
HS-6 Product × Year-month FE	YES	NO	YES	YES	YES	YES	YES
Exchange Rate × HS-10 Product FE	NO	NO	NO	NO	YES	NO	NO

Notes. Column (1) reports import values regressed on the import tariff rates in which the dependent variables are the change in the inverse hyperbolic sine of the import values of China or the U.S. Columns (2) - (5) report tariff-inclusive unit values regressed on the import tariff rates using different fixed effects. Columns (6) and (7) report import values and tariff-inclusive unit values regressed on the import tariff rates in a year-to-year specification. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Sample in Panel A: China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Panel B: U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Table A4: **Cross-product substitution**

	(1)	(2)	(3)	(4)	(5)	(6)
	country-HS-4-product level				country-HS-8-product level	
	China		United States		United States	
	$\Delta lnp^*_{igt}q_{igt}$	Δlnp_{igt}	$\Delta lnp^*_{igt}q_{igt}$	Δlnp_{igt}	$\Delta lnp^*_{igt}q_{igt}$	Δlnp_{igt}
$\Delta ln(1+\tau_{igt})$	-1.27***	0.63***	-0.19	1.04***	-1.57***	1.14***
	(0.35)	(0.08)	(0.17)	(0.07)	(0.24)	(0.19)
Observations	501,031	501,031	332,613	332,613	2,469,012	2,469,012
R-squared	0.23	0.10	0.18	0.13	0.32	0.24
HS-4 Product FE	YES	YES	YES	YES	NO	NO
Country × Year-month FE	YES	YES	YES	YES	YES	YES
HS-8 Product FE	NO	NO	NO	NO	YES	YES
HS-6 Product × Year-month FE	NO	NO	NO	NO	YES	YES

Notes. Columns (1), (3), and (5) report import values regressed on the import tariff rates. Columns (2), (4), and (6) report tariff-inclusive unit values regressed on the import tariff rates. Regressions in Columns (1) - (4) are weighted by the country-HS-4-product-level import value in 2017. Columns (1) - (4) include HS-4 product fixed effects and country-year-month fixed effects. Standard errors in Columns (1) - (4) are clustered by HS-4 product and country. Sample in Columns (1) and (2): China's monthly country-HS-4-product-level import data from all countries from 2017:1 to 2019:12. Sample in Columns (3) and (4): U.S. monthly country-HS-4-product-level import data from all countries from 2017:1 to 2019:12. Regressions in Columns (5) and (6) are weighted by the country-HS-8-product-level import value in 2017. Columns (5) and (6) include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Standard errors in Columns (5) and (6) are clustered by HS-6 product and country. Sample in Columns (5) and (6): U.S. monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Standard errors: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A5: **Preexisting trends**

	(1)	(2)	(3)	(4)
	$\Delta lnp^*_{igt}q_{igt}$	Δlnq_{igt}	Δlnp^*_{igt}	Δlnp_{igt}
Panel A. China				
$\Delta ln(1+\tau_{igt})$	-0.18	-0.21	0.02	0.02
	(0.12)	(0.13)	(0.03)	(0.03)
Observations	57,706	57,141	57,141	57,138
R-squared	0.30	0.31	0.17	0.17
HS-6 Product FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES
Panel B. United States				
$\Delta ln(1+\tau_{igt})$	-0.05	-0.06	0.01	0.00
	(0.03)	(0.04)	(0.02)	(0.02)
Observations	104,320	84,516	84,516	84,516
R-squared	0.18	0.19	0.12	0.12
HS-6 Product FE	YES	YES	YES	YES
Country FE	YES	YES	YES	YES

Notes. Columns (1) - (4) report pre-trend tests for country-product trade outcomes. Columns (1) - (4) report regressions of the 2017:1-2017:12 average monthly changes in import values, import quantities, unit values, and tariff-inclusive unit values against the 2018 tariff changes. Regressions in Columns (1) - (4) are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns (1) - (4) include HS-6 product fixed effects and country fixed effects. Standard errors are clustered by HS-6 product and country. Standard errors are clustered by HS-6 product and country. Standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Table A6: **Sub-sample**

	(1)	(2)	(3)	(4)
	China			United States
	$\Delta lnp^*_{igt}q_{igt}$	Δlnp_{igt}	$\Delta lnp^*_{igt}q_{igt}$	Δlnp_{igt}
Panel A. Winsorize variables at the fraction of 0.025				
$\Delta ln(1+\tau_{igt})$	-1.97***	0.67***	-1.38***	0.87***
	(0.33)	(0.09)	(0.22)	(0.09)
Observations	2,205,132	2,127,210	3,962,725	3,318,350
R-squared	0.36	0.18	0.25	0.17
Panel B. Drop any observations with a ratio of unit values in t relative to t â 12 greater than 3 or less than 1/3				
$\Delta ln(1+\tau_{igt})$	-1.97***	0.76***	-1.66***	0.85***
	(0.44)	(0.08)	(0.35)	(0.10)
Observations	1,870,113	1,826,961	2,834,131	2,833,871
R-squared	0.38	0.19	0.28	0.20
Panel C. Keep continuous products				
$\Delta ln(1+\tau_{igt})$	-1.80***	0.67***	-1.23***	0.98***
	(0.33)	(0.11)	(0.13)	(0.09)
Observations	2,095,556	2,021,703	3,308,833	2,838,287
R-squared	0.36	0.17	0.27	0.16
HS-8 Product FE	YES	YES	NO	NO
HS-10 Product FE	NO	NO	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES

Notes. Columns (1) and (3) report import values regressed on the import tariff rates. Columns (2) and (4) report tariff-inclusive unit values regressed on the import tariff rates. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns (1) and (2) include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns (3) and (4) include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Standard errors are clustered by HS-6 product and country. Sample in Columns (1) and (2): China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Columns (3) and (4): U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Table A7: **Tariff pass-through rates: different waves**

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Var.: Δlnp_{igt}		China			United States	
Sample period	2017m1-2019m12	2017m1-2018m12	2019m1-2019m12	2017m1-2019m12	2017m1-2018m12	2019m1-2019m12
$\Delta ln\,(1+\tau_{igt})$		0.77***	0.55**		1.02***	0.87***
		(0.16)	(0.22)		(0.16)	(0.12)
$I\left(\text{product}_g = wave\,1\right) \times \Delta ln\,(1+\tau_{igt})$	0.85***			1.26***		
	(0.13)			(0.24)		
$I\left(\text{product}_g = wave\,2\right) \times \Delta ln\,(1+\tau_{igt})$	0.29			1.07***		
	(0.21)			(0.14)		
$I\left(\text{product}_g = wave\,3\,or\,wave5\right) \times \Delta ln\,(1+\tau_{igt})$	0.65**			0.81***		
	(0.28)			(0.15)		
$I\left(\text{product}_g = other\,waves\right) \times \Delta ln\,(1+\tau_{igt})$	0.57***			0.65***		
	(0.16)			(0.12)		
Observations	2,127,210	1,378,941	748,117	3,318,350	2,206,348	1,111,492
R-squared	0.17	0.17	0.18	0.17	0.18	0.15
HS-8 Product FE	YES	YES	YES	NO	NO	NO
HS-10 Product FE	NO	NO	NO	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES	YES	YES

Notes. Columns (1) and (4) report tariff-inclusive unit values regressed on the import tariff rates and the interactions of import tariff rates and wave dummies. For China, $I\left(\text{product}_g = other\,waves\right) = 1$ if products were initially imposed punitive tariffs in prelude 1. For the U.S., $I\left(\text{product}_g = other\,waves\right) = 1$ if products were initially imposed punitive tariffs in prelude 1, prelude 2, or waves in which the U.S. targeted other countries. Columns (2), (3), (5), and (6) report tariff-inclusive unit values regressed on the import tariff rates. All regressions are weighted by the country-product-level import value in 2017. For China and the U.S., product codes are defined at the HS-8 level and HS-10 level, respectively. Columns in Columns (1) - (3) include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Columns in Columns (4) - (6) include HS-10 product fixed effects, HS-6-product-year-month fixed effects, and country-year month fixed effects. Sample in Column (1): China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2019:12. Sample in Column (2): China's monthly country-HS-8-product-level import data from all countries from 2017:1 to 2018:12. Sample in Column (3): China's monthly country-HS-8-product-level import data from all countries from 2019:1 to 2019:12. Sample in Column (4): U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2019:12. Sample in Column (5): U.S. monthly country-HS-10-product-level import data from all countries from 2017:1 to 2018:12. Sample in Column (6): U.S. monthly country-HS-10-product-level import data from all countries from 2019:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A8: **Processing vs ordinary**

	(1) $\Delta lnp^*_{igt}q_{igt}$	(2) Δlnq_{igt}	(3) Δlnp^*_{igt}	(4) Δlnp_{igt}
Panel A. Ordinary import				
$\Delta ln(1+\tau_{igt})$	-1.00*	-0.70	-0.30***	0.70***
	(0.52)	(0.59)	(0.11)	(0.11)
Observations	1,814,764	1,814,764	1,814,764	1,814,764
Panel B. Processing import				
$\Delta ln(1+\tau_{igt})$	-0.03	0.11	-0.14	0.86***
	(0.89)	(0.82)	(0.17)	(0.17)
Observations	760,008	760,008	760,008	760,008
Panel C. Other import				
$\Delta ln(1+\tau_{igt})$	-2.45***	-2.47***	0.03	1.03***
	(0.79)	(0.88)	(0.18)	(0.18)
Observations	1,033,463	1,033,463	1,033,463	1,033,463
HS-8 Product FE	YES	YES	YES	YES
HS-6 Product × Year-month FE	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	YES

Notes. Columns (1) - (4) report import values, quantities, tariff-exclusive unit values, and tariff-inclusive unit values regressed on the import tariff rates. All regressions are weighted by the country-HS-8-product-regime-level import value in 2017. All columns include HS-8 product fixed effects, HS-6-product-year-month fixed effects, and country-year-month fixed effects. Sample in Panel A: China's monthly ordinary imports at the country-HS-8-product level from all countries from 2017:1 to 2019:12. Sample in Panel B: China's monthly processing imports at the country-HS-8-product level from all countries from 2017:1 to 2019:12. Sample in Panel C: China's monthly other imports at the country-HS-8-product level from all countries from 2017:1 to 2019:12. Standard errors are clustered by HS-6 product and country. Standard errors are clustered by HS-6 product and country. Standard errors *** p<0.01, ** p<0.05, * p<0.1.

Table A9: **Extensive margins**

	(1)	(2)	(3)	(4)	(5)	(6)
	num_iGt	*num_highuv_iGt*	*num_lowuv_iGt*	*num_Gt*	*num_highuv_Gt*	*num_lowuv_Gt*
Panel A. China						
$ln\,(1+\tau_{iGt})$	-0.62	-0.27	-0.35			
	(0.63)	(0.44)	(0.39)			
$ln\,(1+\tau_{Gt})$				12.92	3.64	9.27**
				(9.87)	(6.19)	(4.01)
Observations	4,238,388	4,238,388	4,238,388	180,240	180,240	180,240
Panel B. United States						
$ln\,(1+\tau_{iGt})$	-0.41	-0.30	-0.11			
	(1.26)	(0.63)	(0.70)			
$ln\,(1+\tau_{Gt})$				-25.99**	-12.04*	-13.94***
				(11.70)	(6.92)	(5.11)
Observations	5,201,984	5,201,984	5,201,984	188,112	188,112	188,112
HS-6 Product FE	YES	YES	YES	YES	YES	YES
Country × Year-month FE	YES	YES	YES	NO	NO	NO
Year-month FE	NO	NO	NO	YES	YES	YES

*Notes.*Columns (1) - (3) report the number of imported varieties, the number of imported varieties with high unit values, and the number of imported varieties with low unit values regressed on the import tariff rates at the country-product level. Columns (4) - (6) report the number of imported varieties, the number of imported varieties with high unit values, and the number of imported varieties with low unit values regressed on the import tariff rates at the product level. Product codes are defined at the HS-6 level. Variables are in log changes. Regressions in Columns (1) - (3) are weighted by the country-product-level import value in 2017. Columns (1) - (3) include HS-6 product and country-year-month fixed effects. Regressions in Columns (4) - (6) are weighted by the product-level import value in 2017. Columns (4) - (6) include HS-6 product and year-month fixed effects. Standard errors are clustered by HS-6 product. Sample in Panel A (B): China's (U.S.) monthly country-HS-6-product-level import data from 2017:1 to 2019:12 in Columns (1) - (3), China's (U.S.) monthly HS-6-product-level import data from 2017:1 to 2019:12 in Columns (4) - (6). Standard errors: *** p<0.01, ** p<0.05, * p<0.1.

B Appendix: Figures

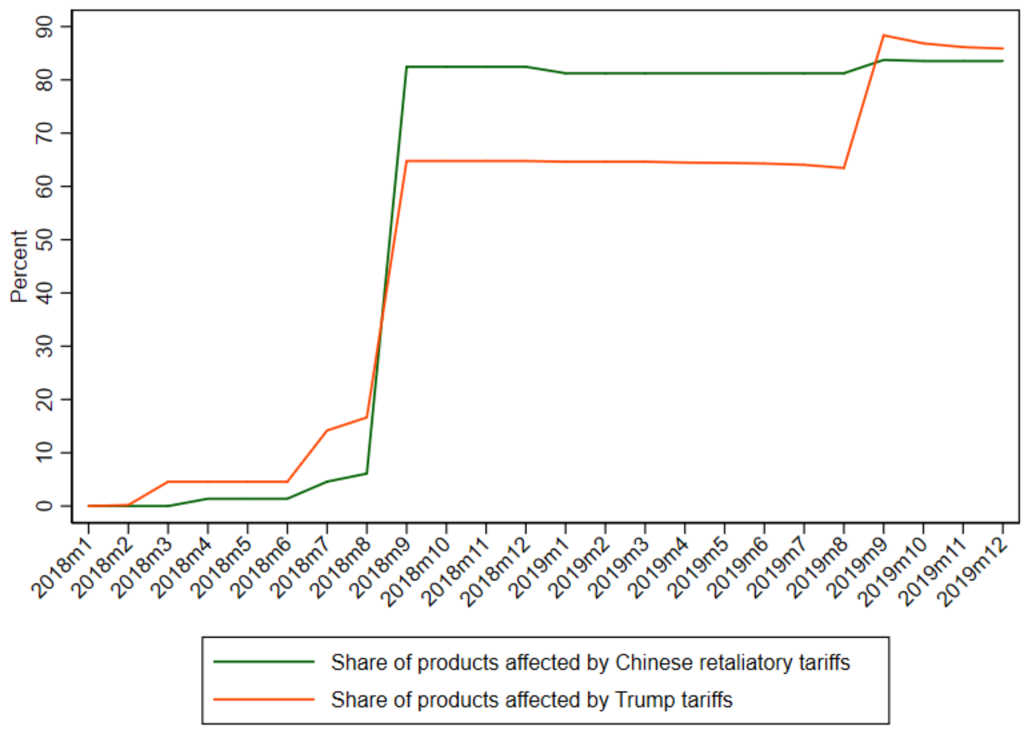


Figure A1: Share of affected products

Note: This figure shows the share of products affected by punitive tariffs in China and the U.S. In Panel A, the numerator is the number of HS-8 products affected by China's retaliatory tariffs. The denominator is the number of HS-8 products imported from the U.S. by China in 2017. In Panel B, the numerator is the number of HS-10 products affected by Trump tariffs, and the denominator is the number of HS-10 products imported from China by the U.S. in 2017.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).

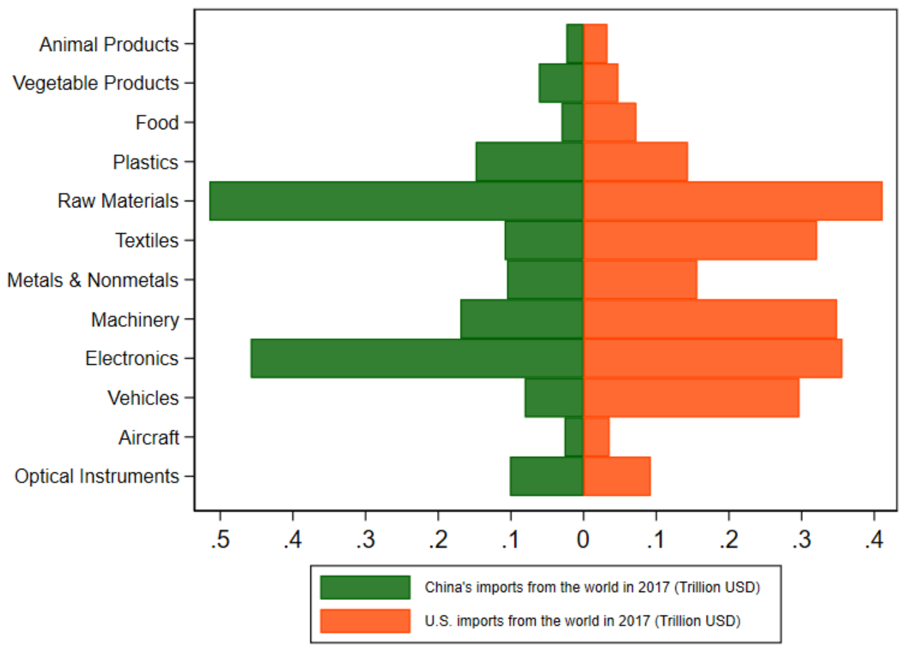
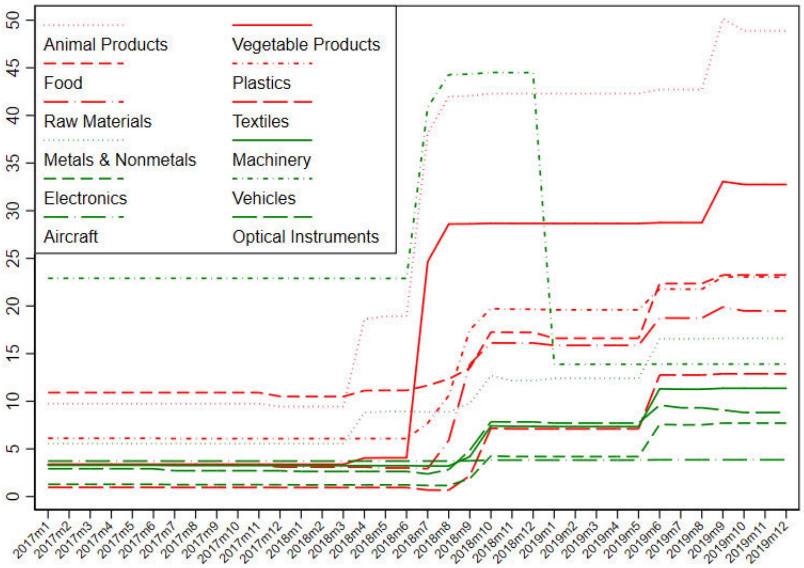
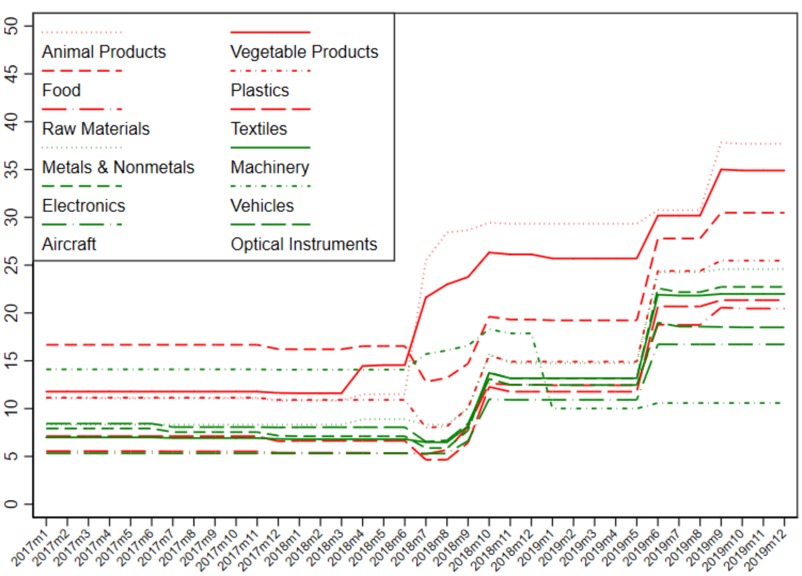


Figure A2: Import value in 2017 by product category

Note: The figure presents China's imports from the world (green box) and U.S. imports from the world in 2017 (red box) by product category. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from UN Comtrade.



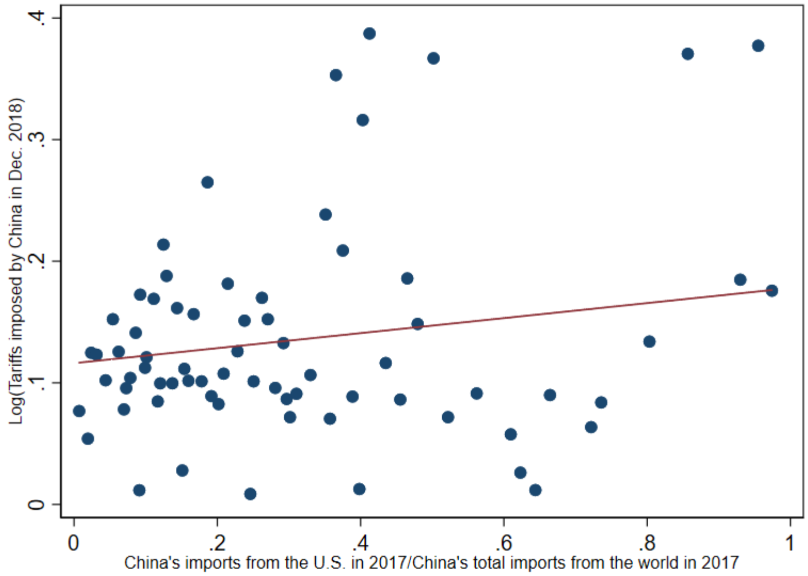
(a) Chinese statutory tariffs (%)



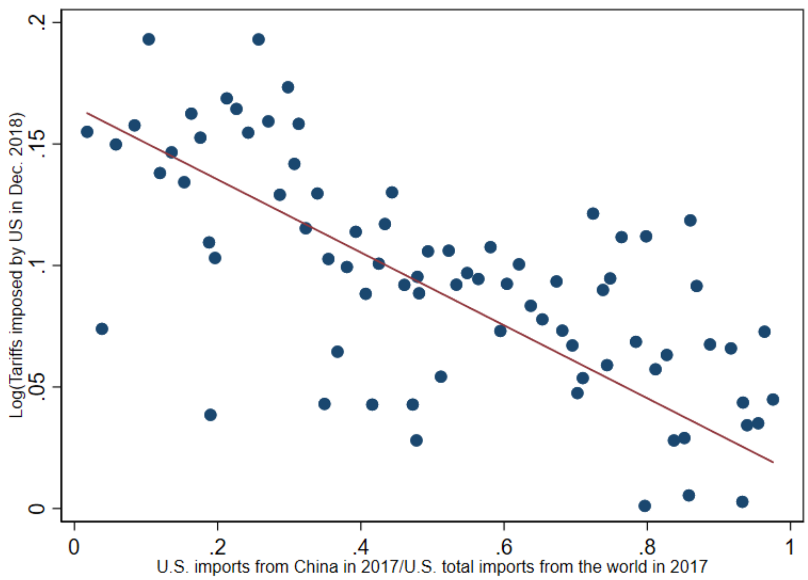
(b) U.S. Import Tariffs (%)

Figure A3: U.S.-China tariff rates toward each other by product category

Note: Panel A presents the import-weighted Chinese tariff rates on U.S. products by sector, where weights are China's imports from the U.S. in 2017 varying by HS-8. Panel B presents the import-weighted U.S. tariff on Chinese products by sector, where weights are U.S. HS-10 imports from China in 2017. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).



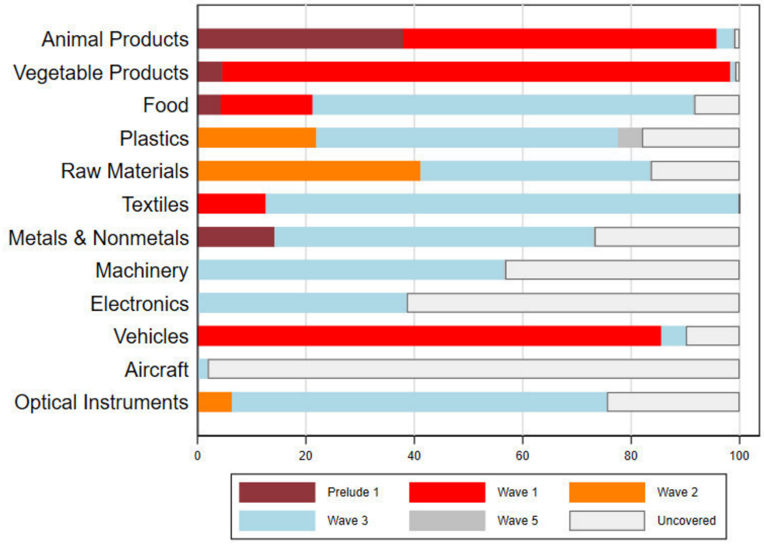
(a) China



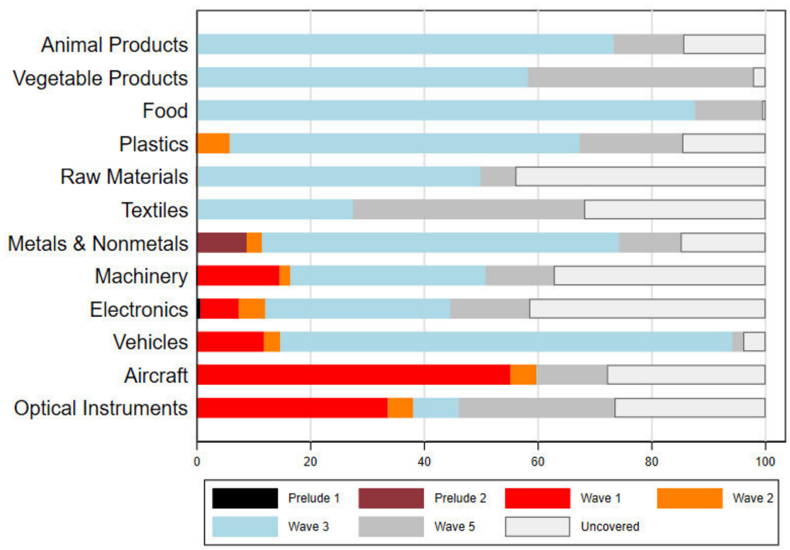
(b) U.S.

Figure A4: Import share and tariff rates: China vs. the U.S.

Note: Panel A shows the relationship between the log of Chinese import tariff rates in Dec. 2018 and the share of imports from the U.S. in 2017 prior to the trade war. Panel B shows the relationship between the log of U.S. import tariff rates in Dec. 2018 and the share of imports from China in 2017 prior to the trade war.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).



(a) Chinese retaliatory-tariff



(b) U.S. tariff

Figure A5: The import shares of products covered by punitive tariffs

Note: We calculate the import shares of products covered by punitive tariffs using import data in 2017. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refers to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refers to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from China's Ministry of Commerce, Customs General Administration of China, the United States Census Bureau, the United States Trade Representative (USTR), and the United States International Trade Commission (USITC).

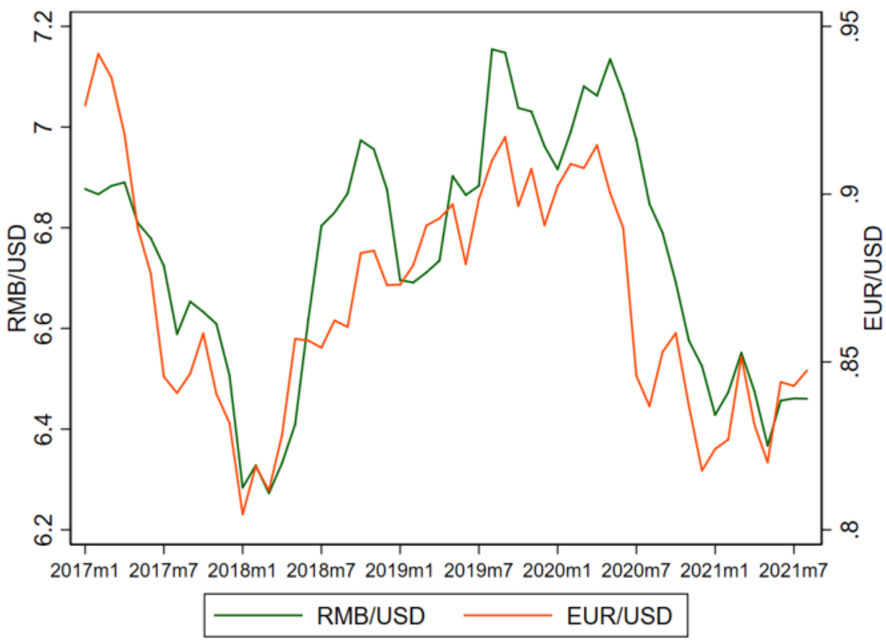


Figure A6: Exchange rate: USD-CNY

Source: Authors' calculations based on data from China Foreign Exchange Trade System(CFETS).

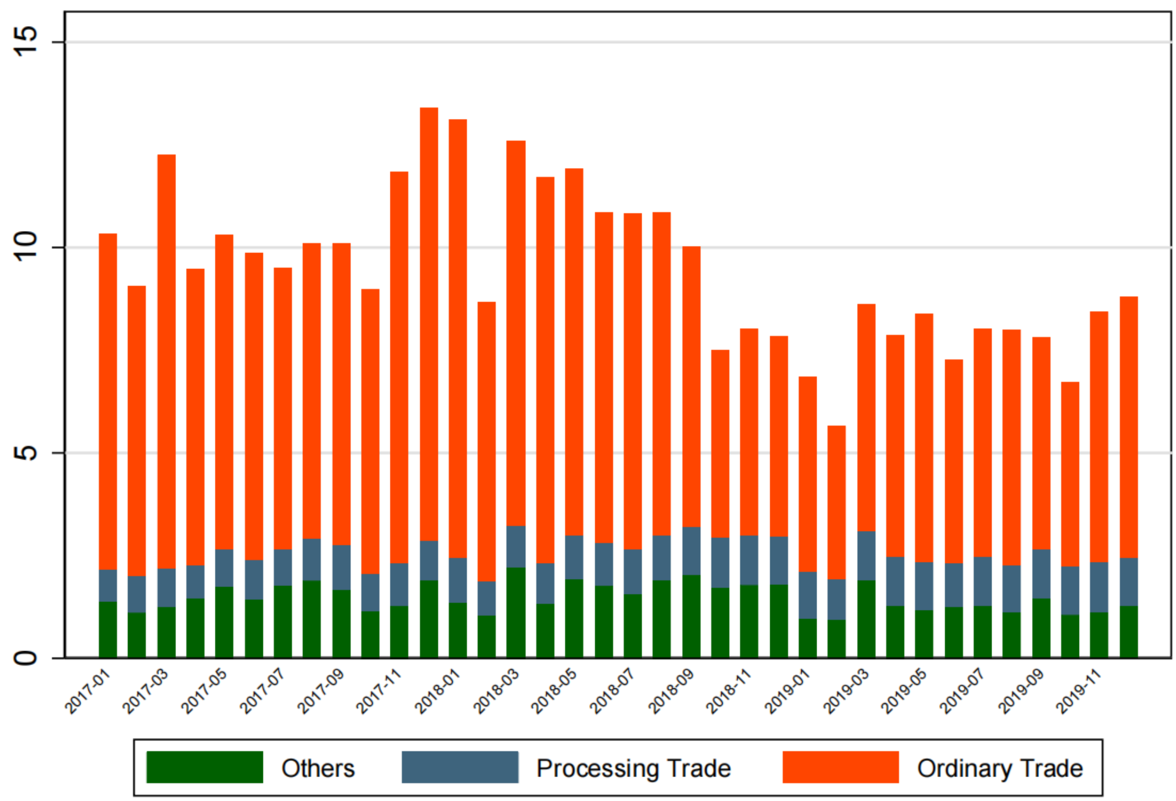


Figure A7: Import values from the U.S. (billion USD)

Source: Authors' calculations based on data from the Customs General Administration of China.

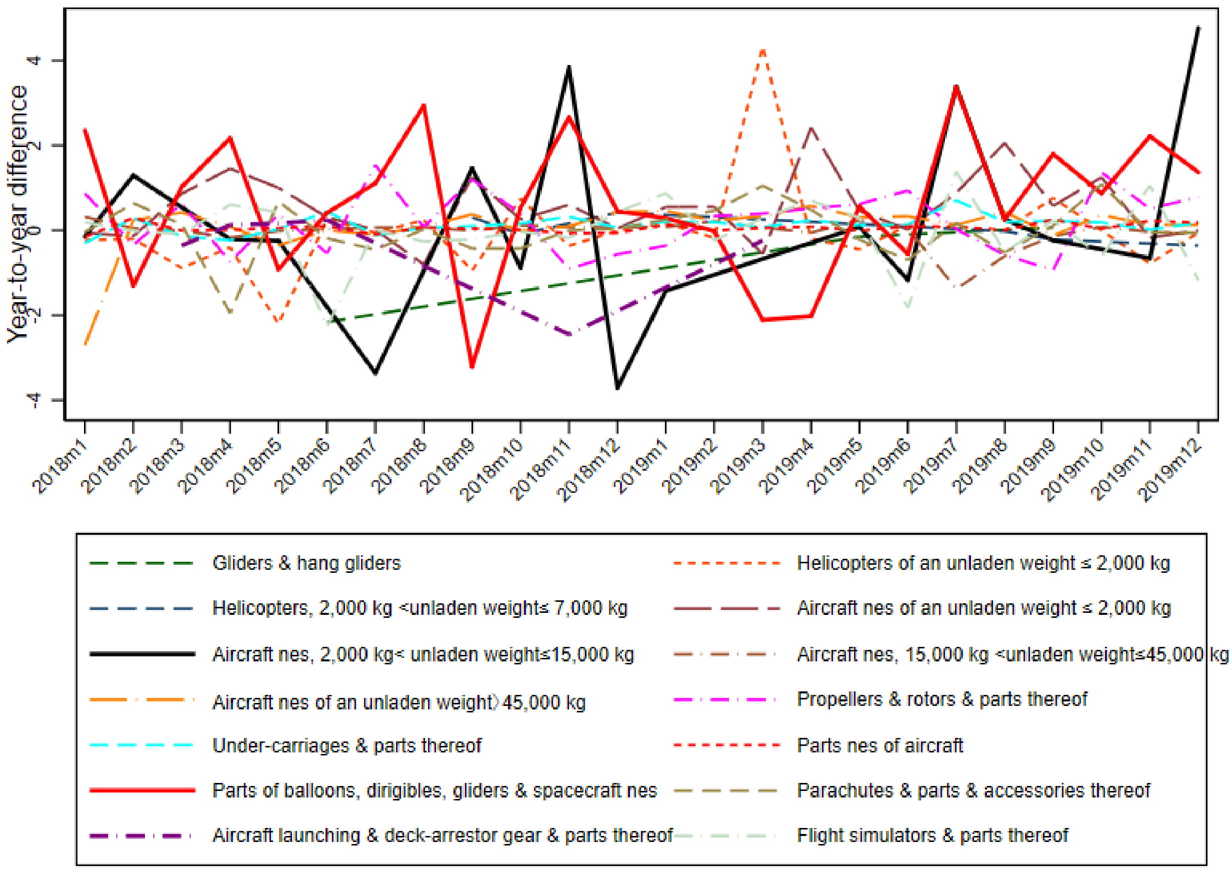
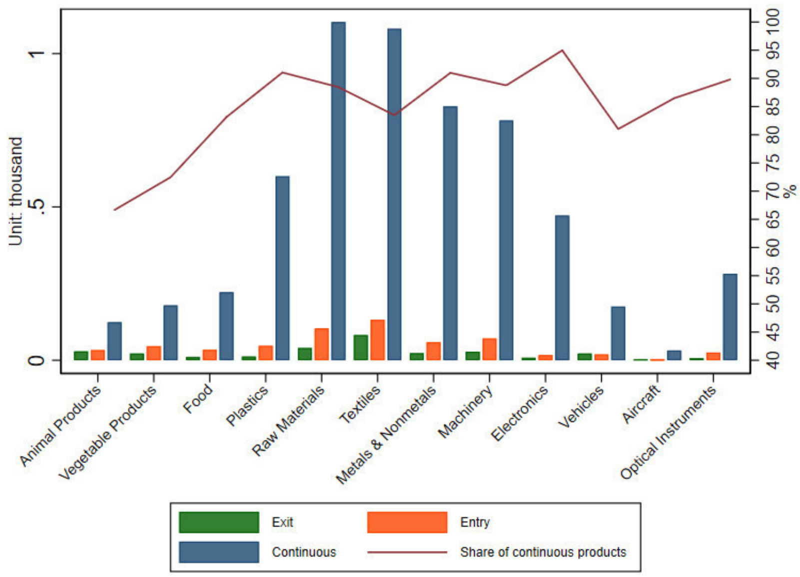


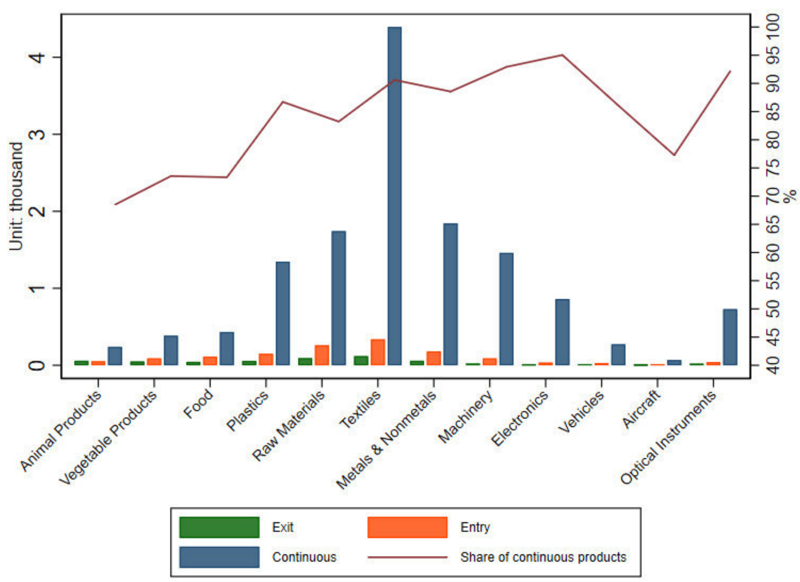
Figure A8: Duty-inclusive unit value

Note: This figure shows the year-to-year log change of tariff-inclusive unit value across HS-8 products in aircraft products (HS-2 code: 88)

Source: Authors' calculations based on data from the Customs General Administration of China.



(a) China



(b) U.S.

Figure A9: Entry and exit

Note: Panel A (Panel B) displays the number of HS-8 (HS-10) products that China (the U.S.) imported from the U.S. (China) that exited, entered, or continued in 2018 or 2019 for each broad product category. The figures also display the share of continuous products relative to 2017. Food refers to cooking oil, sugar, drinks, and tobacco. Plastics refers to plastics, leathers, wood, and paper. Raw Materials refers to chemicals, crude oil, and mineral products. Textiles refer to textiles and footwear, toys, and furniture. Electronics refers to electronics and equipment. Vehicles refer to motor vehicles, ships, and boats. Aircraft refers to aircraft, railways, and weapons.
Source: Authors' calculations based on data from Customs General Administration of China the U.S. Census Bureau.

C Appendix: Decomposition I

C.1 Notations

The number of groups is K. The observations, indexed by $\{1 : n\}$, are partitioned into these K groups: $G_1, G_2, \ldots G_K$. Let $N_0 = 0$; for $g = 1, 2, \ldots, n, N_g$ is the index of the last element of the group G_g, and the n_g is the number of the observations in the group G_g. Note that $N_K = n$, the last element of the last group shall also be the last element of the whole sample.

C.2 The model without intecept

C.2.1 The simple case $K = 2$

The true model: For some $1 \leq n_1 < n$ and $\beta_1 \neq \beta_2$, such that

$$\begin{aligned} Y_i &= X_i'\beta_1 + \varepsilon_i \text{ for } i = 1, \ldots, n_1 \\ Y_i &= X_i'\beta_2 + \varepsilon_i \text{ for } i = n_1 + 1, \ldots, n \end{aligned}$$

Or in a compact form

$$Y_i = \sum_{g=1}^{2} X_i' \left[\beta_g \mathbb{I}\left(i \in G_g\right)\right] + \varepsilon_i, \text{ for } i = 1, \ldots, n$$

where $\mathbb{I}(\cdot)$ is the indicator function of the group membership. The estimated model

$$Y_i = X_i'\beta + \varepsilon_i \text{ for } i = 1, \ldots, n.$$

We have

$$\begin{aligned} \hat{\beta} &= \left(\frac{1}{n}\sum_{i=1}^{n} X_i X_i'\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} X_i Y_i \\ &= \left(\frac{1}{n}\sum_{i=1}^{n} X_i X_i'\right)^{-1} \frac{1}{n}\left[\sum_{i=1}^{n_1} X_i X_i'\beta_1 + \sum_{i=n_1+1}^{n} X_i X_i'\beta_2\right] \\ &+ \left(\frac{1}{n}\sum_{i=1}^{n} X_i X_i'\right)^{-1} \frac{1}{n}\sum_{i=1}^{n} X_i \varepsilon_i \\ &= I_n + II_n. \end{aligned}$$

First, $II_n \to_p 0$.

If X_i is a continuous random scalar, and X is iid distributed with $\mathbb{E}\left(X_i \mid i \in G_g\right) = 0$ for any g, we have for $\mathbb{E}_1\left(X_i^2\right) = \text{Var}_1\left(X_i\right) := \mathbb{E}\left(X_i^2 \mid i \in G_1\right)$ and $\mathbb{E}_2\left(X_i^2\right) = \text{Var}_2\left(X_i\right) := \mathbb{E}\left(X_i^2 \mid i \in G_2\right)$, and

β^* can be interpreted as the true target (probably user-defined) of this pooling regression.

$$
\begin{aligned}
\text{plim}_{n\to\infty}\hat{\beta} \overset{\text{def}}{=} \beta^* &= \text{plim}_{n\to\infty} I_n \\
&= \mathbb{E}\left(X_iX_i'\right)^{-1}\left(s_1\mathbb{E}_1\left(X_iX_i'\right)\beta_1 + s_2\mathbb{E}_2\left(X_iX_i'\right)\beta_2\right) \\
&= \mathbb{E}\left(X_i^2\right)^{-1}\left(s_1\mathbb{E}_1\left(X_i^2\right)\beta_1 + s_2\mathbb{E}_2\left(X_i^2\right)\beta_2\right) \\
&= \frac{s_1\,\text{Var}_1\left(X_i\right)}{\text{Var}\left(X_i\right)}\beta_1 + \frac{s_2\,\text{Var}_2\left(X_i\right)}{\text{Var}\left(X_i\right)}\beta_2
\end{aligned}
$$

C.2.2 The general case of K groups

The true model is

$$Y_i = \sum_{g=1}^{K} X_i'\left[\beta_g \mathbb{I}\left(i \in G_g\right)\right] + \varepsilon_i \text{ for } i = 1, \ldots, n.$$

Recall $N_0 = 0$ and $N_K = n$. We shall have

$$
\begin{aligned}
I_n &= \left(\frac{1}{n}\sum_{i=1}^{n} X_iX_i'\right)^{-1}\frac{1}{n}\left[\sum_{g=1}^{K}\left(\sum_{i=N_{g-1}+1}^{N_g} X_iX_i'\beta_g\right)\right] \\
&= \left(\mathbb{E}\left(X_iX_i'\right) + o_p(1)\right)^{-1}\left(\sum_{g=1}^{K}\frac{n_g}{n}\left(\frac{1}{n_g}\sum_{i=N_{g-1}+1}^{N_g} X_iX_i'\beta_g\right)\right) \\
&\to \mathbb{E}\left(X_iX_i'\right)^{-1}\left(\sum_{g=1}^{K} s_g\mathbb{E}_g\left(X_iX_i'\right)\beta_g\right),
\end{aligned}
$$

where $\mathbb{E}_g\left(X_iX_i'\right) \overset{def}{=} \mathbb{E}\left(X_iX_i' \mid i \in G_g\right)$, and $s_g = \text{plim}_{n\to\infty}\frac{n_g}{n}$. If (i) X_i is a random scalar; (ii) $\mathbb{E}\left(X_i \mid i \in G_g\right) = 0$ for any g (We shall not say if X_i is iid and $\mathbb{E}\left(X_i\right) = 0$. If they are iid they should not belong to different groups, unless the grouping is random), then we have $\mathbb{E}_g\left(X_iX_i'\right) \overset{\text{def.}}{=} \mathbb{E}\left(X_i^2 \mid i \in G_g\right) = \text{Var}\left(X_i \mid i \in G_g\right)$, which is denoted by $\text{Var}_g\left(X_i\right)$. Then

$$
\begin{aligned}
I_n &\to \mathbb{E}\left(X_iX_i'\right)^{-1}\left(\sum_{g=1}^{K} s_g\mathbb{E}_g\left(X_iX_i'\right)\beta_g\right) \\
&= \frac{\sum_{g=1}^{K} s_g\,\text{Var}_g\left(X_i\right)\beta_g}{\text{Var}\left(X_i\right)}.
\end{aligned}
$$

C.3 The case with controls

The true model

$$Y_i = Z_i'\alpha + X_i'\sum_{g=1}^{K}\left[\beta_g\mathbb{I}\left(i \in G_g\right)\right] + \varepsilon_i$$

where $Z_i = (\mathbb{I}(i \in G_1), \mathbb{I}(i \in G_2), \ldots, \mathbb{I}(i \in G_K))'$ and $\alpha = (\alpha_1, \ldots, \alpha_K)'$. This model is in accordance with the one in our paper

$$\underbrace{\Delta \ln y_{igt}}_{Y_{igt}} = \underbrace{\beta \Delta \ln (1 + \tau_{igt})}_{X'_{igt}\beta_g} + \underbrace{\eta_g + \eta_{Gt} + \eta_{it}}_{Z'_i\alpha} + \varepsilon_{igt},$$

where $t, g,$ and G together forms a group system. In this note, this group system is denoted by $G_{1:K}$. Now let $\mathbf{Z}$ be the $n \times K$ matrix of dummy variables for groups. Since we have a full set of dummy variables, we don't need an intercept. Now

$$\begin{aligned}
\hat{\beta} &= \left(\mathbf{X}'\mathbf{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z\mathbf{Y} \\
&= \left(\mathbf{X}'\mathbf{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z(\mathbf{X}\tilde{\beta} + \mathbf{Z}\alpha + \mathbf{e}) \\
&\text{by } \mathbf{M}_z\mathbf{Z} = 0 \\
&= \left(\mathbf{X}'\mathbf{M}_z\mathbf{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z\mathbf{X}\tilde{\beta} \\
&+ \left(\mathbf{X}'\mathbf{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z\mathbf{e} \\
&= I_n + II_n
\end{aligned}$$

where $\tilde{\beta}$ is a changing coefficient, and $\mathbf{X}\tilde{\beta}$ is an $n \times 1$ matrix with its i-the alement specified as $X'_i \sum_{g=1}^{K} [\beta_g \mathbb{I}(i \in G_g)]$

Under the condition $\mathbb{E}(\varepsilon \mid \mathbf{X}, \mathbf{Z}) = 0$, we should have $II_n \to 0$. Now we try to figure out the structure of $\mathbf{M}_z\mathbf{X}$. To this end, we define, for a positive integer d,

$$\iota_d = \begin{pmatrix} 1 \\ 1 \\ \vdots \\ 1 \\ \vdots \\ 1 \end{pmatrix} \text{ this is } d \times 1 \text{ vector of } 1,$$

and

$$J_d = \iota_d \iota'_d = \begin{pmatrix} 1 & \ldots & 1 \\ \vdots & \ldots & \vdots \\ 1 & \ldots & 1 \end{pmatrix} \text{ this is } d \times d \text{ matrix of } 1$$

Now

$$\mathbf{Z} = \begin{pmatrix} 1 & 0 & \dots & 0 \\ 1 & \vdots & \dots & \vdots \\ \vdots & 0 & \dots & \vdots \\ 0 & 1 & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ \vdots & 1 & \dots & 0 \\ \vdots & 0 & \dots & 1 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 0 & \dots & 1 \end{pmatrix} = \begin{pmatrix} l_{n_1} & 0_{n_1 \times 1} & \dots & 0_{n_1 \times 1} \\ 0_{n_2 \times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3 \times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{K-1} \times 1} \\ 0_{n_K \times 1} & 0_{n_K \times 1} & \dots & l_{n_K} \end{pmatrix}$$

$$\mathbf{Z}'\mathbf{Z} = \begin{pmatrix} l_{n_1} & 0_{n_1 \times 1} & \dots & 0_{n_1 \times 1} \\ 0_{n_w \times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3 \times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{K-1} \times 1} \\ 0_{n_K \times 1} & 0_{n_K \times 1} & \dots & l_{n_K} \end{pmatrix}' \begin{pmatrix} l_{n_1} & 0_{n_1 \times 1} & \dots & 0_{n_1 \times 1} \\ 0_{n_w \times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3 \times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{K-1} \times 1} \\ 0_{n_K \times 1} & 0_{n_K \times 1} & \dots & l_{n_K} \end{pmatrix} = \begin{pmatrix} n_1 & 0 & \dots & 0 \\ \vdots & n_2 & \vdots & \\ \vdots & & & \\ 0 & \dots & \vdots & \\ 0 & \dots & n_K & \end{pmatrix}$$

$$\left(\mathbf{Z}'\mathbf{Z}\right)^{-1} = \begin{pmatrix} \frac{1}{n_1} & 0 & \dots & 0 \\ \vdots & \frac{1}{n_2} & \vdots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ 0 & \dots & \dots & \frac{1}{n_K} \end{pmatrix}$$

and

$$\mathbf{Z}\left(\mathbf{Z}'\mathbf{Z}\right)^{-1}\mathbf{Z}' = \begin{pmatrix} l_{n_1} & 0_{n_1\times 1} & \dots & 0_{n_1\times 1} \\ 0_{n_2\times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3\times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{\kappa-1}\times 1} \\ 0_{n_\kappa\times 1} & 0_{n_\kappa\times 1} & \dots & l_{n_\kappa} \end{pmatrix} \begin{pmatrix} \frac{1}{n_1} & 0 & \dots & 0 \\ \vdots & \frac{1}{n_2} & \vdots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ 0 & \dots & \dots & \frac{1}{n_\kappa} \end{pmatrix} \begin{pmatrix} l_{n_1} & 0_{n_1\times 1} & \dots & 0_{n_1\times 1} \\ 0_{n_2\times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3\times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{\kappa-1}\times 1} \\ 0_{n_\kappa\times 1} & 0_{n_\kappa\times 1} & \dots & l_{n_\kappa} \end{pmatrix}'$$

$$= \begin{pmatrix} \frac{1}{n_1}l_{n_1} & 0_{n_1\times 1} & \dots & 0_{n_1\times 1} \\ 0_{n_2\times 1} & \frac{1}{n_2}l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3\times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{n-1}\times 1} \\ 0_{n_\kappa\times 1} & 0_{n_\kappa\times 1} & \dots & \frac{1}{n_\kappa}l_{n_\kappa} \end{pmatrix} \begin{pmatrix} l_{n_1} & 0_{n_1\times 1} & \dots & 0_{n_1\times 1} \\ 0_{n_2\times 1} & l_{n_2} & \dots & \vdots \\ \vdots & 0_{n_3\times 1} & \dots & \vdots \\ \vdots & \vdots & \dots & 0_{n_{\kappa-1}\times 1} \\ 0_{n_\kappa\times 1} & 0_{n_\kappa\times 1} & \dots & l_{n_\kappa} \end{pmatrix}'$$

$$= \begin{pmatrix} \frac{1}{n_1} & \cdots & \frac{1}{n_1} & 0 & \dots & 0 & \cdots & \cdots & \cdots & 0 \\ \vdots & \dots & \vdots & \vdots & \cdots & \vdots & \cdots & \cdots & \cdots & \vdots \\ \frac{1}{n_1} & \cdots & \frac{1}{n_1} & 0 & \dots & 0 & \cdots & \cdots & \cdots & \vdots \\ 0 & \dots & 0 & \frac{1}{n_2} & \cdots & \frac{1}{n_2} & 0 & \cdots & \vdots & \vdots \\ \vdots & \dots & \vdots & \vdots & \cdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ 0 & \dots & 0 & \frac{1}{n_2} & \cdots & \frac{1}{n_2} & 0 & \cdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & 0 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & 0 & \frac{1}{n_\kappa} & \cdots & \frac{1}{n_\kappa} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & 0 & \frac{1}{n_\kappa} & \cdots & \frac{1}{n_\kappa} \end{pmatrix} = \begin{pmatrix} \frac{1}{n_1}J_{n_1} & 0_{n_1\times n_2} & \cdots & 0_{n_1\times n_\kappa} \\ 0_{n_2\times n_1} & \frac{1}{n_2}J_{n_2} & \cdots & \vdots \\ \vdots & \vdots & \cdots & \vdots \\ 0_{n_\kappa\times n_1} & \cdots & \cdots & \frac{1}{n_\kappa}J_{n_\kappa} \end{pmatrix}$$

and

$$\mathbf{Z}\left(\mathbf{Z}'\mathbf{Z}\right)^{-1}\mathbf{Z}'\mathbf{X} = \begin{pmatrix} \frac{1}{n_1}J_{n_1} & 0_{n_1\times n_2} & \cdots & 0_{n_1\times n_\kappa} \\ 0_{n_2\times n_1} & \frac{1}{n_2}J_{n_2} & \cdots & \vdots \\ \vdots & \vdots & \cdots & \vdots \\ 0_{n_\kappa\times n_1} & \cdots & \cdots & \frac{1}{n_K}J_{n_K} \end{pmatrix} \begin{pmatrix} \frac{1}{n_1}\sum_{i=1}^{N_1} X_i \\ \vdots \\ \frac{1}{n_1}\sum_{1}^{N_1} X_i \\ \vdots \\ \frac{1}{n_2}\sum_{i=N_1+1}^{N_2} X_i \\ \vdots \\ \frac{1}{n_2}\sum_{i=N_1+1}^{N_2} X_i \\ \vdots \\ \frac{1}{n_K}\sum_{i=N_{K-1+1}}^{N_K} X_i \\ \vdots \\ \frac{1}{n_K}\sum_{i=N_{K-1+1}}^{N_K} X_i \end{pmatrix} = \begin{pmatrix} \bar{X}_1 l_{n_1} \\ \bar{X}_2 l_{n_2} \\ \vdots \\ \bar{X}_K l_{n_K} \end{pmatrix}$$

where $X_g = \frac{1}{n_s}\sum_{i=N_{s-1}+1}^{N_s} X_i$, the within group average, and the last row is $n \times 1$. Then

$$\begin{pmatrix} \tilde{X}_1 \\ \vdots \\ \tilde{X}_{N_1} \\ \tilde{X}_{N_1+1} \\ \vdots \\ \tilde{X}_{N_2} \\ \vdots \\ \tilde{X}_{N_{K-1}+1} \\ \vdots \\ \tilde{X}_{N_K} \end{pmatrix} \overset{def}{=} \mathrm{M}_z\mathrm{X} = \mathrm{X} - \mathrm{Z}\left(\mathrm{Z}'\mathrm{Z}\right)^{-1}\mathrm{Z}'\mathrm{X} = \begin{pmatrix} X_1 - \bar{X}_1 \\ \vdots \\ X_{N_1} - \bar{X}_1 \\ X_{N_1+1} - \bar{X}_2 \\ \vdots \\ X_{N_2} - \bar{X}_2 \\ \vdots \\ X_{N_{K-1}+1} - \bar{X}_K \\ \vdots \\ X_{N_K} - X_K \end{pmatrix}$$

Recall

$$\left(\mathbf{X}'\mathrm{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z\mathbf{X}\tilde{\beta} = \left(\frac{1}{n}\sum_{i=1}^{n}\tilde{X}_i\tilde{X}_i'\right)^{-1}\left(\sum_{g=1}^{K}\frac{n_g}{n}\left(\frac{1}{n_g}\sum_{i=N_{z-1}+1}^{N_s}\tilde{X}_i X_i'\beta_g\right)\right),$$

and $\left[\frac{1}{n_1}\sum_{i=1}^{n_t}\tilde{X}_i X_i'\right]$ must be non-negative since

$$
\begin{aligned}
\sum_{i=N_{s-1}+1}^{N_s}\tilde{X}_i X_i' &= \sum_{i=N_{s-1}+1}^{N_g}\tilde{X}_i X_i \\
&= \sum_{i=N_{s-i+1}}^{N_g}\left(X_i-\bar{X}_g\right)X_i \\
&= \sum_{i=N_{s-1+1}}^{N_s}\left(X_i-\bar{X}_g\right)\left(X_i-\bar{X}_g\right)+\sum_{i=N_{s-1+1}}^{N_s}\left(X_i-\bar{X}_g\right)\bar{X}_g \\
&= \sum_{i=N_{s-1+1}}^{N_s}\left(X_i-\bar{X}_g\right)^2+\bar{X}_g\sum_{i=N_{s-1}+1}^{N_s}\left(X_i-\bar{X}_g\right) \\
&= \sum_{i=N_{s-1}+1}^{N_s}\left(X_i-\bar{X}_g\right)^2+0 \\
&= \sum_{i=N_{s-1}+1}^{N_s}\left(X_i-\bar{X}_g\right)^2\geq 0,
\end{aligned}
$$

i.e., the weight k always positive. Since X_g is the within group average, it will converge to $\mathbb{E}\left(X_i \mid i\in G_g\right)$, then

$$
\begin{aligned}
\frac{1}{n_g}\sum_{i=N_{s-1}+1}^{N_s}\tilde{X}_i X_i' = \frac{1}{n_g}\sum_{i=N_{s-i}+1}^{N_s}\left(X_i-X_g\right)^2 \\
&\to \mathbb{E}\left(X_i-\mathbb{E}\left(X_i \mid i\in G_g\right) \mid i\in G_g\right)^2 \\
&= \mathrm{Var}\left(X_i \mid i\in G_g\right)
\end{aligned}
$$

and the

$$
\begin{aligned}
\frac{1}{n}\sum_{i=1}^{n}\tilde{X}_i\tilde{X}_i' &= \sum_{g=1}^{K}\frac{n_g}{n}\left(\frac{1}{n_g}\sum_{i=N_{g-1}+1}^{N_g}\tilde{X}_i\tilde{X}_i'\right) \\
&\to \sum_{g=1}^{K}\left[s_g\,\mathrm{Var}\left(X_i \mid i\in G_g\right)\right]
\end{aligned}
$$

Finally,

$$
\begin{aligned}
\hat{\beta}=\left(\mathbf{X}'\mathbf{M}_z\mathbf{X}\right)^{-1}\mathbf{X}'\mathbf{M}_z\mathbf{X}\tilde{\beta}+o_p(1) &= \left(\frac{1}{n}\sum_{i=1}^{n}\tilde{X}_i\tilde{X}_i'\right)^{-1}\left(\sum_{g=1}^{K}\frac{n_g}{n}\left(\frac{1}{n_g}\sum_{i=N_{g-1}+1}^{N_g}\tilde{X}_i X_i'\beta_g\right)\right)+o_p(1) \\
&\to \left(\sum_{g=1}^{K}\left[s_g\,\mathrm{Var}\left(X_i \mid i\in G_g\right)\right]\right)^{-1}\left[\sum_{g=1}^{K}s_g\,\mathrm{Var}\left(X_i \mid i\in G_g\right)\beta_g\right]
\end{aligned} \tag{C.1}
$$

The intepretation, the weight for the coefficient in group g, β_g, is

$$\left(\sum_{g=1}^{K}\left[s_g \operatorname{Var}\left(X_i \mid i \in G_g\right)\right]\right)^{-1}\left[s_g \operatorname{Var}\left(X_i \mid i \in G_g\right)\right]. \tag{C.2}$$

C.3.1 Weighted case

Let w_i be an user-specified weight on each observation. Then the model becomes

$$w_i Y_i = \sum_{g=1}^{K} w_i X_i' \left[\beta_g \mathbb{I}\left(i \in G_g\right)\right] + w_i \varepsilon_i \text{ for } i = 1, \ldots, n$$

The estimated model

$$w_i Y_i = w_i X_i' \beta + w_i \varepsilon_i \text{ for } i = 1, \ldots, n.$$

We can use $w_i X_i$ to replace X_i in C.1 and C.2. That is

$$\hat{\beta} \rightarrow \left(\sum_{g=1}^{K}\left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]\right)^{-1}\left[\sum_{g=1}^{K} s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right) \beta_g\right],$$

and the weight for β_g is

$$\left(\sum_{g=1}^{K}\left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]\right)^{-1}\left[s_g \operatorname{Var}\left(w_i X_i \mid i \in G_g\right)\right]$$

D Appendix: Decomposition II

Weyl and Fabinger (2013) have shown that the tariff pass-through ρ is determined by the elasticity of demand ϵ_D and the elasticity of supply ϵ_S under perfect competition, where the tariff pass-through ρ is defined as the change in the price paid by the consumer in response to the change in tariffs. Following the trade literature, we define the tariff pass-through as the log change of tariff-inclusive import price and verify that the decomposition proposed by Weyl and Fabinger (2013) still holds.[30] By definition, p and p^* denote the price paid by domestic importers and foreign exporters, respectively. Let D be the imports demanded as a function of p and S be the imports supplied as a function of p^*. Then, the equilibrium in the import market is given by

$$D(p) = S\left(p^*\right)$$

where $p^* = \frac{p}{t}$ and $t \equiv 1+\tau$. We thus use the tariff pass-through $\rho = \frac{d\ln p}{d\ln t}$ as the change in the price paid by the importer in response to the change in tariff. By the implicit function theorem, when assuming we begin at zero tariffs, $D(p) = S\left(\frac{p}{t}\right)$ implies that

$$\begin{aligned}
D'(p)\frac{dp}{dt} &= \left(\frac{\frac{dp}{dt}t - p}{t^2}\right) S'\left(\frac{p}{t}\right) \\
\Rightarrow D'(p)\frac{dp}{dt} &= \left(\frac{\frac{dp}{dt}t - p}{t^2}\right) S'(p)t \\
\Rightarrow D'(p)\rho &= (\rho - 1)S'(p) \\
\Rightarrow \rho &= \frac{S'(p)}{S'(p) - D'(p)} = \frac{1}{1 + \left(\frac{\epsilon_D}{\epsilon_S}\right)}
\end{aligned}$$

where $\epsilon_D \equiv -\left(\frac{D'(p)}{p}Q\right)$ denotes the import demand elasticity and $\epsilon_S \equiv \frac{S'(p)}{p}Q$ denotes the export supply elasticity. That is, the pass-through is determined by the relative value of the elasticity of import demand and the elasticity of export supply. The more inelastic side of the market bears the tariff burden more, as the traditional result goes.

[30] For simplicity, Weyl and Fabinger (2013) assume that demand and supply are smooth and that excess supply declines in price so that there exists a unique equilibrium. Consistent with nearly all other literature, they assume all goods outside the industry of interest are supplied perfectly competitively, and thus the welfare of producers arising from consumer substitution to these goods may be ignored.