Escaping the Trade War: Finance and Relational Supply Chains in the Adjustment to Trade Policy Shocks *

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Abstract

The impact of the 2018–2019 trade war on total US exports depends on the direct effect of foreign retaliatory tariffs as well as on the ability of US exporters to reorganize global supply chains and redirect exports to other markets, away from retaliating countries. We document that the sharp decline in US exports to retaliating countries was compensated by a gradual increase in exports to other markets. We then develop a model of export reallocation to study the role of financial constraints and the persistence or stickiness of trade relationships as underlying mechanisms shaping both the direct impact of retaliatory tariffs and the extent of the reallocation toward alternative markets. In line with the predictions of the model, we find that in industries with high leverage, Chinese retaliatory tariffs led to a stronger decline in US exports to China but a larger increase in exports to the rest of the world. We find a similar pattern among industries with less persistent trade relationships. Finally, we document that other potential mechanisms do not appear to be economically and/or statistically significant in shaping the response to tariffs.

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1 Introduction

Starting in 2018, the US has been engaged in an unprecedented trade war involving broad rounds of tariffs imposed on its trading partners (especially China) and equally broad retaliatory tariffs on US exports. An event of this magnitude is unseen in the post-war era, and constitutes a major departure from a decades-long trajectory toward free trade. This trade war constitutes an exceptional testing ground for the effects of trade policy.

In this paper, we assess the overall impact of the trade war on US exports. This overall impact depends both on the direct effect of retaliatory tariffs on exports to retaliating countries and on the extent to which exports can be rerouted to alternative markets. While the literature has focused on the direct effect, our goal is to understand the full impact of the trade war on US exports. In addition, a key goal of this paper is to understand the mechanisms behind both the direct effect of tariffs and the rerouting of exports. We show that finacial conditions of exporters (specifically, leverage ratios) and the stickiness of trading relationships play a key role in shaping the response of US exports to tariffs.

To guide our analysis, we develop a theoretical model of US exporters facing foreign tariffs and derive precise testable implications that we can map to the data. We consider a model of US exporting firms selling to two markets, China and the rest of the world. In the original Melitz [2003] model, as well as in other canonical models of international trade, a tariff in one market does not affect a firm's exports to other markets, because marginal cost is constant. For this reason, we focus on an environment with an increasing marginal cost, as in Almunia et al. [2021], in which China's retaliatory tariff leads not only to a decline in exports to China, but also to an increase in exports to the rest of the world. We incorporate the role of relationship stickiness by adding a structure of firm–to–firm trade, a per–relationship fixed cost, and a cost of terminating existing relationships. Under this structure, exporters are unwilling to terminate unprofitable relationships in response to higher tariffs, and consequently exports are more responsive to tariffs when relationship stickiness is low. We also incorporate the role of finance following Manova [2013]. Exporters have a working capital requirement for their fixed costs which is financed by borrowing. Under a higher leverage ratio, an exporter's fixed cost is higher, and an increase in China's tariff has a higher probability of leading to terminating relationships and reducing export volumes. Thus, this financial channel magnifies the decline in exports to China. At the same time, the increasing marginal cost mechanism can lead to a larger increase in exports to the rest of the world through this financial channel. Finally, the elasticity of substitution, which is the only determinant of the response of a firm's exports to tariffs in the original Melitz [2003] model, also plays a role in our model. Exports to China fall by more in response to an increase in China's tariff when the elasticity of substitution is high (i.e. when products are less differentiated).

Our empirical analysis starts by documenting the impact of foreign retaliatory tariffs on US exports to retaliating countries. Beyond the average response documented in recent work [Amiti et al., 2019, Fajgelbaum et al., 2020], we show there is a large degree of heterogeneity in the impact of tariffs across both destinations and sectors. The effect of Chinese and Canadian tariffs on trade volumes was at least twice as large as the effect of tariffs imposed by the European Union. At the same time, retaliatory tariffs led to a larger decline in exports of industrial supplies followed by agricultural goods and consumer goods, but there was little impact on exports of capital goods. Consistent with much of the literature, we find no significant adjustment in export prices in response to retaliatory tariffs.

We then extend our analysis to focus on the reallocation of exports away from retaliating countries and toward alternative markets. We find a gradual reallocation of exports away from China in product categories facing larger increases in Chinese tariffs. This reallocation led to an increase in exports primarily to East and South Asia and to Europe. We find that this reallocation of exports was directed primarily to countries to which the US exports a similar export basket than the one it exports to China. To establish the total effect of the trade war on US exports, we estimate product–level regressions of foreign tariffs on US exports. We find that the sum of the large and negative direct effect and the increase in exports through the reallocation toward other markets add up to a small effect on US total exports. This effect on total exports is not statistically significant except in the very short term, given that reallocation is gradual. Nevertheless, a breakdown into sectors shows that total exports of industrial supplies do fall as a result of the trade war.

Next, we document the mechanisms that explain both the direct effect of retaliatory tariffs and the reallocation effect. To examine the role of financial conditions, we construct industry–level leverage ratios from COMPUSTAT during the period prior to the trade war. Consistent with our model, we find that in high–leverage industries, Chinese tariffs lead to a larger decline in exports to China and a larger increase in exports to the rest of the world. To provide further evidence, we explore alternative financial measures that also yield results consistent with our model. [1]

Also consistent with the model, we find in the data that relationship stickiness is another important factor that shapes the response of exports to tariffs. For this purpose, we use a new measure by Martin et al. [2020] built using microdata on firm–to–firm trade relationships. In industries with low stickiness, the decline of exports to retaliating countries is larger and the increase in exports toward other markets is also larger. In line with our model, these findings can be interpreted as suggesting that in sectors with higher degrees of relationship stickiness, it is more costly to terminate existing relationships with importers in China. As an important check to our results, we find that the role of relationship stickiness is much stronger in industries with higher degrees of arms–length trade, among which we would expect the mechanisms in our model to be more relevant.

In line with another testable implication of the model, we observe that in industries with less differentiated products there is a larger decline in exports to China and larger growth in exports to other markets in response to Chinese tariffs. This result is intuitive, and goes in line with the role of elasticities of substitution as the determinant of the response of firms' exports to tariffs in canonical trade models.

To conclude, we assess jointly the importance of these determinants that can shape the response to retaliatory tariffs. Aside from those mentioned earlier, we include a number of other potential mechanisms including inventories, upstreamness, contract intensity, and quality ladders. In this joint assessment, we find that leverage ratios and relationship stickiness stand out as the determinants of the effect of Chinese tariffs on US exports, while other determinants are not economically and/or statistically significant.

Related literature This paper complements recent work analyzing the consequences of the US–China trade war on trade flows. Fajgelbaum et al. [2020] and Amiti et al. [2019] document the direct average impact of foreign retaliatory tariffs on US exports to all destinations. We

[1] In the model, a higher working capital requirement can be interpreted as higher external finance dependence, which is a variable used frequently in the trade and finance literature [Chor and Manova, 2012]. We find that exports to China fall more strongly and exports to the rest of the world increase more in industries with higher external finance dependence. Further, we also find a larger decline in exports to China and a larger increase in exports to the rest of the world in industries with low levels of trade credit. This is consistent with the argument in the literature that in industries with low levels of trade credit, firms are forced to borrow more from financial institutions [Chor and Manova, 2012], so the results for industries with low levels of trade credit are in line with those for industries with high leverage ratios.

make two contributions relative to this work. First, we analyze the *overall* effect of retaliatory tariffs on US exports, which is the sum of the direct effect and the reallocation in response to these tariffs. Second, we analyze the underlying heterogeneity and mechanisms behind these effects, establishing an important role for financial conditions and relationship stickiness.

Other important work on the trade war includes Cavallo et al. [2021] who study tariff passthrough on to prices using data on both border prices and retail prices. They establish a full passthrough of US import tariffs on to border prices but an incomplete passthrough to retail prices. In contrast, they find a decline in US export prices in response to retaliatory tariffs, driven by nondifferentiated and agricultural goods.[2] Flaaen et al. [2020] find a large impact on consumer prices of 2018 US tariffs on washing machines imposed on various trading partners and show that production relocation can dampen this passthrough. Handley et al. [2020] establish the impact of US import tariffs on US exports through input–output linkages. Waugh [2019] documents that retaliatory tariffs led to a decline in consumption in more exposed regions across the US. In addition, Benguria and Saffie [2021] show that beyond tariffs, the presence of Chinese state–owned enterprises led to a decline in US exports during the trade war. From the perspective of the Chinese economy, Benguria et al. [2022] establish that trade policy uncertainty led to a decline in investment among Chinese listed firms. Finally, Fajgelbaum and Khandelwal [2022] provide a detailed survey of the literature analyzing the effects of the 2018–2019 trade war.

Our paper is connected and contributes to other work that studies how trade is reallocated in response to tariffs or other shocks. From a global perspective, Fajgelbaum et al. [2021] analyze the reallocation of third country exports in response to the trade war, finding that third countries increased exports to the US and reduced exports to China, and that the trade war did not slow down global trade.[3] In a different context, Almunia et al. [2021] document how Spanish firms increase their exports substantially in response to reduced domestic demand during the Great Recession. In the context of the trade war, Jiao et al. [2022] document the response of exporting firms in a Chinese prefecture to US trade war tariffs. Their analysis

[2]The lack of adjustment in unit values we find is consistent with other work using Census data constructed from customs records [Fajgelbaum et al., 2020, Amiti et al., 2019]. In contrast, Cavallo et al. [2021] use data from the BLS survey of international prices. Consistent with Cavallo et al. [2021], the only subsample for which we find evidence of a decline in unit values corresponds to food and agricultural goods.

[3]Recent work by Dang et al. [2023] is also focused on understanding the impact of the trade war on the trade flows of bystander countries.

finds a mild increase in exports to other markets (with the exception of a moderate increase in exports to Europe), and no adjustment in domestic sales. As a consequence, they find a large decline in total exports and total revenue for Chinese exporters during the trade war. In a similar vein, Ma et al. [2021] find diversion of Chinese imports in response to US tariffs use product–level data among non–differentiated products. More recently, Jiang et al. [2023] and Sheng et al. [2023] also examine the reallocation of Chinese exports. None of these papers, however, focus on financial constraints or relationship stickiness, nor on the reallocation of US exports, which is our case. A potential reason why we find more reallocation of US exports than these studies focusing on Chinese trade flows is because our empirical specification allows us to measure the dynamics of this reallocation, which is not immediate but increases gradually over time.

Our result that industries with high financial leverage face a larger decline in exports to retaliating countries connects our work to evidence on the role of leverage in other contexts. In particular, Kalemli-Özcan et al. [2022] study the role of leverage in the context of Europe's slow recovery from the 2008 financial crisis. They establish that firms with a higher degree of leverage were more likely to reduce investment. In related work, Giroud and Mueller [2017] show that firms with high leverage were more likely to reduce employment in response to demand shocks during the 2008–2009 financial crisis. To the best of our knowledge, the notion that leverage shapes the response to shocks has not been documented in the context of the reorganization of global supply chains in response to trade policy shocks. More broadly, a large literature has studied the role of finance in shaping trade flows. Much of the recent work in this literature was motivated by the trade collapse during the 2008–2009 global financial crisis, and our paper is connected to work assessing the role of finance in the response of trade flows to that event [Chor and Manova, 2012, Levchenko et al., 2010, 2011, Ahn et al., 2011, Benguria and Taylor, 2020].

In addition, our finding that relationship stickiness shapes the response of US exports connects our work to Martin et al. [2020], who establish that this feature also determines the response of trade flows to uncertainty shocks. It also links our paper to work on relational global value chains surveyed by Antràs and Chor [2022] which studies how firm to firm relationships shape the response to trade policy shocks. In fact, Antràs and Chor [2022] conjecture that the US–China trade war could have a differential impact on relational versus spot trade relationships.

Finally, from a theoretical perspective, we build a model of export reallocation extending the framework of Almunia et al. [2021] to analyze the role of finance and of relationship stickiness in the response of exports to tariffs. Perhaps due to the low tariff rates of recent decades, the literature has not focused much on understanding the mechanisms behind the response of trade flows to tariffs, yet one would expect a renewed interest in this issue following the trade war.

Organization The rest of the paper is organized as follows. In Section 2, we present our theoretical model and the testable implications derived from it. In Section 3, we provide a brief summary of the trade war focused on foreign retaliatory tariffs and describe our data sources. In Section 4, we document the effect of foreign tariffs on US exports to retaliatory countries as well as to other markets. Finally, in Section 5, we analyze the determinants of this effect of foreign tariffs on US exports.

2 A model of export reallocation

We consider a model of exporting firms selling to two markets, China and the rest of the world. The model extends Melitz [2003] in several dimensions. A first point of departure is motivated by the fact that in Melitz [2003], tariffs imposed in one market do not lead to changes in exports to other markets. To make the export decisions in both markets interdependent, such that tariffs set by China lead to changes in exports not only to China but also to the rest of the world, we follow Almunia et al. [2021] and allow for an increasing marginal cost. For the sake of clarity, we first present this baseline version of the model, and derive the response of trade flows to an increase in Chinese tariffs. We then extend the model to show how the elasticity of exports to tariffs in each market depends on financial aspects (firm leverage) and on the nature of buyer-seller relationships (relationship stickiness), as well as on the elasticity of substitution which is the sole determinant of the effect of tariffs on a firm's exports in Melitz [2003]. Model details and proofs are provided in Appendix A.1 .

2.1 Baseline model

Consider US exporting firms indexed by e facing a demand in each market $m = (CHN, ROW)$ stemming from CES preferences and given by:

$$q_e = A_m \cdot p_e^{-\sigma}, \tag{1}$$

with an elasticity of substitution $\sigma > 1$ and where q_e represents the quantity demanded and p_e represents the price. The demand level is $A_m = E_m \cdot P_m^{\sigma-1}$ (where P_m represents the price index and E_m represents aggregate expenditure). We consider the demand level and wages to be exogenous, as we are not concerned with general equilibrium effects.[4] Following the specification in Almunia et al. [2021], each exporting firm's variable cost is:

$$\frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1} \cdot (q_{e,CHN} + \cdot q_{e,ROW})^{\lambda+1}, \tag{2}$$

where $\lambda > 0$ captures the extent to which marginal cost is increasing. In this expression φ_e denotes the exporting firm's productivity. The tariffs in each market (τ_{CHN} and τ_{ROW}) are modeled as iceberg trade costs as is standard in the literature. This implies $\tau_{CHN} > 1$ and $\tau_{ROW} > 1$.[5]

Firm's decisions in each market are interdependent due to the increasing marginal cost assumption, and each firm maximizes total profits in both markets:

$$\pi_e = p_{e,CHN} \cdot q_{e,CHN} + p_{e,ROW} \cdot q_{e,ROW} - \frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1} (q_{e,CHN} \cdot \tau_{CHN} + q_{e,ROW} \cdot \tau_{ROW})^{\lambda+1} - f_{CHN} - f_{ROW}, \tag{3}$$

where f_{CHN} and f_{ROW} represent the fixed cost of exporting to each market. This implies the export revenue of each US exporting firm in China and the rest of the world is:

$$r_{e,CHN} = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot A_{CHN} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \tau_{CHN}^{1-\sigma} \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{4}$$

[4] We set wages equal to one in both markets. In addition and without loss of generality, we abstract from domestic demand.

[5] In Appendix A.1.5, we present a robustness check in which tariffs are modeled as ad-valorem tariffs. We obtain the same propositions in that case.

and

$$r_{e,ROW} = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot A_{ROW} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \tau_{ROW}^{1-\sigma} \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}}, \qquad (5)$$

respectively. As is evident from these expressions, export revenue from each market depends on the demand level and the tariffs in both markets. This framework leads to:

Proposition 1a An increase in the tariff in China is associated with a decline in exports to China.

Proposition 1b An increase in the tariff in China is associated with an increase in exports to the rest of the world.

Proof: See Appendix A.1.

The increase in the Chinese tariff has the direct effect of reducing exports to China, as in Melitz [2003]. As the exporting firm's output falls, its marginal cost falls as well. This makes the firm more competitive, leading to an increase in exports to the rest of the world. These propositions lead to the following testable implications:

Testable Implication 1a Exports to China will see a relative decrease among products facing larger relative increases in Chinese tariffs.

Testable Implication 1b Exports to the rest of the world will see a relative increase among products facing larger relative increases in Chinese tariffs.

Next, we study the determinants that shape the response of exports to tariffs. We focus first on the role of finance, and next on the role of relationship stickiness. To analyze these two elements, we extend the baseline model to a version featuring firm–to–firm trade. We prefer to treat these two extensions separately for the sake of clarity, although it is feasible to combine them in a single model. Finally, we discuss the role of the elasticity of substitution using the baseline model.

2.2 Firm to firm trade

Assume that exporting firms sell differentiated intermediate inputs, which are imported and assembled by final good producers in each market. Assume there are N_m final good producers in each market m, and they differ in their productivity within each market. These final good producers then sell these differentiated final goods they assemble to consumers. Each importer combines these imported inputs based on a CES production function.[6] This structure is consistent with the baseline model, in the sense that the demand for US exporters derived from this framework has the same structure as before.

The production function of each importer i is:

$$Q_i = \psi_i \cdot \left(\int_{\Omega_i} c_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \tag{6}$$

where ψ_i is the productivity of the importing firm i, Ω_i is the set of varieties available to the importing firm, and $c_i(\omega)$ is the quantity of each input ω used by the importing firm. Thus, the demand for each US exporter e from each importing firm i is:

$$q_{ei} = A_m \cdot \psi_i \cdot p_{ei}^{-\sigma}, \tag{7}$$

and the total demand for each exporter is the sum of the demand across all importers it trades with. In other words, the demand for US exporters has the same form as in the baseline model, but this extension allows us to focus on relationships between exporting and importing firms.

Assume that in addition to the per-period fixed exporting cost introduced earlier (f_m), there is also a relationship–specific per-period fixed cost for the exporting firm (g_m). This captures the cost of maintaing already existing relationships. This type of relationship–specific fixed cost is common in firm–to–firm trade models (e.g. Eaton et al. [2021]).[7] This implies that the exporting firm will engage in trade with a specific importer as long as the increase in total operating profits obtained from adding that relationship is larger than the relationship–specific fixed cost. The per–relationship fixed cost is constant across importers in each market. The exporting firm is thus more likely to trade with more productive importers, because a

[6] This structure is standard in the literature on firm–to–firm trade. See for example Bernard et al. [2018].

[7] Eaton et al. [2021] justify this relationship–specific fixed cost with evidence from surveys of Colombian exporters. They also infer this relationship–specific fixed cost is substantial by estimating their firm–to–firm trade model.

higher productivity of the importer implies a larger demand for the exporting firm.

2.3 Financial constraints

We extend this model with firm–to–firm trade and incorporate the role of finance following Manova [2013]. We assume that exporting firms have a working capital requirement, such that they need to borrow funds to finance a fraction $\delta < 1$ of their fixed cost before production takes place.[8]

In line with Manova [2013], we assume exporters borrow the funds required from investors, and that exporters repay the amount borrowed with probability ν and default with probability $1-\nu$, such that ν captures the degree of financial contractibility. If the exporter defaults, the lender seizes the collateral χ. The amount payed back by exporters to investors, Φ, is such that the investor's participation constraint is met with equality (i.e., investors break even).[9] This implies:

$$\delta \cdot \tilde{f} = \nu \cdot \Phi + (1-\nu) \cdot \chi. \tag{8}$$

where $\tilde{f}$ represents the sum of the fixed costs of exporting (including the per–relationship fixed costs) and where the collateral χ is equal to a constant fraction of the sunk entry cost. This structure results in an additional financial fixed cost payed by exporting firms equal to $\frac{\delta}{\nu} \cdot \tilde{f} - \frac{(1-\nu)}{\nu} \cdot \chi > 0$.

Because the working capital requirement applies to the fixed cost, the price, quantity and revenue in each trading relationship between a US exporter and a foreign importer are not affected by the working capital requirement.

In this context, the effect of China's tariffs is described by the following propositions. We express these propositions in terms of the leverage ratio of an exporting firm (defined as the amount borrowed over total revenue), which as we show in the Appendix is increasing in the working capital requirement δ and has the advantage that it can be measured in the data.

Proposition 2a If exporting fixed costs are high in China relative to the rest of the world, an increase in China's tariff is associated with a decline in exports to China which is increasing in

[8] In out context, this includes the relationship–specific fixed costs, although this assumption is not critical.

[9] The timing and financial contracting specifications are such that at the start of each period, each exporting firm makes a take-it-or-leave-it offer to a potential investor, which describes the amount borrowed, the amount to be repayed, and the collateral. Each exporting firm pays the investor back after export revenue is realized.

the firm's leverage ratio.

Proposition 2b If exporting fixed costs are high in China relative to the rest of the world, an increase in China's tariff is associated with an increase in exports to the rest of the world, which is increasing in the firm's leverage ratio.

Proof: See Appendix A.1.

To decide whether to keep or terminate a trading relationship with a Chinese importer, a US exporter compare the operating profits (i.e. revenue minus variable cost) to the fixed costs. An increase in China's tariff leads to a decline in operating profits which is independent of the working capital requirement and has no effect on the fixed cost. A higher working capital requirement (higher δ, associated with a higher leverage ratio), the fixed cost is higher (due to the higher financial component of it). This implies that an increase in China's tariff is more likely to terminate trading relationships with a Chinese importer if the leverage ratio is higher.

As stated in the proposition, we assume that the fixed cost of exporting to China is sufficiently high relative to the rest of the world, such that exporters that sell to any Chinese importer also sell to all importers in the rest of the world.[10] This implies that the expansion in the rest of the world market will occur through the intensive margin, and will not depend on the fixed cost of selling to the rest of the world.

This proposition leads to the following testable implications:

Testable Implication 2a The decline in exports to China in response to an increase in Chinese tariffs will be larger among high leverage sectors.

Testable Implication 2b The increase in exports to the rest of the world in response to an increase in Chinese tariffs will be larger among high leverage sectors.

As a robustness check, in Appendix A.1.6, we examine a model of financial constraints with different assumptions, following a structure that is also common in the literature. In that case, exporters face a working capital requirement and are subject to a borrowing limit. We are able to derive equivalent propositions, that do not rely on the firm–to–firm dimension of the

[10] We express this assumption mathematically in the Appendix. This assumption is consistent with the fact that the number of US firms exporting to China is lower than the number of US exporters selling to Canada, Mexico, or the European Union. Controlling for market size, this pattern is even more significant [US Census Bureau, 2020].

model and are not conditioned to certain parameter ranges. In consequence, we believe our predictions are quite general.

2.4 Relationship stickiness

To capture the role of relationship stickiness, we assume that in addition to the per–period relationship–specific fixed cost, there is a cost to terminating a relationship. In response to a shock that reduces the profits obtained from a relationship, exporters might wish to terminate a relationship if maintaining it does not merit paying the per–period relationship–specific fixed cost. However, the cost of terminating relationships can prevent exporters from doing so, leading to "sticky relationships". This termination cost is thus a simple way of introducing relationship stickiness in our model.[11] One possible interpretation for this cost of terminating relationships is that it captures the loss of relationship specific capital.

Proposition 3a An increase in China's tariff is associated with a decline in exports to China which is decreasing in the cost of terminating relationships.

Proposition 3b An increase in China's tariff is associated with an increase in exports to the rest of the world, which is decreasing in the cost of terminating relationships.

Proof: See Appendix A.1.

In response to the increase in Chinese tariffs, the exporting firm will terminate the least profitable relationships with Chinese importers (i.e., the relationships with the least productive Chinese importers). However, if the cost of terminating relationships is high (which we associate with high relationship stickiness), the exporting firm is more likely to keep unprofitable relationships. Through the increasing marginal cost mechanism, the larger decline in exports to China in the case of lower relationship stickiness is associated with a larger increase in exports to the rest of the world. These propositions lead to the following testable implications:

[11] This termination cost will lead to similar predictions than those obtained in dynamic models [Martin et al., 2020], which also feature costs of starting and/or terminating relationships, or related switching costs. The implications of the model are similar if we include a cost of terminating relationships, a cost of starting new relationships, or both. For simplicity, we focus on the case where there is only a cost of terminating relationships.

Testable Implication 3a The decline in exports to China in response to increases in Chinese tariffs will be larger among sectors with lower relationship stickiness.

Testable Implication 3b The increase in exports to the rest of the world in response to increases in Chinese tariffs will be larger among sectors with lower relationship stickiness.

2.5 Product Differentiation (elasticity of substitution)

Finally, we consider the role of the elasticity of substitution. For this purpose, it is simpler and sufficient to go back to the baseline model described in Section 2.1. In the standard version of Melitz [2003], with a constant marginal cost, the elasticity of substitution is the sole determinant of the response of a firm's exports to tariffs. In our case, with an increasing marginal cost, we derive the following propositions:

Proposition 4a An increase in China's tariff is associated with a decline in exports to China which is increasing in the elasticity of substitution.

Proposition 4b An increase in China's tariff is associated with an increase in exports to the rest of the world which is increasing in the elasticity of substitution.

Proof: See Appendix A.1.

This result is equivalent to the case of the standard Melitz [2003] model, in which the elasticity of trade flows to tariffs is larger for products with high elasticity of substitution (i.e. less differentiated goods). These propositions lead to the following testable implications:

Testable Implication 4a The decline in exports to China in response to increases in Chinese tariffs will be larger among sectors with higher elasticity of substitution (i.e. lower product differentiation).

Testable Implication 4b The increase in exports to the rest of the world in response to increases in Chinese tariffs will be larger among sectors with higher elasticity of substitution (i.e. lower product differentiation).

3 Context and data sources

3.1 The 2018-2019 trade war

In this section, we briefly summarize recent trade policies imposed by the US and retaliatory trade policies imposed on US exports by some of its main trading partners. We summarize the events up to and including August 2019, which is the last month in our dataset. For further details, see Bown and Kolb [2019] who provide an excellent and detailed timeline of the trade war.

The first trade barriers imposed by the US were global safeguard tariffs on imports of washing machines and solar panels in October and November 2017, under the argument of a material injury to these industries based on Section 201 of the 1974 Trade Act. This led to WTO disputes being filed by South Korea and China. The US later imposed tariffs on imports of steel (at a 25% rate) and aluminum (at a 10% rate) in March 2018 based on a national security threat argument under Section 232 of the 1962 Trade Expansion Act. While these tariffs were originally going to be applied to all trading partners, several were temporarily exempt, including Canada, Mexico and the European Union. China retaliated immediately targeting about $2.4 billion in US exports. After the exemption on Canada, Mexico and the European Union ended in June 2018, these countries imposed retaliatory tariffs covering $17.8, $4.5 and $8.2 billion of US exports respectively.

Starting in mid 2018, new trade barriers imposed by the US focused exclusively on China. Following an investigation on China's treatment of US intellectual property rights and based on Section 301 of the 1974 Trade Act, the US imposed a first round of tariffs covering $50 billion. This tariff round was announced in April 2018 and was imposed in two waves, in July ($34 billion) and August ($16 billion) 2018. China immediately retaliated with tariffs targeting an equivalent amount in US goods with a 25% rate. This $50 billion round targeted mostly food and agricultural products (40% in terms of value), followed by industrial supplies (31%) and consumer goods (24%).

In September 2018 the US applied a broader set of tariffs at a 10% rate covering $200 billion in imports from China. The announcement included a further increase of the rate to 25% to be implemented in January 2019 and later postponed until May 2019. China retaliated with a $52 billion round applying 5% and 10% rates.[12] These Chinese tariffs targeted primarily industrial supplies (46% in terms of value) and capital goods (42%).

Further tariff increases were postponed amid negotiations to halt the trade war. However, in May 2019 the US raised tariffs on China on the same list of products included in the $200 billion September 2018 round. China retaliated in June 2019 also increasing tariffs on part of the products included in its previous $52 billion round. Later, in September 2019 the US once again imposed tariffs on a $112 billion list, which was the first part of a broader $300 billion list. China retaliated immediately, raising tariffs on a first segment of a $57 billion list. The second part of these tariff lists were not enacted as a result of the Phase One agreement reached by the end of that year.

3.2 Data sources

To assess the impact of the trade war on US exports, we assemble a monthly panel of US exports by product and destination spanning the period from January 2015 to August 2019. We combine these data with MFN tariffs faced by US exports in each destination and additional retaliatory tariff increases during the trade war imposed by China, Canada, Mexico, the European Union, Turkey, Russia and India. Finally, we build data on several product–level characteristics used to assess the mechanisms shaping the response of US exports to retaliatory tariffs. We describe each of these datasets below.

3.2.1 Monthly US exports

US exports detailed by product and destination at a monthly frequency are available from the Census Bureau's "US Exports of Merchandise" publication. In these data, products are detailed at the 10-digit level of the US version of the Harmonized System (HS).[13] Export values and quantities are aggregated to the level of product-destination-month cells for the analysis. We compute unit values ("prices") as the ratio of export values and quantities. We restrict the

[12] This Chinese tariff round was initially labeled as a $60 billion round given the approximate amount of trade targeted.

[13] At this level of disaggregation products are very specific. The following is a useful example: HS 4-digit code 6109 is "T-shirts, singlets, tank tops and similar garments, knitted or crocheted". HS 6-digit code 6109.10 restricts this product to "Of cotton:". HS 10-digit code 6109.10.0004 restricts it further to "Men's or boys': T-shirts, all white, short hemmed sleeves, hemmed bottom, crew or round neckline, or V-neck, with a mitered seam at the center of the V, without pockets, trim or embroidery".

analysis to domestic exports.[14]

3.2.2 Retaliatory tariffs

The tariffs faced by US exports in each destination are computed as the sum of MFN tariffs and the additional retaliatory tariff rates imposed by China, the European Union, Canada, Mexico, Turkey, Russia and India. Our main source of data is Fajgelbaum et al. [2020], which we extend as follows. We use data from Bown et al. [2019] to include several reductions in retaliatory tariffs and changes in MFN tariffs by China. In addition, we extend the sample in time, obtaining data on the 2019 retaliatory tariffs from official sources.

Most US trading partners imposing retaliatory tariffs (including China, the European Union, Canada, and Mexico) report these at the 8-digit level of their national versions of the Harmonized System (HS).[15] HS codes are identical for all countries up to the 6-digit level of disaggregation. Following Fajgelbaum et al. [2020] we work with tariffs at the 6-digit level to make them comparable across destinations. It is also worth noting that most of the retaliatory tariff rounds during the trade war have a single ad–valorem rate, and the variation across products within each round depends on whether they are targeted or not, rather than on the rate.[16]

3.2.3 Product characteristics

End–use classification We distinguish between four different product categories based on the Census Bureau's End-Use classification. This classification divides products into food and agricultural goods, industrial supplies, capital goods, and consumer goods.[17] The largest categories in exports to China are industrial supplies (each accounting for 37% of total exports in 2017) followed by capital goods (34%), food and agricultural products (15%), and consumer goods (13%). Exports to the rest of the world, in turn, have a similar composition, with a smaller share of food and agricultural products and a larger share of industrial supplies and consumer goods.

[14]Domestic exports exclude exports manufactured in other countries and temporarily stored without further processing in the US to be re-exported.

[15]India's tariffs are reported at the HS 6-digit level and Russian tariffs at the HS 10-digit level.

[16]An exception is China's $52 billion round which assigns a 10% rate to 69% of products and a 5% rate to the remaining ones.

[17]The original end use classification has automobiles as a separate category. We assign passenger cars (end use code 300) to consumer goods; trucks, buses and special purpose vehicles (301) to capital goods; and parts, engines, bodies, and chassis (302) to industrial supplies.

Leverage ratios We use COMPUSTAT to compute leverage ratios in each industry. Following Giroud and Mueller [2017], we define a leverage ratio equal to the sum of debt in current liabilities and long-term debt to total assets. We use annual data over 2012–2016. Following Levchenko et al. [2011], we first compute the median for each firm across time. We then compute the median across firms within each NAICS 4–digit industry. We match these measures to HS10 codes in the trade data using a concordance provided by the US Census Bureau.

Relationship stickiness We use the new measure of relationship stickiness provided by Martin et al. [2020]. They construct this measure based on the duration of firm to firm trade relationships computed using French customs data for trade with European countries over 2002–2006. These data are provided at the HS 6–digit level. In Appendix A.2.1 we provide descriptive statistics for this measure. In addition, to validate its use in our context, we show that there are substantially fewer interruptions over time in US exports at the HS10 level in industries with higher relationship stickiness. .

Product differentiation We distinguish between differentiated and nondifferentiated products using the Rauch [1999]'s classification. This is originally reported using the SITC classification, and we use a concordance to assign it to HS codes.

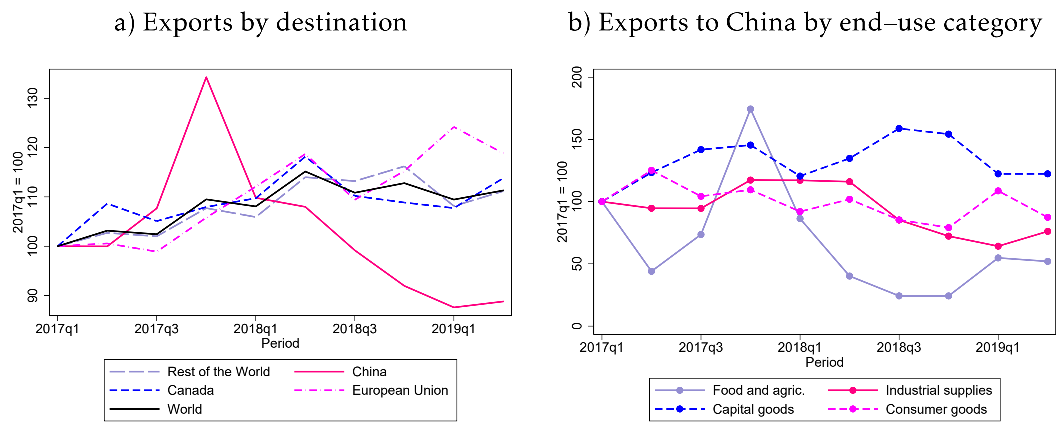
Other measures Appendix A.2.2 provides details on the construction of other industry–level or product–level measures, including external finance dependence, trade credit, inventories, upstreamness, contract intensity and quality ladders.

3.2.4 Trends in US exports

Figure 1 plots trends in US exports to China, to other retaliating countries and to the rest of the world. US exports to the world increased in nominal terms by 8% from 2017 to 2019, while US exports to China fell 12.1% during the same period.[18] The same figure also plots exports to China by end–use product categories. The largest decline over 2017–2019 corresponds to industrial supplies (-27.0%), followed by consumer goods (-13.6%) and agricultural goods (-10.9%), while exports of capital goods see a small (2.1%) increase during this period.

[18] These magnitudes are computed considering January through August in each year given that our data does not extend to the end of 2019.

Figure 1: Trends in US Exports



Notes: Panel a) plots the value of US exports to China, Canada, the European Union, and to the rest of the world at a quarterly frequency in nominal terms, normalizing 2017q1 to 100. Panel b) plots the value of US exports to China split by end–use categories at a quarterly frequency in nominal terms, normalizing 2017q1 to 100.

4 The direct and indirect effects of retaliatory tariffs on US exports

We begin our empirical analysis with an assessment of the effect of retaliatory tariffs on US exports to retaliating countries and to the rest of the world, as described by Testable Implication 1.

We first analyze the impact of retaliatory tariffs on US exports to retaliating countries. We use the following dynamic specification which follows the literature [Amiti et al., 2020]:

$$\log \mathrm{Y}_{cpt} = \sum_{k=-\underline{T}}^{\overline{T}} \beta_k \left(I_{cpk} \times \ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}} \right) \right) + \eta_{cp} + \delta_{cst} + \epsilon_{cpt} \, . \tag{9}$$

The sample consists of US exports by HS10 product, destination country and month. The dependent variable Y_{cpt} is the exported value of product p to country c at time t. On the right side, $\sum_{k=-\underline{T}}^{\overline{T}} \beta_k \left(I_{cpk} \times \ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}} \right) \right)$ measures the dynamic effect of retaliatory tariffs in each destination. The term I_{cpk} represents a treatment month indicator variable equal to one in the first month a tariff is raised and zero otherwise. The size of the tariff increase is represented by the term $\ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}} \right)$. Given the length of our sample, we allow for 8 leads and 10 lags ($\underline{T} = 8$ and

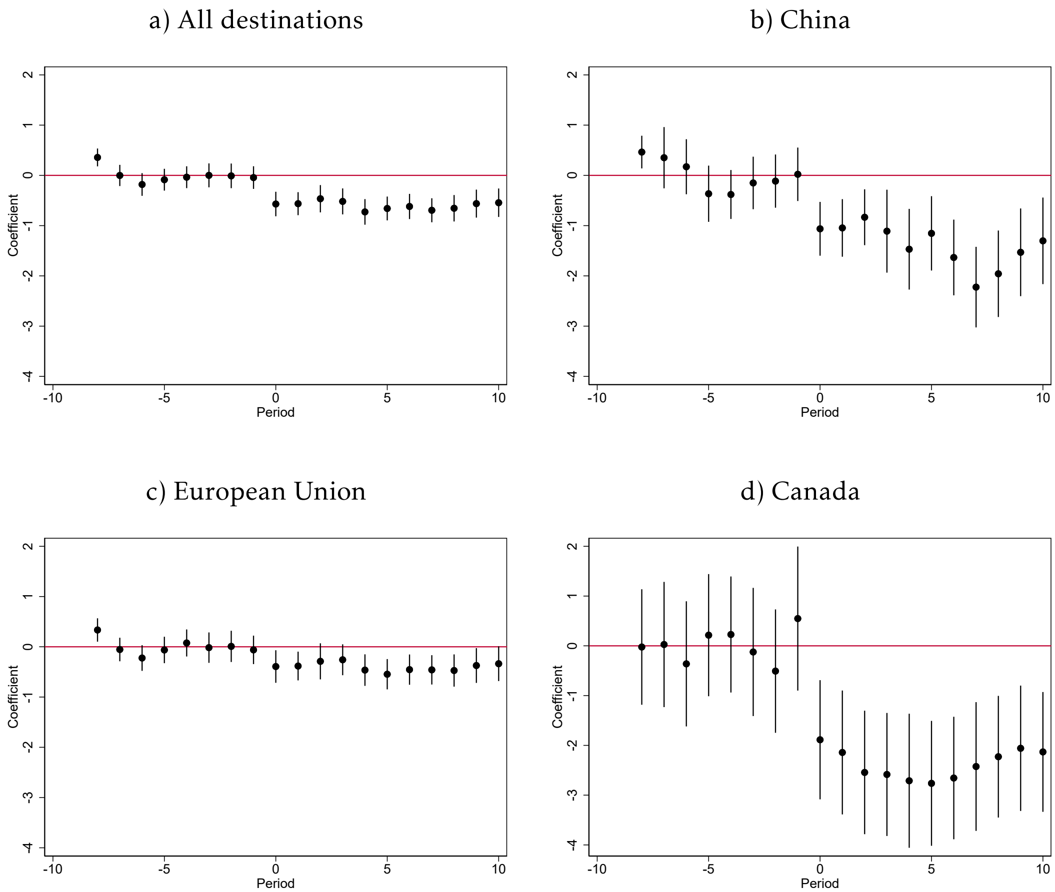
$\overline{T} = 10$). We include country × product and country × sector (HS2) × time (year–month) fixed effects. We estimate this equation by OLS, with standard errors clustered by product at the HS6 level. In this regression, the coefficients of interest, β_k, capture the evolution of US exports of products hit by retaliatory tariffs relative to untargeted products (or across products targeted with tariffs of different magnitude). The fixed effects imply that the coefficients capture the difference across HS10 products exported to the same destination and within the same HS2 sector. Figure 2a shows the result considering US exports to all destinations. There are no apparent pre–trends, and there is a large decline in exports immediately following the imposition of retaliatory tariffs. The magnitude is such that a ten percent increase in retaliatory tariffs is associated to a 5 percent decline in US exports at a six month horizon. The effect is stable and persistent over time.[19] This result is consistent with Testable Implication 1a.

Next, we document a substantial degree of heterogeneity in this effect of retaliatory tariffs both across destinations and sectors. Figure 2b through 2d shows the result of estimating equation (9) separately for the main retaliating countries or regions. We find that the coefficients based on Chinese retaliatory tariffs are roughly twice as large as those found using the worldwide sample.[20] The effect of Canadian tariffs is equally large. In contrast, tariffs imposed by the European Union result in a substantially milder impact.

[19] In Appendix Figure A.11 we show the results are robust to using alternative fixed effects. In Appendix Figure A.14 we show the results are robust to using other forms of clustering standard errors. In Appendix Figure A.7 we show the results are very similar when aggregating trade defining products at the HS6 instead of the HS10 level.

[20] Appendix Figure A.12 and panel d) in Appendix Figure A.14 report robustness checks with alternative fixed effects and alternative clustering of standard errors.

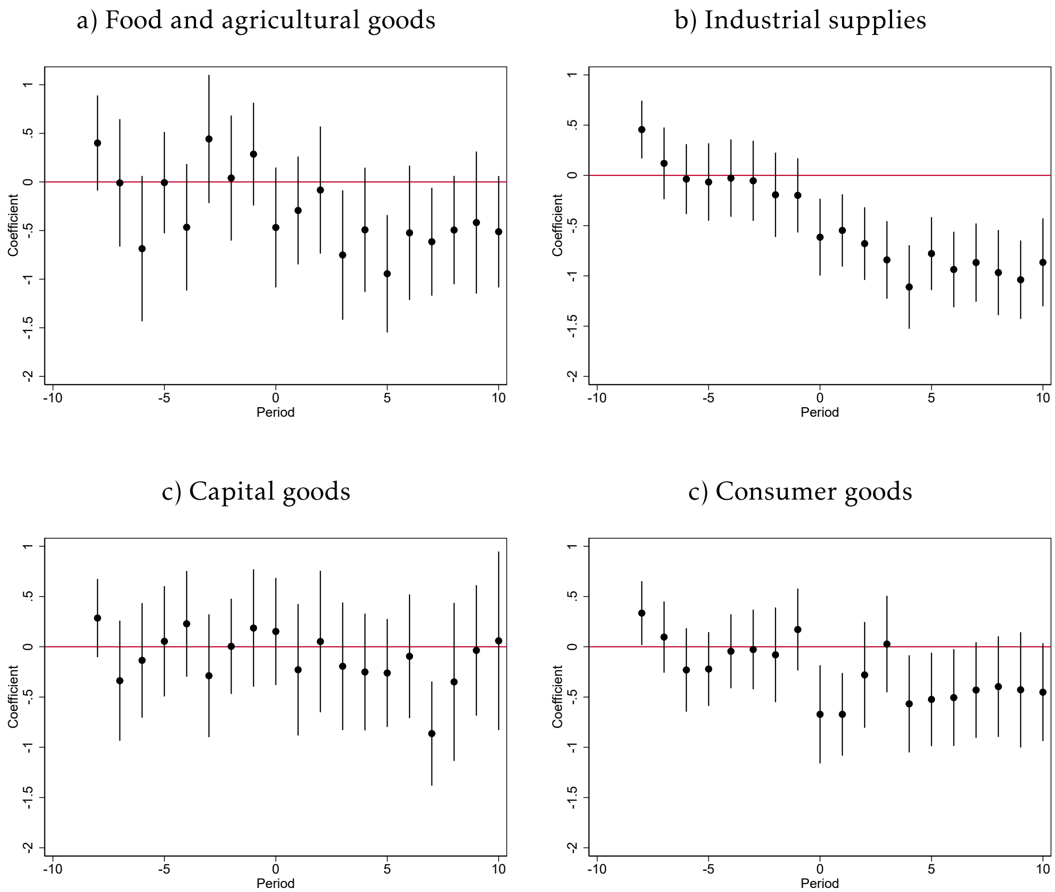
Figure 2: Retaliatory tariffs and US exports



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure 3 splits the sample by sectors, focusing again on exports to all destinations. In this case, tariffs on industrial supplies have the largest negative impact on US exports. The magnitude for this sector is such that a ten percent increase in retaliatory tariffs leads to about an 8 percent decline in US exports at a six month horizon. Among consumer goods and agricultural products, tariffs also have a negative impact on trade flows, but the magnitude is smaller than that found for industrial supplies. In contrast, we do not find an economically or statistically significant effect of tariffs on capital goods. One potential explanation for this result is that the US exports machinery that is difficult to replace with products from other source countries. In Appendix Figure A.2, we show similar patterns of heterogeneity across sectors focusing only on US exports to China, with results being driven even more by industrial supplies.

Figure 3: Retaliatory tariffs and US exports by sector



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

The decline in exports in response to retaliatory tariffs can be due to an adjustment of quantities or prices (unit values). Appendix Figure A.3 plots the results of the estimation of equation (9) replacing the dependent variable by the log of exported quantity or f.o.b. (free on board) unit value. In line with other work using the same type of data [Amiti et al., 2019, Fajgelbaum et al., 2020] we do not find signs of adjustment in (f.o.b.) prices; the full adjustment corresponds to quantities.[21]

Finally, we analyze the response of the extensive margin. For that purpose, we construct a balanced sample such that for each country – HS10 product combination exported at least

[21] Appendix Figure A.4 shows a similar pattern when analyzing separately exports to China or other main retaliating countries. In addition, Appendix Figure A.5 splits the sample by end–use sectors. Consistent with Cavallo et al. [2021] (who use survey data on export prices from the Bureau of Labor Statistics), we find a decline in f.o.b. export prices among agricultural goods (even though the result is not statistically significant at conventional levels).

once, we have observations for all time periods. We replace the dependent variable in equation (9) by a dummy variable equal to one for observations with positive trade flows and zero otherwise. The results, in Appendix Figure A.6, indicate that there was no statistically significant adjustment in the extensive margin in response to retaliatory tariffs.

4.1 Indirect effect: Export reallocation

As we argued in the introduction, the overall impact of the trade war on US exports depends not only on the direct effect of retaliatory tariffs but crucially also on the ability of US exporters to redirect trade to other markets. From a policy standpoint, it is important not only to quantify the extent to which this rerouting occured, but also which determinants influenced it.

Testable Implication 1b predicts an increase in exports to the rest of the world in response to retaliatory tariffs. To test this, we use a similar dynamic specification to that discussed earlier. Because China imposed the largest retaliatory tariff rounds by far, we focus first on the extent to which US exports can be redirected away from Chinese tariffs. Thus, the sample considers US exports to all destinations in the rest of the world, excluding China. Specifically, we estimate the following regression:

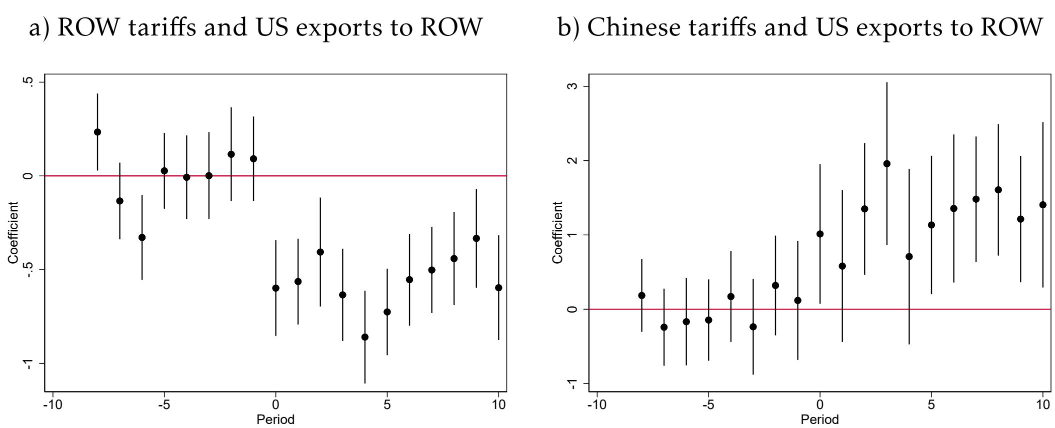
$$\log Y_{cpt} = \sum_{k=--\underline{T}}^{\overline{T}} \beta_k \left(I_{cpk} \times \ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}}\right)\right) + \sum_{k=--\underline{T}}^{\overline{T}} \gamma_k \left(I_{pk}^{CHN} \times \ln\left(\frac{1+\tau_{pk}^{CHN}}{1+\tau_{p0}^{CHN}}\right) \times S_{p0}^{CHN}\right)$$
$$+ \eta_{cp} + \delta_{cst} + \epsilon_{cpt}\,, \tag{10}$$

in which the dependent variable Y_{cpt} represents the value exported of product p to country c at time t. The independent variables capture both the effect of tariffs on each destination market and the effect of Chinese tariffs imposed on each product. The term $\sum_{k=--\underline{T}}^{\overline{T}} \beta_k \left(I_{cpk} \times \ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}}\right)\right)$ measures the dynamic effect of retaliatory tariffs in each destination. In this expression, I_{cpk} is a treatment month indicator variable which is one in the first month a tariff is raised and zero otherwise. The size of the tariff increase is represented by the term $\ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}}\right)$ which is equal to the ratio between the higher tariff and its original value. The term $\sum_{k=--\underline{T}}^{\overline{T}} \gamma_k \left(I_{pk}^{CHN} \times \ln\left(\frac{1+\tau_{pk}^{CHN}}{1+\tau_{p0}^{CHN}}\right) \times S_{p0}^{CHN}\right)$ measures the impact of Chinese retaliatory tariffs corresponding to each product p on exports to the rest of the world. In this case, I_{pk}^{CHN} is a treatment month indicator and the size of the tariff increase is represented by $\ln\left(\frac{1+\tau_{pk}^{CHN}}{1+\tau_{p0}^{CHN}}\right)$. Naturally, the effect of Chinese tariffs on US exports to other destinations should be a function of the importance of China as a market for each product. For example, if China represents a negligible market for a given product prior to the trade war, there would be little trade to reallocate. For this reason, we include the market share of China in US exports for each product, S_{p0}^{CHN}, which we compute in 2017. In this regression, the coefficients of interest, γ_k, capture the evolution of US exports to non–China destinations of products hit by Chinese retaliatory tariffs relative to untargeted products (or across products targeted with tariffs of different magnitude). Once again, the fixed effects used lead to a comparison across HS10 products within destination and within HS2 sector.

Figure 4*a* illustrates the impact of tariffs in each non–China destination market on US exports, which is captured by the coefficients β_k. Retaliatory tariffs have an immediate and persistent negative impact on US exports, consistent with the discussion in the previous section.

The main coefficients of interest in this section (γ_k) are shown in Figure 4b. There is a clear increase in exports to the rest of the world in response to Chinese tariffs. This increase takes place gradually over time. To get a sense of the magnitude of this reallocation, at a six month horizon, a ten percent increase in Chinese tariffs leads to a 0.8 percent increase in US exports to the rest of the world.[22] This result is consistent with Testable Implication 1b.

Figure 4: China's retaliatory tariffs and US exports to ROW



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

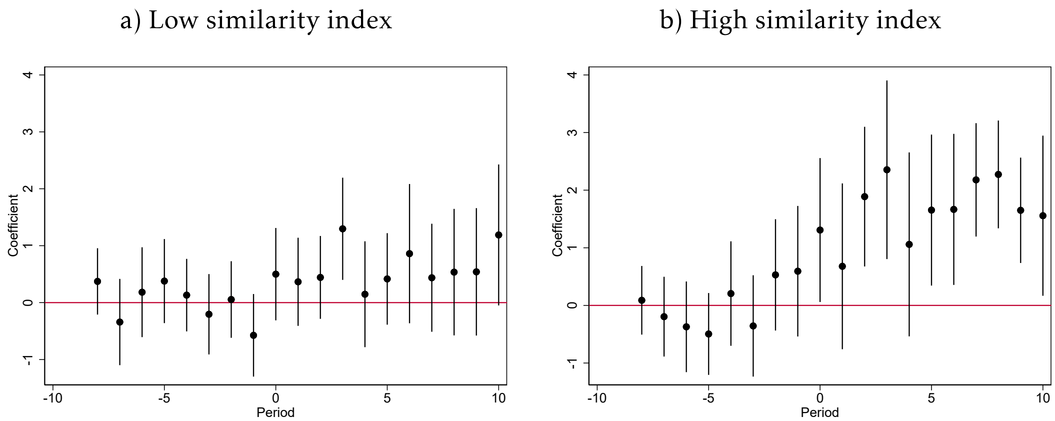
[22]To compute this elasticity, we multiply 10% × 0.06 ×1.35, where 1.35 is the estimated γ coefficient on the 6th lag, and 0.06 is the mean of S_{p0}^{CHN}.

While our focus has been on reallocation in response to Chinese tariffs, in Appendix A.3.3 we show results from augmenting equation (10) to consider export reallocation in response to Canadian, European and Mexican retaliatory tariffs. We still find a strong reallocation in response to Chinese tariffs. In addition, we don't see signs of export reallocation in response of Canadian, European and Mexican tariffs. This is reasonable given the much smaller magnitude (in terms of products targeted) of these other tariff lists. We also verify the robustness of these results to using alternative fixed effects (Appendix Figure A.13) and alternative ways of clustering standard errors (Appendix Figure A.15).

Next, we examine the patterns of reallocation by geographic regions. Appendix Figure *A*.8 indicates that the overall increase in US exports to rest of the world destinations is driven by exports to East and South Asia and by exports to Europe. In contrast, we do not see statistically or economically significant changes in exports to other regions including North America, South and Central America, or the Middle East and Africa. One potential explanation for this result is that the US can redirect exports to destinations where the composition of exports is similar. To test this, we use an index first proposed by Finger and Kreinin [1979] and also used by Schott [2008] measuring the similarity between US exports to China and US exports to each other destination.[23] In Figure 5, we split the sample between rest of the world destinations receiving US exports with above and below median similarity to US exports to China. Indeed, it is within the high similarity sample where we find a larger (and statistically significant) increase in exports to the rest of the world.

[23]This export similarity index is computed using 2017 values and defined for each country c as $ESI_c = \sum_p min\left(s_{pc}, s_{p,CHN}\right)$. In this expression, s_{pc} is the ratio between US exports to country c in product p and total US exports to country c. Similarly, $s_{p,CHN}$ is the ratio between US exports to China in product p and total US exports to China. This index would take a value of one for a country importing from the US a basekt of products in the same proportion than China, and would be zero in the other extreme.

Figure 5: China's retaliatory tariffs and US exports to ROW: Similarity index



s

Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

Once again, in Appendix Figure A.9 we extend these results to look at the behavior of quantities and prices (unit values). As with the direct effect, there are no signs of a change in unit values charged to the rest of the world in response to Chinese tariffs (Figure A.9b). The full the adjustment is due to changes in quantities (Figure A.9a).

Finally, we analyze the response of the extensive margin. To this end, we construct a balanced panel containing the combination of all products, destinations and time periods. We replace the dependent variable in equation (10) for a dummy variable equal to one for observations with positive trade flows. Differently than in the previous section, we do find a positive and gradual response of the extensive margin to Chinese tariffs, as shown in Appendix Figure A.10. In other words, increased Chinese tariffs has led US exporters to enter new markets with their products, or to export more frequently to existing markets. However, the magnitude is very small. A ten percent increase in Chinese tariffs is associated to a 0.1 percentage point increase in the probability of exporting to a certain product destination, which is small when comparing it to the 7.9% unconditional probability.

4.2 Total impact of retaliatory tariffs on US exports

We have documented a decline in US exports to retaliating countries and an increase in exports to other markets in product categories targeted by retaliatory tariffs. To assess the overall impact of retaliatory tariffs on US exports, we estimate the following product–level regression. In this regression, exports are aggregated across all destination markets.

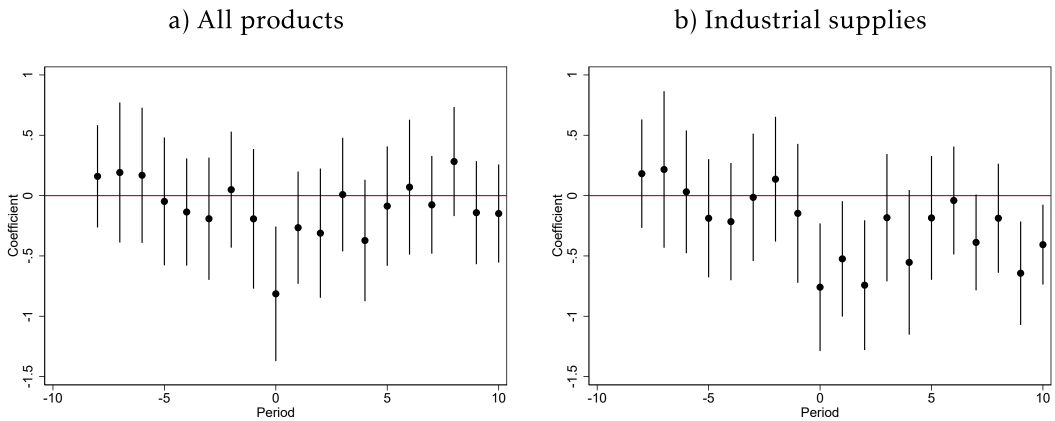
$$\log Y_{pt} = \sum_{k=--\underline{T}}^{\overline{T}} \beta_k \left(I_{pk} \times \ln\left(\frac{1+\tau_{pk}}{1+\tau_{p0}}\right)\right) + \eta_p + \delta_{st} + \epsilon_{pt} \,. \tag{11}$$

The dependent variable Y_{pt} represents the exported value, quantity or unit value of product p at time t. The term $\sum_{k=--\underline{T}}^{\overline{T}} \beta_k \left(I_{pk} \times \ln\left(\frac{1+\tau_{pk}}{1+\tau_{p0}}\right)\right)$ captures the dynamic effect of retaliatory tariffs in each product. Product–level tariffs τ_{pk} are weighted averages of country–by–product tariffs, with weights equal to exports in 2017. As before, I_{cpk} is a treatment month indicator variable which is one in the first month a tariff is raised and zero otherwise and the magnitude of the tariff increase is captured by the ratio between the higher tariff and its original value ($\ln\left(\frac{1+\tau_{pk}}{1+\tau_{p0}}\right)$). We include product and sector (HS2) × time (year–month) fixed effects.

The results are shown in Figure 6*a*, and indicate that the overall impact of retaliatory tariffs on US exports is not statistically significant and close to zero. This implies that US exporters successfully reallocate the exports lost in retaliating countries. The exception is the first month in which a tariff is raised, in which we do find a negative and statistically significant coeffficient. This is consistent with the fact that the direct effect of retaliatory tariffs documented earlier is immediate, while the reallocation effect is more gradual. Looking at specific sectors by end use, we do find a significant decline in total exports in the industrial supplies category (see Figure 6*b*). This is the sector which was facing the largest decline in exports directly to retaliating countries, as discussed earlier.[24]

[24] In the next section, we show how the decline in exports to China in response to Chinese tariffs is larger among industries with higher leverage ratios. In the industrial supplies sector, 75% of industries have an above median leverage ratio, while only 28% do in other sectors. This explains the larger fall in exports to China within this sector. We also find a larger increase in exports to the rest of the world among the industrial supplies sector, but this is not enough to compensate for the larger decline in exports to China.

Figure 6: Retaliatory tariffs and US exports: Product–level regression



Notes: This figure plots the coefficients obtained from the estimation of equation (11). Vertical bars represent 90% confidence intervals.

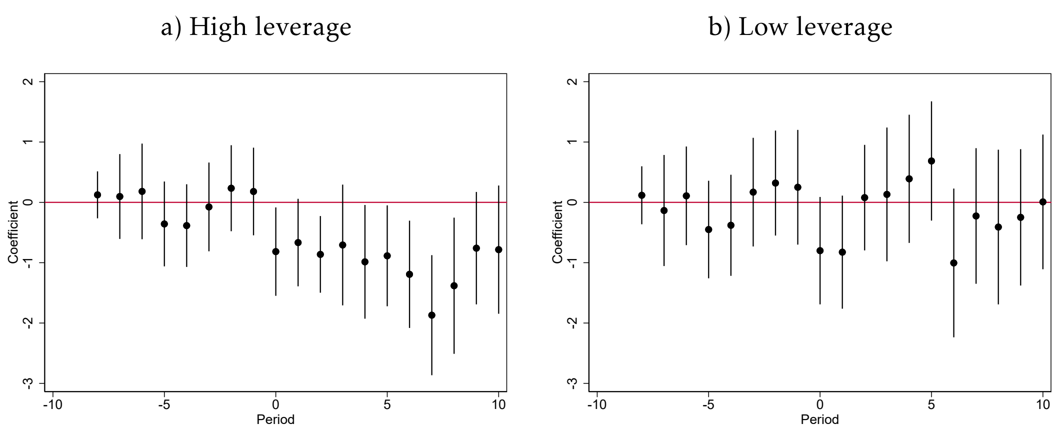
5 Mechanisms

Next, we explore the determinants behind the impact of Chinese tariffs on US exports to China (direct effect) and on US exports to other destinations (reallocation effect). We first assess the role of the three key determinants featured in the model: financial constraints (captured by leverage ratios), the degree of stickiness in trading relationships, and the degree of product differentiation (associated with elasticities of substitution). We then evaluate these and other potential determinants jointly, including inventories, upstreamness, contract intensity, and the degree of vertical differentiation (quality ladders). Our approach to assess the role of each of these factos consists of constructing industry–level measures capturing each of these elements and comparing the response of trade flows across different industries. This joint assessment indicates that leverage ratios and relationship stickiness stand out as determinants of the response to retaliatory tariffs, while other elements are not economically and/or statistically significant.

5.1 Financial conditions

We first document that financial constraints shaped the response of US exports to retaliatory tariffs as described by Testable Implications 2a and 2b. To this end, we construct leverage ratios defined as the sum of debt in current liabilities and long–term debt to total assets. They are constructed for NAICS 4–digit industries with data prior to the trade war and matched to the trade flows data as described in Section 3.2.3. We examine first the direct effect of retaliatory tariffs on US exports to China, estimating equation (9) splitting the sample between industries with above– and below–median leverage. The results (shown in Figure 7) are striking and show no significant impact of retaliatory tariffs on exports to China among low–leverage industries. This contrasts with the impact on the high–leverage sample, in which there is a clear decline in exports with a magnitude such that a ten percent increase in retaliatory tariffs is associated to an approximately ten percent decline in US exports at a six month horizon.[25] Financial conditions also play a role in the redirection of exports toward alternative markets. To this end, we estimate equation (10), again splitting the sample between high– and low–leverage industries. Figure 8 shows that there is a substantial increase in exports to rest of the world destinations as a result of Chinese tariffs among high–leverage industries. In contrast, there is no statistically significant reallocation effect in the low–leverage sample.[26]

Figure 7: China's retaliatory tariffs and US exports to China: High vs. low leverage

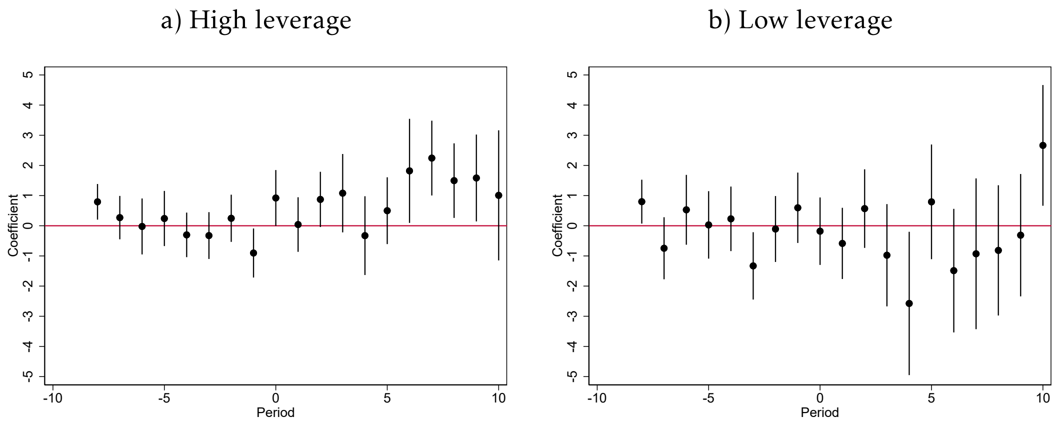


Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

[25] Appendix Figure A.18 indicates that these result is driven by an adjustment in quantities, and no adjustment in prices. Appendix Figure A.19 indicates that there is no adjustment along the extensive margin.

[26] Appendix Figure A.20 indicates the adjustment along the extensive margin for exports toward the rest of the world is not statistically significant in both samples.

Figure 8: China's retaliatory tariffs and US exports to ROW: High vs. low leverage



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

Other measures of financial constraints To provide further evidence in favor of this financial mechanism, we also examine alternative measures of financial constraints. We first consider external finance dependence, defined as the share of capital expenditures that cannot be financed through internal cash flows from operations, and which has been used in the past in the trade and finance literature Chor and Manova [2012]. This variable is also connected to our model, because the working capital requirement can also be interpreted as a need for external finance. Appendix Figures A.21 and A.22 show that industries with high external finance see a larger decline in exports to China as well as a larger increase in exports to the rest of the world, in line with the results described earlier.

In addition, we consider trade credit. While this variable does not have a direct link to our model, Chor and Manova [2012] argue that in industries with low levels of trade credit, firms are forced to borrow more from financial institutions.[27] This means one would expect low levels of trade credit to be associated to a larger decline in exports to China. Appendix Figures A.23 and A.24 show that indeed in industries with low levels of trade credit we see the same results as in industries with high leverage or high external finance dependence (a larger decline in exports to China and a larger increase in exports to the rest of the world).

[27] Chor and Manova [2012] find that exports fall more in response to the 2008–2009 financial crisis in sectors with high external finance dependence and in sectors with low levels of trade credit.

5.2 Stickiness of trade relationships

Next, we document that the type of trade relationships held by exporting and importing firms is also an important factor shaping the response of US exports. Facing an increase in tariffs, US exporters had to assess whether to terminate relationships with Chinese importers. As our model describes, a higher cost of terminating relationships leads to a lower probability of terminating relationships, and consequently, a lower decline in exports to China. From an empirical standpoint, we can associate relationship stickiness with the cost of terminating relationships, because a higher cost of terminating relationships will lead to more persistent (i.e. stickier) relationships. Thus, Testable Implication 3a predicts a smaller decline in exports to China in industries with high relationship stickiness. Due to the increasing marginal cost assumption in the model, industries facing a larger decline in exports to China will also experience a larger increase in exports to the rest of the world. Consequently, Testable Implication 3b predicts a smaller increase in exports to the rest of the world in industries with high relationship stickiness.

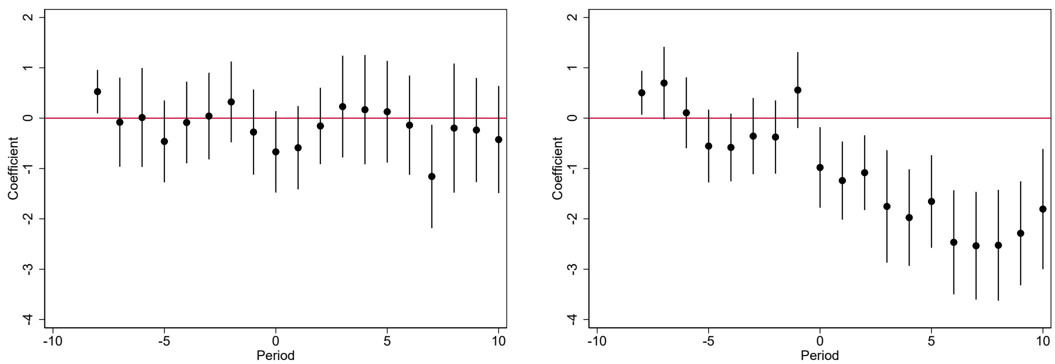
To assess this, we use a novel measure of relationship stickiness constructed by Martin et al. [2020] based on the duration of relationships observed in firm–to–firm trade data. We divide the sample into products with above– or below–median relationship stickiness. Figure 9 shows that exports to China fell more in response to Chinese tariffs in industries with low relationship stickiness.[28] A ten percent increase in Chinese tariffs is associated to an 18 percent decline in US exports at a six month horizon. At the same time, Figure 10 shows that exports to the rest of the world increased more in response to Chinese tariffs in the same set of industries.[29]

[28] Appendix Figure A.25 analyzes the response of quantities and prices, finding as before that the entire adjustment is through the quantity margin. Appendix Figure A.26 shows that there is no adjustment along the extensive margin.

[29] Appendix Figure A.20 shows no signs of an adjustment along the extensive margin for exports toward the rest of the world both in the high or low relationship stickiness samples.

Figure 9: China's retaliatory tariffs and US exports to China: High vs. low relationship stickiness

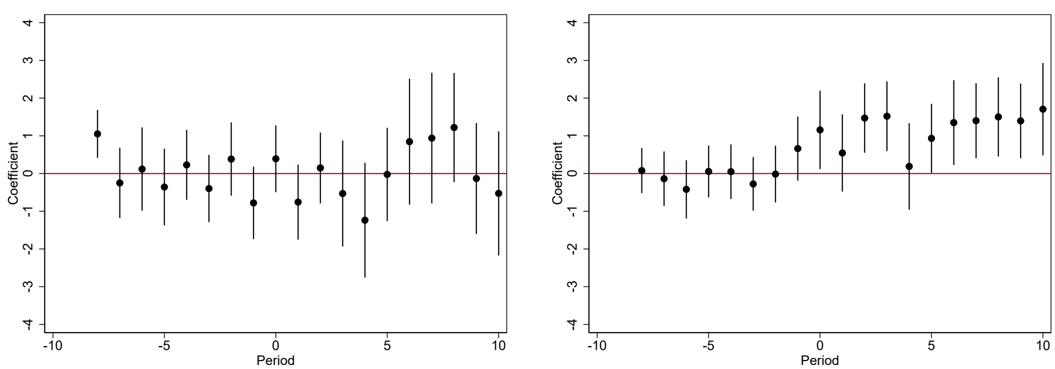
a) High relationship stickiness b) Low relationship stickiness



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure 10: China's retaliatory tariffs and US exports to ROW: High vs. low relationship stickiness

a) High relationship stickiness b) Low relationship stickiness



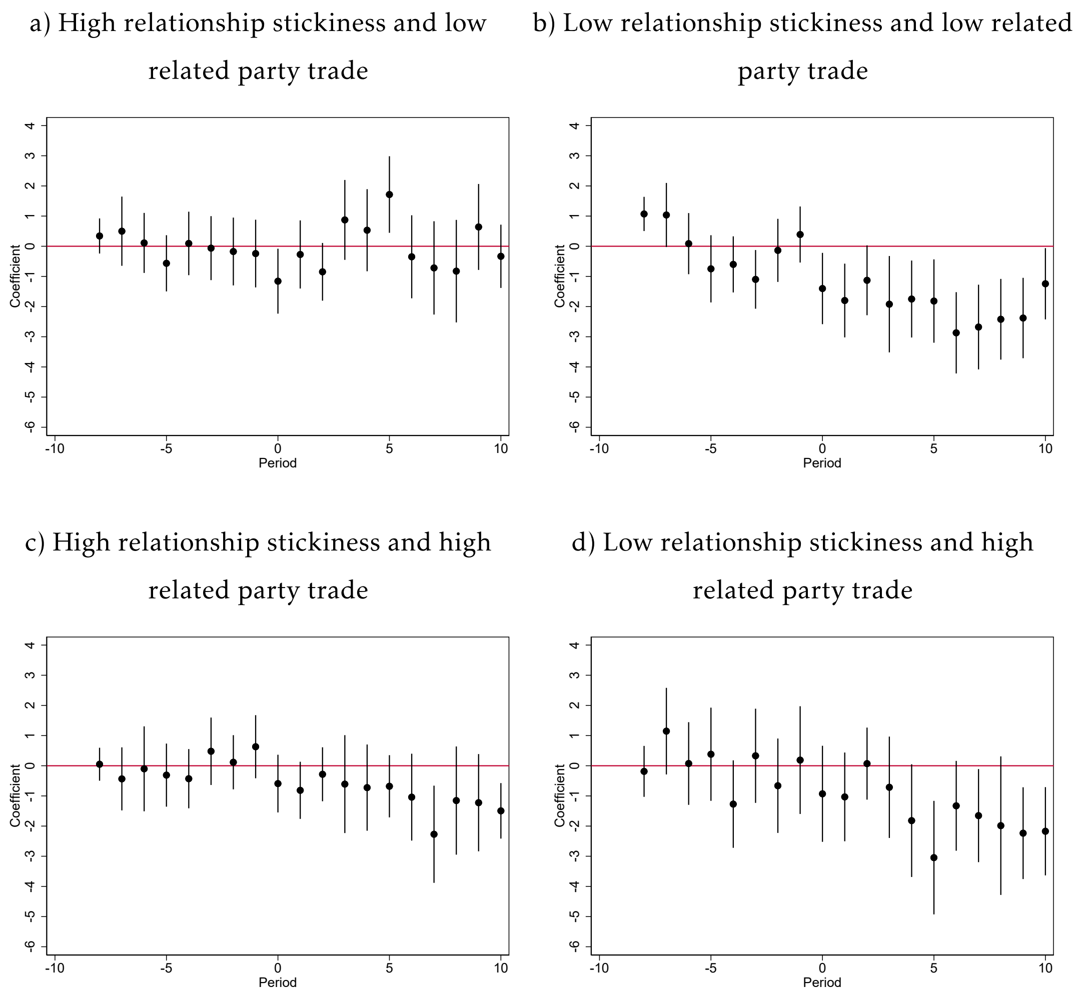
Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

We would expect that the mechanisms described in our model are more relevant in a context of arms–length trade, given that related–party trade might be less responsive to market forces. In an important check to our results, we verify that this is indeed the case. To this end, we compute the share of related–party trade in exports from the US to China in 2017 (prior to the trade war).[30] In Figure 11, we split the results for the effect of relationship stickiness on exports

[30] Details of the construction of this variable are provided in Appendix A.2.

to China for industries with a low (panels 11a and 11b) or high (panels 11c and 11d) share of related party trade. Among industries with low related party trade, we find that relationship stickiness matters, in the sense that there is a wide difference in the fall in exports between the high and low relationship stickiness industries. Among industries with high shares of related party trade, relationship stickiness appears to be less relevant, as this difference narrows.

Figure 11: China's retaliatory tariffs and US exports to China: Relationship stickiness and related party trade



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

5.3 Product differentiation

Another element that shapes the response of trade flows to tariffs is product differentiation. In Appendix Figure A.28 we split exports to China into differentiated and nondifferentiated products according to Rauch [1999]'s classification. We see a clear and very large decline among nondifferentiated products, such that a ten percent increase in retaliatory tariffs is associated to a 40 percent decline in US exports at a six month horizon. In contrast, there is only a temporary and smaller decline within the differentiated products sample.[31] Appendix Figure A.30 reports the results for the estimation of equation (10) (measuring the reallocation effect). In line with the direct effect, we see a large and statistically significant reallocation effect only among nondifferentiated goods. The magnitude is such that at a six month horizon, a ten percent increase in Chinese tariffs leads to a 1.7 percent increase in US exports to the rest of the world. In Appendix Figures A.31 and A.32 we provide further evidence in the same direction splitting the sample based on elasticities of substitution.

5.4 Comparing the mechanisms

Finally, we quantify the relative importance of the mechanisms discussed earlier and featured in our model as well as other determinants which could shape the response of US exports to trade war tariffs.

In addition to leverage ratios, relationship stickiness and product differentiation, we consider the following. First, the literature has also emphasized the role of inventories in shaping the response of trade flows to policy changes or crises [Alessandria et al., 2010, Levchenko et al., 2010, Alessandria et al., 2019]. In particular, this work suggests that firms would optimally hold higher levels of inventories in industries in which it is costly to reorganize supply chains in response to disruptions.[32] Second, we consider the role of upstreamness (as defined by Antràs et al. [2012]), which captures the position of exporters along supply chains. Third, we also consider contract intensity (as defined by Nunn [2007]) as a potential determinant, because exporters in contract–intensive industries might be less reliant to break relationships. In this regard, controlling for the role of contract intensity is related, and possibly and underlying cause of the relationship stickiness discussed earlier. Fourth, we consider the role of quality ladders (as measured by [Khandelwal, 2010]), which capture the extent of vertical differentiation for each industry. Like before, we construct industry–level measures of each of these

[31] Appendix Figure A.29 analyzes the response of quantities and prices, finding one again that the results are driven by an adjustment of quantities only.

[32] In these type of models, firms face disruptions in trade flows (which can be due to tariffs, as in our setting). If reorganizing supply chains to export to alternative destinations is costly, it is optimal to hold higher level of inventories.

determinants as described in Section 3.2.3.

To assess all these determinants, we focus on exports to China and the effect of Chinese retaliatory tariffs. In order to allow for the various elements to simultaneously mediate the effect of tariffs, we simplify our empirical approach and estimate a regression of changes in product–level exports to China between 2017 and 2019 as a function of changes in Chinese tariffs during the same period. We interact the change in tariffs with all the industry–level measures described earlier.[33]

Because our sample ends in August 2019, we compute differences between January to August of 2017 and January to August of 2019. Specifically, for each HS10 product, we aggregate total exports for each of these periods, and define the dependent variable as the log difference. Similarly, we compute the average tariff for each product within each of these periods and also compute the log difference.

$$\Delta log(V_p) = \beta_1 \cdot \Delta log(\tau_p) + \beta_2 \cdot \Delta log(\tau_p) \cdot X_p + \epsilon_p \qquad (12)$$

In this regression, the term X_p includes each of the industry characteristics described earlier. The results are reported in Table 1. Columns 8 and 9 include all determinants jointly, and indicate that leverage ratios and relationship stickiness stand out as the determinants with a statistically significant interaction term with tariffs.[34] To assess the magnitude of these effects, consider that the elasticity of the change in exports with respect to the change in tariffs is -0.118 at the 75th percentile of the leverage ratio variable and -0.060 at the 25th percentile (with other variables evaluated at their means), which implies a difference of -0.057 moving from the 75th to 25th percentile. The equivalent difference is -0.035 for relationship stickiness.

6 Conclusions

In this paper, we have established the total effect of of the 2018–2019 trade war's retaliatory tariffs on US exports and shed light on the underlying mechanisms.

[33] In the previous sections we split the sample between above and below–median values of each of these variables with the goal of reporting results visually. Here, we find our results are robust to using continous measures of these variables.

[34] Column 8 includes all determinants except quality ladders, while column 9 does include quality ladders. Note that the number of observations is smaller when including quality ladders because these are not defined for all goods [Khandelwal, 2010].

Table 1: China's Retaliatory Tariffs and US Exports to China: Comparing the Mechanisms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta log(\tau_p)$	0.062	0.105	-0.136***	-0.137**	0.018	-0.190***	-0.018	0.037	0.185
	(0.072)	(0.127)	(0.047)	(0.067)	(0.081)	(0.059)	(0.082)	(0.245)	(0.302)
$\Delta log(\tau_p) \times$ Leverage ratio$_p$	-0.661***							-0.528*	-0.499*
	(0.252)							(0.289)	(0.303)
$\Delta log(\tau_p) \times$ Rel. Stickiness$_p$		-0.068*						-0.077*	-0.072*
		(0.040)						(0.041)	(0.043)
$\Delta log(\tau_p) \times$ Differentiated$_p$			0.073					0.023	-0.036
			(0.046)					(0.065)	(0.074)
$\Delta log(\tau_p) \times$ Inventories ratio$_p$				0.300				0.213	-0.008
				(0.404)				(0.424)	(0.574)
$\Delta log(\tau_p) \times$ Upstreamness$_p$					-0.044			0.037	0.023
					(0.027)			(0.050)	(0.063)
$\Delta log(\tau_p) \times$ Contract Intensity$_p$						0.216**		0.189	0.191
						(0.099)		(0.195)	(0.227)
$\Delta log(\tau_p) \times$ Quality Ladder$_p$							-0.032		-0.031
							(0.035)		(0.036)
Observations	3918	3918	3918	3918	3918	3918	3554	3918	3554

Notes: This table reports the estimation of equation (12). ***, **, and * indicate statistical significance at the 1%, 5% and 10% level.

The total effect of retaliatory tariffs on US exports results from the combination of the direct effect of these tariffs on exports to retaliating countries and the reallocation away from retaliating countries toward alternative markets. We show that this reallocation was gradual but important in magnitude, nearly compensating the decline in exports due to the direct effect of retaliatory tariffs.

We have also documented the determinants that shape the impact of retaliatory tariffs on US exports. A joint assessment of all these determinants indicates that financial conditions and relationship stickiness are the dominant factors shaping the response of US exports to retaliatory tariffs. First, we find that in high–leverage industries, there is a larger decline in US exports to retaliating countries, and at the same time a larger increase in exports to alternative markets. Second, we have found a larger decline in exports and a larger reallocation effect in industries with low degrees of relationship persistence or stickiness. Our empirical results are consistent with a model of export reallocation featuring the role of finance and relationship stickiness in shaping the response of exports to tariffs.

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A Appendix

A.1 Appendix to Section 2

A.1.1 Baseline model

Regarding the response of exports to China to changes in China's tariff, we can use the expression for an exporter's revenue in the Chinese market in equation (4) to write:

$$\frac{\mathrm{dlog} r_{e,CHN}}{\mathrm{dlog} \tau_{CHN}} = (1-\sigma) \cdot \frac{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma}\left(\frac{\lambda+1}{\lambda\sigma+1}\right) + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)}{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)} < 0 \tag{13}$$

given that $\sigma > 1$.

Regarding the response of exports to the rest of the world to changes in China's tariff, we can use the expression for an exporter's revenue in the rest of the world market in equation (5) to write:

$$\frac{\mathrm{dlog} r_{e,ROW}}{\mathrm{dlog} \tau_{CHN}} = \frac{\lambda(\sigma-1)^2}{\lambda\sigma+1} \cdot A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \frac{1}{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)} > 0 \tag{14}$$

This proves propositions 1a and 1b.

A.1.2 Financial constraints

As discussed in the main text, we assumed that in the initial equilibrium (before China's tariff is raised) a US exporter that sells to any importer in China will also sell to all importers in the rest of the world. A sufficient condition for this is a high enough fixed cost of exporting to China, and we provide a mathematical expression for this assumption below. We focus, without loss of generality, in the case of an exporter that sells to all importers in China (and all importers in the rest of the world) in the initial equilibrium.

We proceed in the following order. First, we show that a higher working capital constraint (associated with a higher leverage ratio as we show later) implies that an exporter is more likely to terminate a trading relationship with an importer in response to an increase in China's tariff. Second, we show that exports to China decline in response to an increase in China's tariff, and that this decline is larger in the case a relationship is terminated. Third, we show that terminating a relationship in China leads to an increase in exports to the rest of the world. Fourth, we show that a higher working capital constraint is associated with a higher leverage ratio.

■ An exporting firm's profits obtained from selling to all importers take the form:[35]

$$\pi_e^{(N_{CHN},N_{ROW})} = k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - \left(1+\frac{\delta}{\nu}\right)(N_{CHN} \cdot g_{CHN} + N_{ROW} \cdot g_{ROW} + f_{CHN} + f_{ROW}) + \frac{(1-\nu)}{\nu}\chi \tag{15}$$

Note that the fixed cost is increasing in the working capital requirement δ.

A sufficiently large tariff can lead the exporter to terminate the relationship with the least productive Chinese importer. This decision is made comparing the profits from selling to all importers against the profits excluding the least productive Chinese importer. The profits obtained from selling to all importers except the least productive Chinese importer are:

$$\pi_e^{(N_{CHN}-1,N_{ROW})} = k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - \left(1+\frac{\delta}{\nu}\right)((N_{CHN}-1) \cdot g_{CHN} + N_{ROW} \cdot g_{ROW} + f_{CHN} + f_{ROW}) + \frac{(1-\nu)}{\nu}\chi \tag{16}$$

In these expressions we have indexed Chinese importers in decreasing order of productivity, such that $i = N_{CHN}$ corresponds to the lowest productivity importer.

Terminating the trading relationship with the least productive Chinese importer will save the exporter the per-relationship fixed cost g_{CHN}, and will make the exporter face a decline in operating profits (revenue minus variable cost).[36] The fixed–cost saved does not depend on

[35] Note that k_π absorbs the exporter's productivity parameter.

[36] The decline in operating profits is the difference between

$$k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}}$$

and

$$k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}}$$

.

the Chinese tariff level. In contrast, the decline in operating profits is smaller under a higher Chinese tariff. Consequently, a higher tariff can lead to terminating a relationship. In other words, the exporter will choose to terminate its relationship with the least productive Chinese importer if this change in profits is positive:

$$\pi_e^{(N_{CHN}-1,N_{ROW})}(\tilde{\tau}_{CHN}) - \pi_e^{(N_{CHN},N_{ROW})}(\tau_{CHN}) > 0\,, \tag{17}$$

where τ_{CHN} and $\tilde{\tau}_{CHN}$ (with a tilde) denote the initial (low) level and the trade war (high) level of the Chinese tariff respectively.

A higher working capital requirement leads to a larger fixed cost (due to the financial component of the fixed cost). On the other hand, the decline in operating profits from terminating a relationship due to the increase in China's tariff is independent of the working capital requirement. Consequently, an exporter is more likely to terminate a relationship with a Chinese importer when the fixed cost is higher (i.e. under a higher working capital constraint).

■ Now, we show that a higher Chinese tariff indeed lowers exports to China if a relationship is terminated.

First, note that for an exporter that sells to all importers in China and the rest of the world, exports to one importer in China are:

$$r_{ei,CHN}^{(N_{CHN},N_{ROW})} = k_r \cdot A_{CHN} \cdot \psi_i^{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{18}$$

and exports to all importers in China are:

$$r_{e,CHN}^{(N_{CHN},N_{ROW})} = k_r \left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{19}$$

In these expressions, $k_r = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}}$.

Terminating the relationship with the least productive importer leads to a decline in exports to China if:

$$k_r \cdot \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{-\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}$$
$$< k_r \cdot \left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{-\frac{\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{20}$$

This can be rearranged as:

$$\frac{\left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right)}{\left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right)} < \frac{\left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}}{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}} \tag{21}$$

The inequality holds because the left hand side is smaller than one and the right hand side i) adds the same positive term to the numerator and denominator and ii) has an exponent that is positive and lower than one (each of these reasons is sufficient for the right hand side to be larger).

■ The decline in exports to China is larger if a relationship is terminated than if it is not. If a relationship is terminated, exports to China fall from the expression in (19) to:

$$r_{e,CHN}^{(N_{CHN}-1,N_{ROW})} = k_r \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{22}$$

If a relationship is not terminated, exports to China fall from the expression in (19) to:

$$r_{e,CHN}^{(N_{CHN},N_{ROW})} = k_r \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{23}$$

That (22) is lower than (23) implies that:

$$\frac{\sum_{i=1}^{N_{CHN-1}} \psi_i^{CHN}}{\sum_{i=1}^{N_{CHN}} \psi_i^{CHN}} < \frac{\left(A_{CHN}\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}-1}\psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}}{\left(A_{CHN}\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}}\psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}} \tag{24}$$

The inequality holds because the left hand side is smaller than one and the right hand side i) multiplies the numerator and denominator by the same positive term and adds the same positive term to both ii) has an exponent that is positive and lower than one (each of these reasons is sufficient for the right hand side to be larger).

■ Note that it is straightforward to generalize this argument for the case of a larger tariff such that the tariff leads to terminating relationships with any number of Chinese importers.

■ We have argued that a higher working capital requirement, which entails a higher fixed cost, makes terminating relationships in response of an increase in China's tariff more likely. We have showed that this leads to a larger decline in exports to China. For this reason, it will also lead to a larger decline in marginal cost. As shown in the discussion for the baseline model, this leads to a larger increase in exports to the rest of the world.

Exports to the rest of the world for an exporter that sells to all importers in China and the rest of the world are:

$$r_{e,ROW}^{(N_{CHN},N_{ROW})} = k_r\left(A_{ROW}\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right)\cdot\left(A_{CHN}\cdot\tau_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}}\psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{25}$$

The increase in exports to the rest of the world is larger is larger if a relationship in China is terminated than if it is not. If a relationship in China is terminated as a result of the higher tariffs, exports to the rest of the world increase from the expression in (25) to:

$$\begin{aligned} r_{e,ROW}^{(N_{CHN}-1,N_{ROW})} &= k_r\left(A_{ROW}\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right) \\ &\quad\cdot\left(A_{CHN}\cdot\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}-1}\psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}}\psi_i^{ROW}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \end{aligned} \tag{26}$$

If a relationship in China is not terminated, exports to the rest of the world increase from the expression in (25) to:

$$r_{e,ROW}^{(N_{CHN},N_{ROW})} = k_r \left(A_{ROW} \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{27}$$

We can see from inspection of (26) and (27) that the case in which a relationship in China is terminated leads to a higher increase in exports in the rest of the world (because (27) has an extra positive term inside the second parenthesis, and the second parenthesis has a negative exponent).

■ We have assumed that in the initial equilibrium (before tariffs are raised), if US exporters export to any importer in China, they also export to all importers in the rest of the world. In other words, that China is a harder market to export to. We show below that a sufficient condition for this is that the fixed cost of exporting to China is sufficiently high.

For this to hold, an exporter that already exports to $N_{ROW}-1$ importers in ROW will prefer (i.e. will receive a larger increase in profits from) to export to the least productive importer in ROW than to the most productive importer in China.

$$\pi_e^{(0,N_{ROW})} - \pi_e^{(0,N_{ROW}-1)} > \pi_e^{(1,N_{ROW}-1)} - \pi_e^{(0,N_{ROW}-1)} \tag{28}$$

This implies:

$$\pi_e^{(0,N_{ROW})} > \pi_e^{(1,N_{ROW}-1)} \tag{29}$$

We can write

$$\pi_e^{(0,N_{ROW})} = k \cdot \left(A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \cdot \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - N_{ROW} \cdot g_{ROW} - f_{ROW} \tag{30}$$

and

$$\pi_e^{(1,N_{ROW}-1)} = k \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \psi_1^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \cdot \sum_{i=1}^{N_{ROW}-1} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}}$$
$$- g_{CHN} - (N_{ROW}-1) \cdot g_{ROW} - f_{CHN} - f_{ROW} \tag{31}$$

Upon comparison of the last two expressions, if we assume that initial tariffs are the same in both markets and the per–relationship fixed cost is also the same in both markets, a sufficiently large fixed cost of selling to the Chinese market (f_{CHN}) will be sufficient for this assumption to hold. Specifically, this would be the case if:

$$f_{CHN} > k \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \psi_1^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \cdot \sum_{i=1}^{N_{ROW}-1} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - k \cdot \left(A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \cdot \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} \quad (32)$$

■ Finally, note that a higher fraction δ of the total cost to be financed implies a higher leverage ratio. The leverage ratio is defined as the ratio between the amount borrowed and the firm's revenue and in the initial equilibrium it is:

$$L_e = \frac{\delta \cdot \tilde{f}}{r_{e,CHN}^{(N_{CHN},N_{ROW})} + r_{e,ROW}^{(N_{CHN},N_{ROW})}} \quad (33)$$

where $\tilde{f}$ represents the sum of the fixed costs of exporting (including the per–relationship fixed costs but not the financial component resulting from the working capital requirement). A small increase in δ that does not lead to an adjustment along the subextensive margin (adding or terminating relationships) implies an increase in the numerator and no change in the denominator. Now consider a larger increase in δ that leads to terminating a trading relationship. A relationship is terminated when the decline in operating profits (revenue minus variable cost) from doing so is larger than the per–relationship fixed cost the exporter saves on. The decline in revenue is larger than the decline in profits, and consequently, larger than the per–relationship fixed cost the exporter stops paying. Thus, the increase in δ leads to a larger decline in the denominator than in the numerator, and is associated with a higher leverage ratio.

A.1.3 Relationship stickiness

In the case of financial constraints analyzed in the previous subsection, we assumed that in the initial equilibrium (before China's tariff is raised) a US exporter that sells to any importer in China will also sell to all importers in the rest of the world. This assumption is not necessary in the case of relationship stickiness, but we keep it here for ease of exposition, even though the proofs generalize to any initial equilibrium. We focus, without loss of generality, in the case of an exporter that sells to all importers in China (and all importers in the rest of the world) in the initial equilibrium.

Consider an increase in Chinese tariffs that is large enough such that the exporter's profits are higher if it sells to all Chinese importers except the least productive one. Assume, on the other hand, that the increase in tariffs is not too large such that the US exporter still finds it profitable to sell to all other Chinese importers. (In other words, the exporter sells to the N_{ROW} rest of the world importers and to $N_{CHN}-1$ Chinese importers).[37]

An exporting firm's profits obtained from selling to all importers take the form:[38]

$$\pi_e^{(N_{CHN},N_{ROW})} = k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - N_{CHN} \cdot g_{CHN} - N_{ROW} \cdot g_{ROW} - f_{CHN} - f_{ROW} \tag{34}$$

and the profits obtained from selling to all importers except the least productive Chinese importer are:

$$\pi_e^{(N_{CHN}-1,N_{ROW})} = k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}} - (N_{CHN}-1) \cdot g_{CHN} - N_{ROW} \cdot g_{ROW} - f_{CHN} - f_{ROW} \tag{35}$$

In these expressions we have indexed Chinese importers in decreasing order of productivity, such that $i = N_{CHN}$ corresponds to the lowest productivity importer.

Terminating the trading relationship with the least productive Chinese importer will save the exporter the per-relationship fixed cost g_{CHN}, and will make the exporter face a decline in operating profits (revenue minus variable cost).[39] The fixed–cost saved does not depend on

[37] It is straightforward to generalize the argument for a larger tariff increase such that multiple relationships become unprofitable. If the tariff is smaller than this, relationship stickiness would not play a role.

[38] Note that k_π absorbs the exporter's productivity parameter.

[39] The decline in operating profits is the difference between

$$k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}}$$

the Chinese tariff level. In contrast, the decline in operating profits is smaller under a higher Chinese tariff. Consequently, a higher tariff can lead to terminating a relationship.

When there is a cost of terminating a relationship (denoted Γ), the exporter will choose to terminate its relationship with the least productive Chinese importer if this change in profits is larger than the termination cost Γ:

$$\pi_e^{(N_{CHN}-1,N_{ROW})}(\tilde{\tau}_{CHN}) - \pi_e^{(N_{CHN},N_{ROW})}(\tau_{CHN}) > \Gamma, \tag{36}$$

where τ_{CHN} and $\tilde{\tau}_{CHN}$ (with a tilde) denote the initial (low) level and the trade war (high) level of the Chinese tariff respectively.

If the termination cost Γ is low (i.e. if relationship stickiness is low), the US exporter will indeed terminate the relationship with the least productive Chinese importer. If the termination cost Γ is high (i.e. if relationship stickiness is high), the US exporter will not terminate the relationship with the least productive Chinese importer.

■ Now, we show that a higher Chinese tariff indeed lowers exports to China if a relationship is terminated.

First, note that for an exporter that sells to all importers in China and the rest of the world, exports to one importer in China are:

$$r_{ei,CHN}^{(N_{CHN},N_{ROW})} = k_r \cdot A_{CHN} \cdot \psi_i^{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{37}$$

and exports to all importers in China are:

$$r_{e,CHN}^{(N_{CHN},N_{ROW})} = k_r \left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{38}$$

In these expressions, $k_r = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}}$.

Terminating the relationship with the least productive importer leads to a decline in exports

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and

$$k_\pi \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda+1}{\lambda\sigma+1}}$$

.

to China if:

$$k_r \cdot \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{-\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}$$

$$< k_r \cdot \left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{-\frac{\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{39}$$

This can be rearranged as:

$$\frac{\left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right)}{\left(A_{CHN} \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right)} < \frac{\left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}}{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}} \tag{40}$$

The inequality holds because the left hand side is smaller than one and the right hand side i) adds the same positive term to the numerator and denominator and ii) has an exponent that is positive and lower than one (each of these reasons is sufficient for the right hand side to be larger).

■ The decline in exports to China is larger if a relationship is terminated than if it is not. If a relationship is terminated, exports to China fall from the expression in (38) to:

$$r_{e,CHN}^{(N_{CHN}-1,N_{ROW})} = k_r \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{41}$$

If a relationship is not terminated, exports to China fall from the expression in (38) to:

$$r_{e,CHN}^{(N_{CHN},N_{ROW})} = k_r \left(A_{CHN} \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{42}$$

That (41) is lower than (42) implies that:

$$\frac{\sum_{i=1}^{N_{CHN-1}} \psi_i^{CHN}}{\sum_{i=1}^{N_{CHN}} \psi_i^{CHN}} < \frac{\left(A_{CHN}\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}}{\left(A_{CHN}\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}}} \tag{43}$$

The inequality holds because the left hand side is smaller than one and the right hand side i) multiplies the numerator and denominator by the same positive term and adds the same positive term to both ii) has an exponent that is positive and lower than one (each of these reasons is sufficient for the right hand side to be larger).

■ Note that it is straightforward to generalize this argument for the case of a larger tariff such that the tariff leads to terminating relationships with any number of Chinese importers.

■ Because the case of higher relationship stickiness, which can prevent terminating relationships, leads to a smaller decline in exports to China, it will also lead to a smaller decline in marginal cost. As shown in the discussion for the baseline model, this leads to a lower increase in exports to the rest of the world.

Exports to the rest of the world for an exporter that sells to all importers in China and the rest of the world are:

$$r_{e,ROW}^{(N_{CHN},N_{ROW})} = k_r\left(A_{ROW}\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right)\cdot\left(A_{CHN}\cdot\tau_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{44}$$

The increase in exports to the rest of the world is larger if a relationship in China is terminated than if it is not. If a relationship in China is terminated as a result of the higher tariffs, exports to the rest of the world increase from the expression in (44) to:

$$\begin{aligned} r_{e,ROW}^{(N_{CHN}-1,N_{ROW})} = k_r&\left(A_{ROW}\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right) \\ &\cdot\left(A_{CHN}\cdot\tilde{\tau}_{CHN}^{1-\sigma}\sum_{i=1}^{N_{CHN}-1} \psi_i^{CHN} + A_{ROW}\cdot\tau_{ROW}^{1-\sigma}\sum_{i=1}^{N_{ROW}} \psi_i^{ROW}\right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \end{aligned} \tag{45}$$

If a relationship in China is not terminated, exports to the rest of the world increase from the expression in (44) to:

$$r_{e,ROW}^{(N_{CHN},N_{ROW})} = k_r \left(A_{ROW} \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right) \cdot \left(A_{CHN} \cdot \tilde{\tau}_{CHN}^{1-\sigma} \sum_{i=1}^{N_{CHN}} \psi_i^{CHN} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma} \sum_{i=1}^{N_{ROW}} \psi_i^{ROW} \right)^{\frac{-\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{46}$$

We can see from inspection of (45) and (46) that the case in which a relationship in China is terminated leads to a higher increase in exports in the rest of the world (because (46) has an extra positive term inside the second parenthesis, and the second parenthesis has a negative exponent).

A.1.4 Product Differentiation (elasticity of substitution)

■ Recall from the baseline model that:

$$\frac{dlog(r_{CHN})}{dlog(\tau_{CHN})} = (1-\sigma) \frac{\left(A\tau_A^{1-\sigma} \cdot \left(\frac{1+\lambda}{\lambda\sigma+1} \right) + B \cdot \tau_B^{1-\sigma} \right)}{\left(A\tau_A^{1-\sigma} + B \cdot \tau_B^{1-\sigma} \right)} \tag{47}$$

Define:

$$G = \frac{\left(A\tau_A^{1-\sigma} \cdot \left(\frac{1+\lambda}{\lambda\sigma+1} \right) + B \cdot \tau_B^{1-\sigma} \right)}{\left(A\tau_A^{1-\sigma} + B \cdot \tau_B^{1-\sigma} \right)} \tag{48}$$

such that:

$$\frac{d^2 log(r_{CHN})}{(dlog(\tau_{CHN}))(d\sigma)} = -G + (1-\sigma) \frac{dG}{d\sigma} \tag{49}$$

Call G_{NUM} the numerator of G and G_{DEN} the denominator of G, such that:

$$\frac{dG}{d\sigma} = \frac{\frac{dG_{NUM}}{d\sigma} \cdot G_{DEN} - \frac{dG_{DEN}}{d\sigma} \cdot G_{NUM}}{G_{DEN}^2} \tag{50}$$

We find:

$$\frac{dG_{NUM}}{d\sigma} = -A\tau_A^{1-\sigma} \cdot log(\tau_A) \left(\frac{1+\lambda}{\lambda\sigma+1} \right) - A\tau_A^{1-\sigma} \frac{\lambda(1+\lambda)}{(\lambda\sigma+1)^2} - B\tau_B^{1-\sigma} log(\tau_B) \tag{51}$$

and

$$\frac{dG_{DEN}}{d\sigma} = -A\tau_A^{1-\sigma} \cdot log(\tau_A) - B\tau_B^{1-\sigma} log(\tau_B) \tag{52}$$

Considering that $\sigma > 1$ and simplifying these expressions, we obtain $\frac{d^2 log(r_{CHN})}{(dlog(\tau_{CHN}))(d\sigma)} < 0$, which corresponds to proposition 4a.

■ Recall from the baseline model that:

$$\frac{\text{dlog} r_{e,ROW}}{\text{dlog}\tau_{CHN}} = \frac{\lambda(\sigma-1)^2}{\lambda\sigma+1} \cdot A_{CHN} \cdot \tau_{CHN}^{1-\sigma} \cdot \frac{1}{\left(A_{CHN} \cdot \tau_{CHN}^{1-\sigma} + A_{ROW} \cdot \tau_{ROW}^{1-\sigma}\right)} \tag{53}$$

Define:

$$F = \frac{\lambda(\sigma-1)^2}{\lambda\sigma+1} \tag{54}$$

and

$$G = \frac{A\tau_A^{1-\sigma}}{\left(A\tau_A^{1-\sigma} + B \cdot \tau_B^{1-\sigma}\right)} \tag{55}$$

such that:

$$\frac{d^2 log(r_{CHN})}{(dlog(\tau_{CHN}))(d\sigma)} = \frac{dF}{d\sigma} \cdot G + \frac{dG}{d\sigma} \cdot F \tag{56}$$

We find:

$$\frac{dF}{d\sigma} = \frac{2\lambda(\sigma-1)(\lambda\sigma+1) - \lambda^2(\sigma-1)^2}{(\lambda\sigma+1)^2} \tag{57}$$

Call G_{NUM} the numerator of G and G_{DEN} the denominator of G, such that:

$$\frac{dG}{d\sigma} = \frac{\frac{dG_{NUM}}{d\sigma} \cdot G_{DEN} - \frac{dG_{DEN}}{d\sigma} \cdot G_{NUM}}{G_{DEN}^2} \tag{58}$$

We find:

$$\frac{dG_{NUM}}{d\sigma} = -A\tau_A^{1-\sigma} \cdot log(\tau_A) \tag{59}$$

and

$$\frac{dG_{DEN}}{d\sigma} = -A\tau_A^{1-\sigma} \cdot log(\tau_A) - B\tau_B^{1-\sigma} log(\tau_B) \tag{60}$$

Considering that $\sigma > 1$ and simplifying these expressions, we obtain $\frac{d^2 log(r_{ROW})}{(dlog(\tau_{CHN}))(d\sigma)} > 0$, which corresponds to proposition 4b.

A.1.5 Additional results: Baseline model with ad–valorem tariffs

The standard approach to modeling tariffs in the literature is using the iceberg cost assumption [Melitz, 2003]. As a robustness check, we show are results when modeling tariffs as ad-valorem, departing from the iceberg cost assumption. In the standard version of Melitz [2003] with a constant marginal cost, modeling tariffs as ad–valorem tariffs or iceberg trade costs yields the same result for prices, quantities and revenue [Cole, 2011]. In our case, with an increasing marginal cost, the results from both approaches differ to some extent, although we show below that the propositions of our baseline model also hold under the ad-valorem modeling approach.

In this case, we write preferences as follows,

$$q_e = A_m \cdot \tilde{p}_e^{-\sigma} \tag{61}$$

where $\tilde{p}_e$ represents the price paid by consumers. Under the iceberg trade cost assumption, the price paid by consumers is equal to the price received by producers. Here, instead, the price received by producers is $p_{e,m} = \frac{\tilde{p}_{e,m}}{\tau_m}$. Each exporting firm's variable cost is:

$$\frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1} \cdot (q_{e,CHN} + \cdot q_{e,ROW})^{\lambda+1} \tag{62}$$

The difference with the baseline model in the main text is that we are not multiplying the quantities in the expression for the variable cost by the iceberg–type tariffs. Total profits in both markets are:

$$\pi_e = p_{e,CHN} \cdot q_{e,CHN} + p_{e,ROW} \cdot q_{e,ROW} - \frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1} (q_{e,CHN} + q_{e,ROW})^{\lambda+1} - f_{CHN} - f_{ROW}\,, \tag{63}$$

The export revenue of each US exporting firm in China and the rest of the world is:

$$r_{e,CHN} = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot A_{CHN} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \tau_{CHN}^{\frac{-\sigma(\lambda+1)}{\lambda\sigma+1}} \cdot \left(\frac{\tau_{ROW}^{\sigma}}{A_{CHN} \cdot \tau_{ROW}^{\sigma} + A_{ROW} \cdot \tau_{CHN}^{\sigma}}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{64}$$

and

$$r_{e,ROW} = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot A_{ROW} \cdot \varphi_e^{\frac{\sigma-1}{\lambda\sigma+1}} \cdot \tau_{ROW}^{\frac{-\sigma(\lambda+1)}{\lambda\sigma+1}} \cdot \left(\frac{\tau_{CHN}^{\sigma}}{A_{ROW} \cdot \tau_{CHN}^{\sigma} + A_{CHN} \cdot \tau_{ROW}^{\sigma}}\right)^{\frac{\lambda(\sigma-1)}{\lambda\sigma+1}} \tag{65}$$

respectively. This framework leads to the same propositions as in the baseline model.

Regarding the response of exports to China to changes in China's tariff, we can use the expression for an exporter's revenue in the Chinese market in equation (64) to write:

$$\frac{\mathrm{d}r_{e,CHN}}{\mathrm{d}\tau_{CHN}} = \frac{r_{e,CHN}}{\tau_{CHN}} \cdot \frac{\sigma}{\lambda\sigma + 1}\left(-(\lambda+1) - \lambda(\sigma-1)\frac{A_{ROW}\tau_{CHN}^{\sigma}}{A_{CHN}\tau_{ROW}^{\sigma} + A_{ROW}\tau_{CHN}^{\sigma}}\right) < 0 \qquad (66)$$

Regarding the response of exports to the rest of the world to changes in China's tariff, we can use the expression for an exporter's revenue in the rest of the world market in equation (65) to write:

$$\frac{\mathrm{d}r_{e,ROW}}{\mathrm{d}\tau_{CHN}} = \frac{r_{e,ROW}}{\tau_{CHN}} \cdot \frac{\lambda\sigma(\sigma-1)}{\lambda\sigma + 1}\left(1 + \frac{A_{ROW}\tau_{CHN}^{\sigma}}{A_{CHN}\tau_{ROW}^{\sigma} + A_{ROW}\tau_{CHN}^{\sigma}}\right) > 0 \qquad (67)$$

A.1.6 Additional results: Alternative model of financial constraints

As a robustness check, we examine an alternative model of financial constraints. We extend the baseline model (we abstract from firm–to–firm trade) and incorporate the role of financial constraints in a framework in which exporting firms have a working capital requirement and face a borrowing limit. This structure is common in the literature and is used, for example, in Benguria and Taylor [2020] to study the response of trade flows to deleveraging shocks.

Specifically, we assume that exporting firms have a working capital requirement, such that they need to borrow funds to finance a fraction $\delta < 1$ of their variable cost before production takes place. There is a binding borrowing constraint that limits the amount that exporting firms can borrow to meet the working capital requirement, such that $\delta C_e \leq \bar{D}$, where C_e stands for the firms' variable cost and $\bar{D}$ represents the borrowing limit.

The binding borrowing constraint implies that the variable cost will be equal to a constant $(\frac{\bar{D}}{\delta})$. This results in a restriction on the sum of the output in both markets, $q_{CHN} + q_{ROW}$. We show below that exports are more responsive to tariffs when the borrowing limit is higher. As in the main text, we express the results in terms of the leverage ratio of an exporting firm (defined as the amount borrowed over total revenue), which as we show below is increasing in the borrowing limit.

We use the ad-valorem tariff assumption described in detail earlier in Appendix Section A.1.5.

In this context, an exporting firm maximizes profits:

$$\pi_e = p_{e,CHN} \cdot q_{e,CHN} + p_{e,ROW} \cdot q_{e,ROW} - \frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1}\left(q_{e,CHN} + q_{e,ROW}\right)^{\lambda+1} - f_{CHN} - f_{ROW}, \qquad (68)$$

subject to the borrowing constraint $\delta C_e \leq \bar{D}$, where C_e stands for the exporter's variable cost. Given that variable cost is:

$$\frac{1}{\varphi_e} \cdot \frac{1}{\lambda+1} \cdot (q_{e,CHN} + q_{e,ROW})^{\lambda+1} \tag{69}$$

the constraint can be written as:

$$q_{e,CHN} + q_{e,ROW} \leq \left(\frac{\bar{D} \cdot (\lambda+1) \cdot \varphi_e}{\delta}\right)^{\frac{1}{\lambda+1}} \tag{70}$$

Solving this problem yields exports to China:

$$r_{CHN} = A_{CHN} \cdot \tau_{CHN}^{-1} \cdot \left(\frac{\tau_{ROW}^{\sigma}}{A_{ROW}\tau_{CHN}^{\sigma} + A_{CHN}\tau_{ROW}^{\sigma}}\right)^{\frac{\sigma-1}{\sigma}} \cdot \left(\frac{\bar{D} \cdot (\lambda+1) \cdot \varphi_e}{\delta}\right)^{\frac{\sigma-1}{\sigma(\lambda+1)}} \tag{71}$$

and exports to the rest of the world:

$$r_{ROW} = A_{ROW} \cdot \tau_{ROW}^{-1} \cdot \left(\frac{\tau_{CHN}^{\sigma}}{A_{ROW}\tau_{CHN}^{\sigma} + A_{CHN}\tau_{ROW}^{\sigma}}\right)^{\frac{\sigma-1}{\sigma}} \cdot \left(\frac{\bar{D} \cdot (\lambda+1) \cdot \varphi_e}{\delta}\right)^{\frac{\sigma-1}{\sigma(\lambda+1)}} \tag{72}$$

Regarding the response of exports to China to changes in China's tariff:

$$\frac{dr_{e,CHN}}{d\tau_{CHN}} = \frac{r_{e,CHN}}{\tau_{CHN}} \cdot \left(-1 - (\sigma-1) \cdot \frac{A_{ROW}\tau_{CHN}^{\sigma}}{A_{ROW}\tau_{CHN}^{\sigma} + A_{CHN}\tau_{ROW}^{\sigma}}\right) < 0 \tag{73}$$

Regarding the response of exports to the rest of the world to changes in China's tariff:

$$\frac{dr_{e,ROW}}{d\tau_{CHN}} = \frac{r_{e,ROW}}{\tau_{CHN}}(\sigma-1)\frac{A_{CHN} \cdot \tau_{ROW}^{\sigma}}{A_{ROW}\tau_{CHN}^{\sigma} + A_{CHN}\tau_{ROW}^{\sigma}} > 0 \tag{74}$$

Regarding the effect of the borrowing limit on the response of exports to China to changes in China's tariff:

$$\frac{d^2 r_{e,CHN}}{d\tau_{CHN} d\bar{D}} = \frac{\sigma-1}{\sigma(\lambda+1)} \cdot \frac{dr_{e,CHN}}{d\tau_{CHN}} \cdot \frac{1}{\bar{D}} < 0 \tag{75}$$

This implies a higher borrowing limit leads to a larger decline in exports to China in response to an increase in China's tariff.

Regarding the effect of the borrowing limit on the response of exports to the rest of the world to changes in China's tariff:

$$\frac{d^2 r_{e,ROW}}{d\tau_{CHN} d\bar{D}} = \frac{\sigma - 1}{\sigma(\lambda+1)} \cdot \frac{d r_{e,ROW}}{d\tau_{CHN}} \cdot \frac{1}{\bar{D}} > 0 \tag{76}$$

This implies a higher borrowing limit leads to a larger increase in exports to the rest of the world in response to an increase in China's tariff.

Finally, we can show that the leverage ratio is increasing in the borrowing limit. The leverage ratio L is the ratio between the amount borrowed ($\bar{D}$) and total revenue:

$$\begin{aligned} L &= \frac{\bar{D}}{r_{e,CHN} + r_{e,ROW}} \\ &= \bar{D}^{\frac{\sigma\lambda+1}{\sigma(\lambda+1)}} \cdot \frac{1}{A_{ROW}\tau_{CHN}^{\sigma} + A_{CHN}\tau_{ROW}^{\sigma}} \cdot \left(\frac{A_{CHN}\tau_{ROW}^{\sigma}}{\tau_{CHN}} + \frac{A_{ROW}\tau_{CHN}^{\sigma}}{\tau_{ROW}} \right) \cdot \left(\frac{(\lambda+1)\varphi_e}{\delta} \right)^{-\frac{\sigma-1}{\sigma(\lambda+1)}} \end{aligned} \tag{77}$$

This implies that i) An increase in China's tariff is associated with a decline in exports to China which is increasing in the firm's leverage ratio; and ii) An increase in China's tariff is associated with an increase in exports to the rest of the world, which is increasing in the firm's leverage ratio.

A.2 Appendix to Section 3

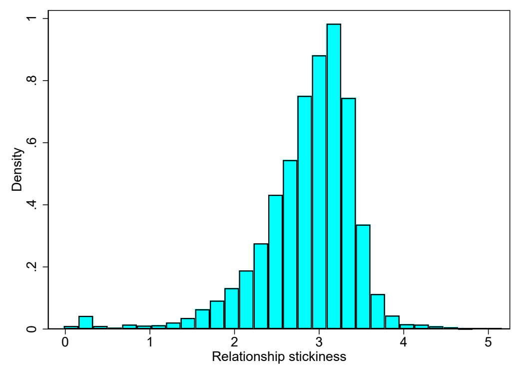
A.2.1 On the measure of relationship stickiness

Here, we describe in more detail the measure of relationship stickiness from Martin et al. [2020]. In addition, we provide a validation exercise that suggests that while this measure is constructed from microdata on French exporters and their foreign importers, it seems applicable to the US context.

- Figure A.1 reports an histogram of the relationship stickiness measure across HS6 product categories (which is the level at which Martin et al. [2020] report this measure and which we use in this paper).

- To assess how applicable is this measure in this context, we examine the duration of exports at the highly disaggregate HS10 product category and show that among products that have an above median degree of relationship stickiness, exports at the HS10 level are much less likely to see breaks over time. Specifically, we consider exports to China between 2015 and 2017 before the trade war. We examine data by month and HS10 product. For each product, we compute the number of months with positive exports. We then divide these products into those with above or below median relationship stickiness according to Martin et al. [2020]'s measure. First, we find that positive exports occur 66% vs. 42% of the months in industries with high vs. low relationship stickiness. Second, we estimate a regression of the number of months with positive exports on relationship stickiness, controlling for the log of exports in each product and by HS2 fixed effects. The results in Table A.1 indicate that a one standard deviation increase in relationship stickiness is associated with a 0.13 standard deviations increase in the number of months with positive exports. In other words, the mean duration of trade spells at the HS10 level is higher in industries with higher relationship stickiness.

Figure A.1: Histogram of the relationship stickiness measure



Notes: This figure reports an histogram of the relationship stickiness measure of Martin et al. [2020] across HS6–digit products.

Table A.1: Relationship stickiness and trade duration

	(1)	(2)
Relationship stickiness	0.161***	0.125***
	(0.008)	(0.009)
Observations	6244	6244

Notes: This table reports the results of a regression in which the dependent variable is the number of months with positive exports over 2015–2017 for each HS10 product exported to China. Both columns control for the log of exports in each HS10 product. Column 2 controls for HS2 fixed effects. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level.

A.2.2 Other Variables

Here, we briefly mention the source and definition of supplementary variables used in the analysis.

1. **Inventory ratios:** We measure the inventory intensity of each industry using COMPUSTAT. We first compute the inventory to revenue ratio of each firm, then compute the median within firms over time between 2012 and 2016, and finally compute the median across firms within NAICS 4–digit industries, which are then matched to HS 10–digit codes.

2. **External finance dependence:** We measure the external finance dependence of each industry using COMPUSTAT. We first compute the ratio of capital expenditure minus cash flow from operations over capital expenditure of each firm, then compute the median within firms over time between 2012 and 2016, and finally compute the median across firms within NAICS 4–digit industries, which are then matched to HS 10–digit codes.

3. **Trade credit:** We measure the trade credit intensity of each industry using COMPUSTAT. We first compute the ratio of accounts receivable minus accounts payable over total assets for each firm, then compute the median within firms over time between 2012 and 2016, and finally compute the median across firms within NAICS 4–digit industries, which are then matched to HS 10–digit codes.

4. **Upstreamness:** Antràs et al. [2012] define and compute a measure of upstreamness that captures the relative position of different industries in supply chains using input-output tables. The data is originally reported using the industry classification of the 2002 input–output table of the US, and assigned to HS10 products using a concordance provided by the Census.

5. **Contract intensity:** Nunn [2007] defines contract intensity as the fraction of a final good's inputs that are relationship–specific. This is constructed by Nunn using input–output tables as the share of value of a final good's inputs that are not sold in organized exchanges and are not referenced priced.

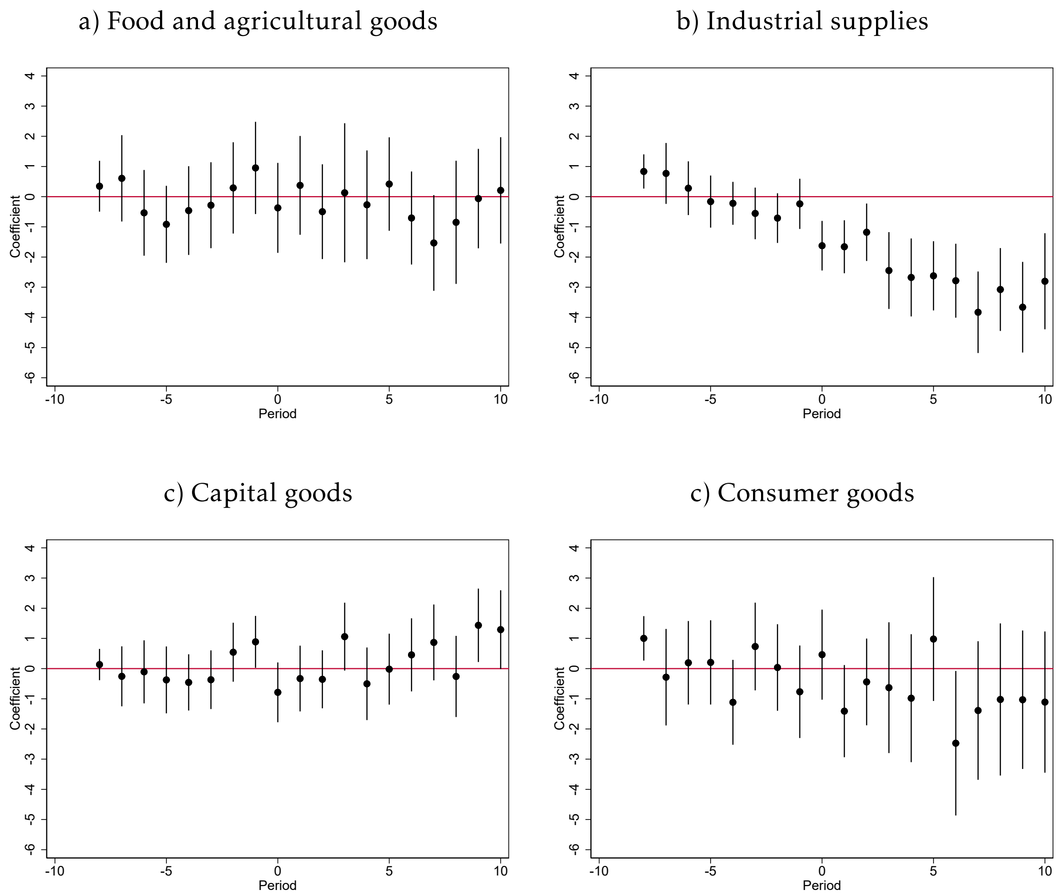
6. **Quality ladders:** Khandelwal [2010] estimates the quality of traded goods at the HS10 level using data on trade volumes and prices and the intuition that conditional on prices,

higher market shares imply higher quality. Khandelwal [2010] defines the length of quality ladders as the range of qualities for each product.

7. **Related-party trade** We compute the share of related-party trade in US exports in 2017 using data reported by the US Census. The data is originally reported at the level of NAICS 6–digit industries, and we use a concordance provided by the US Census Bureau to assign it to HS10 products.

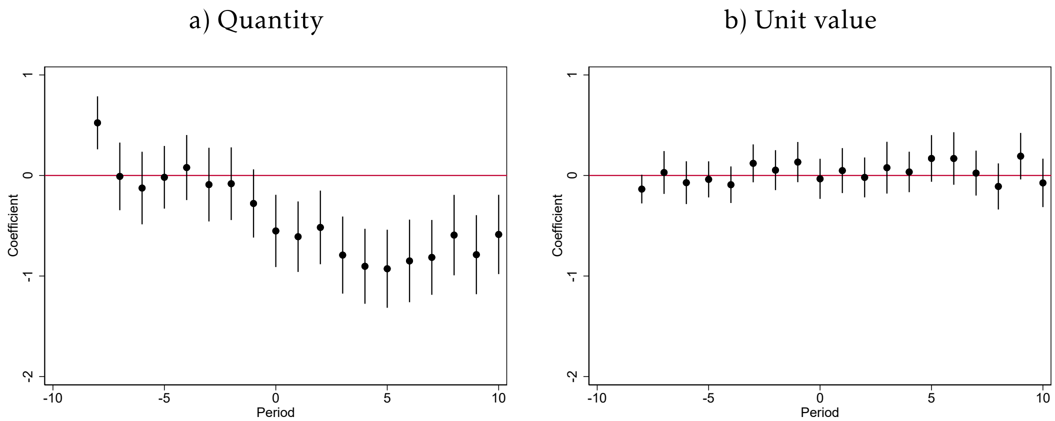
A.3 Appendix to Section 4

Figure A.2: China's retaliatory tariffs and US exports by sector



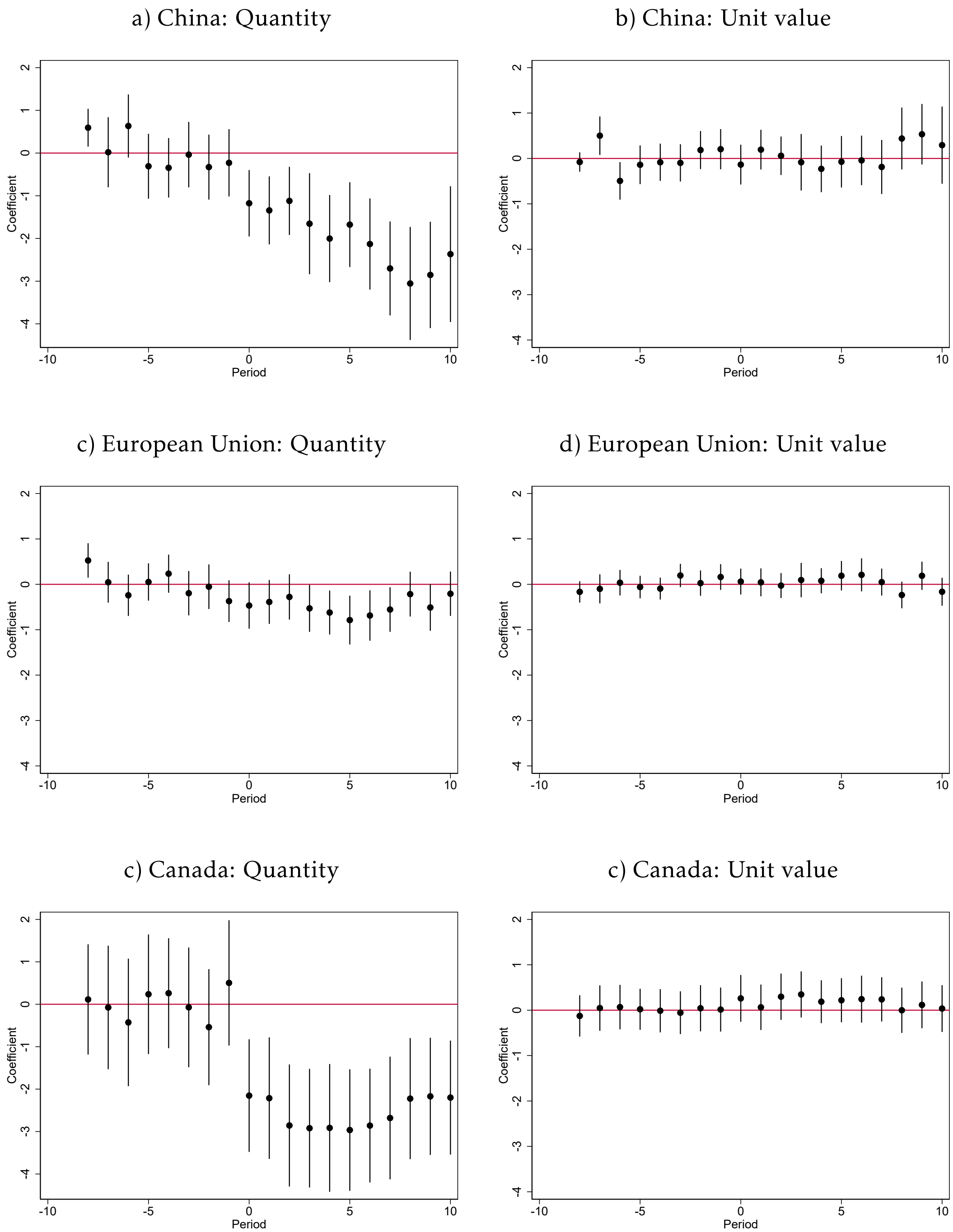
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.3: Retaliatory tariffs and US exports: Quantities and unit values



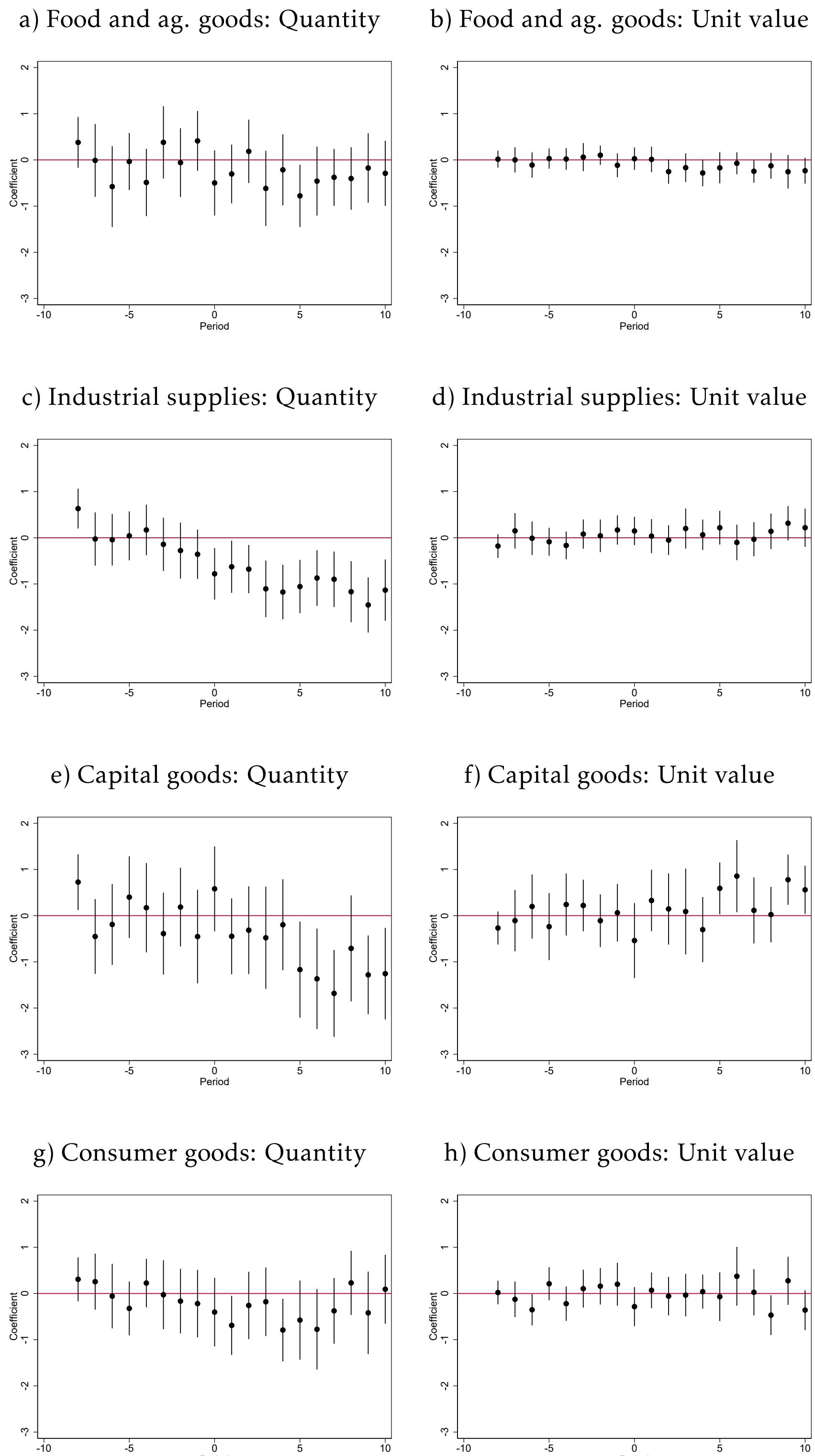
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.4: Retaliatory tariffs and US exports to main retaliating countries: Quantities and unit values



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

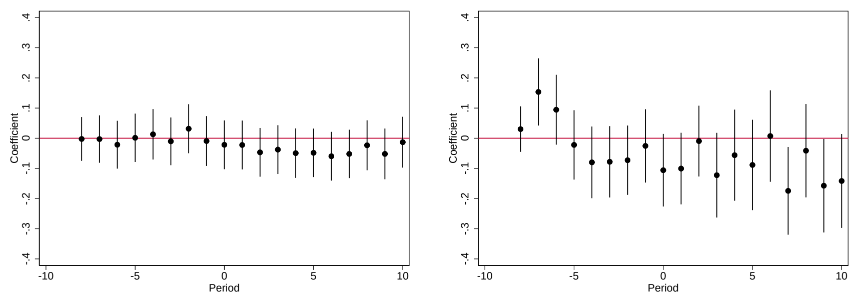
Figure A.5: Retaliatory tariffs and US exports by sector: Quantities and unit values



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.6: China's retaliatory tariffs and US exports: Extensive margin

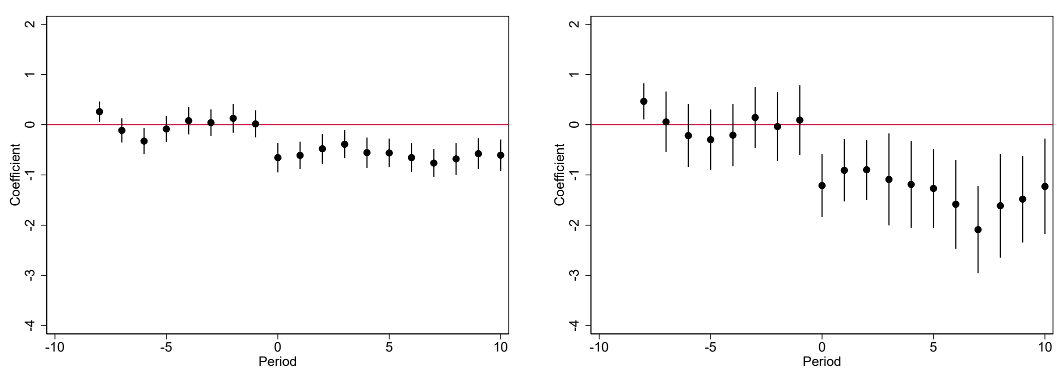
a) All destinations b) China



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

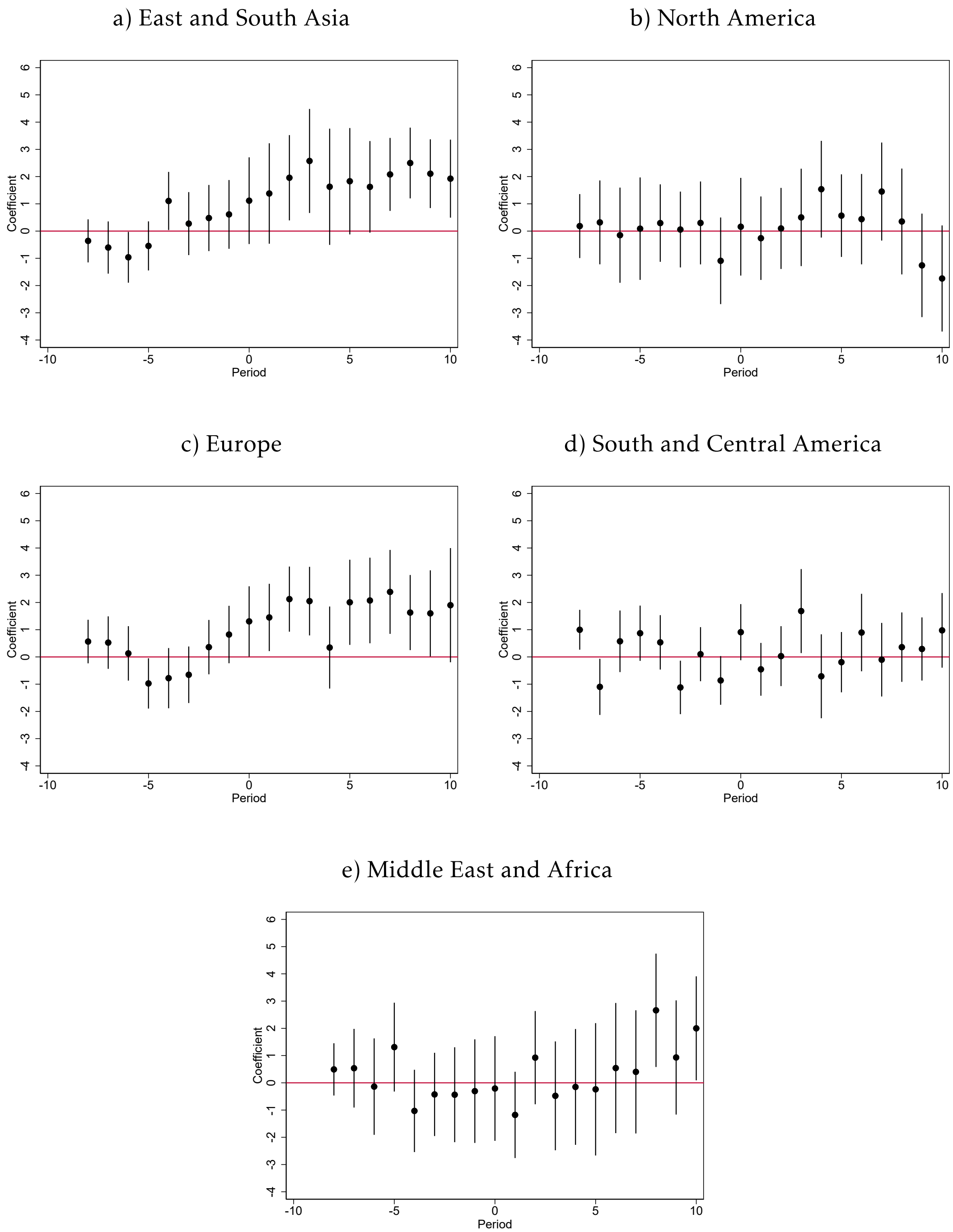
Figure A.7: Retaliatory tariffs and US exports: Products defined at the HS 6–digit level

a) All destinations b) China



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.8: China's retaliatory tariffs and US exports to ROW: Breakdown by regions

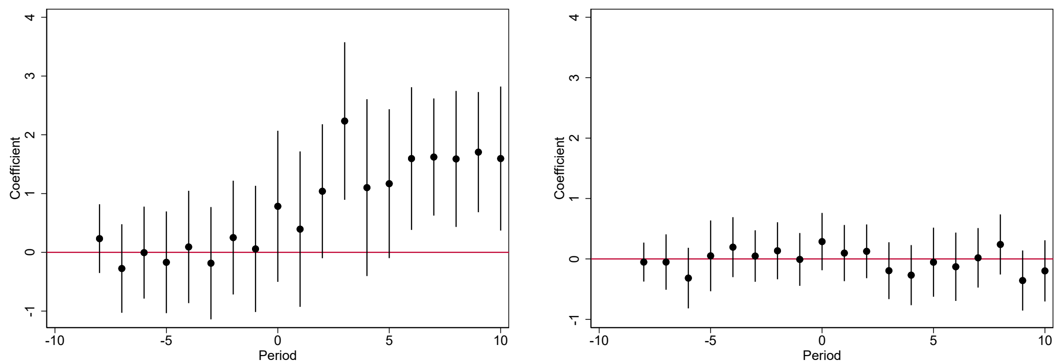


Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

Figure A.9: China's retaliatory tariffs US and exports to ROW: Quantities and unit values

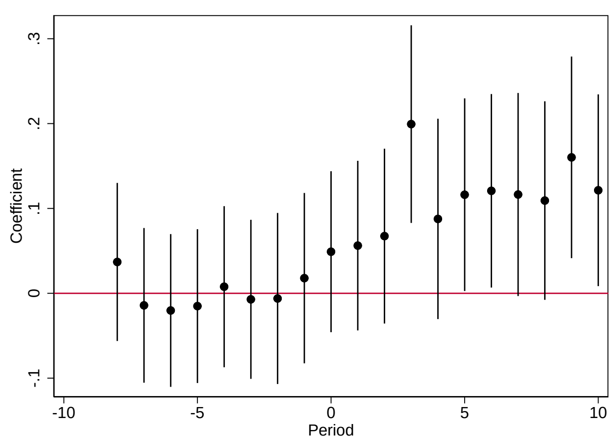
a) Chinese tariffs and US exports to ROW: Quantity

b) Chinese tariffs and US exports to ROW: Unit value



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

Figure A.10: China's Retaliatory Tariffs and US Exports to ROW: Extensive margin



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

A.3.1 Alternative fixed effects

Here, we show that the results in Section 4 are robust to alternative sets of fixed effects. In the case of exports to all destinations (in Figure 2a), the baseline analysis includes country × HS10 product fixed effects and country × HS2 sector × time (year–month) fixed effects. In Appendix Figure A.11 below, we show the results are robust to including the following sets of fixed effects:

- country × HS10 product fixed effects and time (year–quarter) fixed effects.
- country × HS10 product fixed effects and country × time (year–quarter) fixed effects.
- country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS2 sector × time (year–quarter).
- country × HS10 product fixed effects and country × HS4 industry × time (year–month) fixed effects.
- country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS10 product × time (year–quarter) fixed effects.

In the case of exports to a China (in Figure 2b), the baseline analysis includes HS10 product fixed effects and HS2 sector × time (year–month) fixed effects. In Appendix Figure A.12 below, we show the results are robust to including the following sets of fixed effects:

- HS10 product fixed effects and time (year–quarter) fixed effects.
- HS10 product fixed effects and HS4 industry × time (year–month) fixed effects.

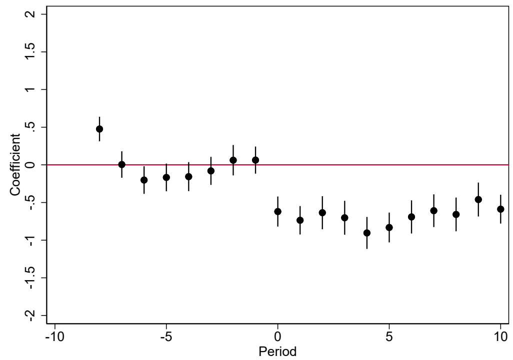
In the case of export reallocation in response to Chinese retaliatory tariffs (in Figure 4), the baseline analysis includes country × HS10 product fixed effects and country × HS2 sector × time (year–month) fixed effects. In Appendix Figure A.13 below, we show the results are robust to including the following sets of fixed effects:

- country × HS10 product fixed effects and time (year–quarter) fixed effects.
- country × HS10 product fixed effects and country × time (year–quarter) fixed effects.

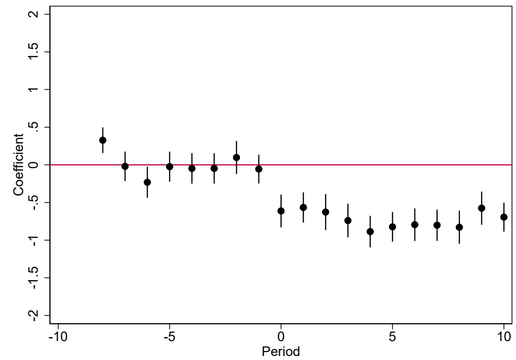
- country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS2 sector × time (year–quarter).
- country × HS10 product fixed effects and country × HS4 industry × time (year–month) fixed effects.

Figure A.11: Retaliatory tariffs and US exports to all destinations: Alternative fixed effects

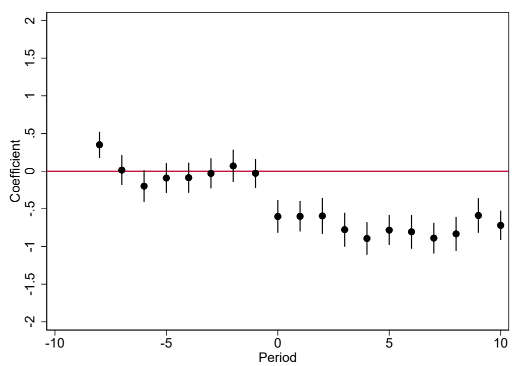
a) Country × HS10 product fixed effects and time (year–quarter) fixed effects



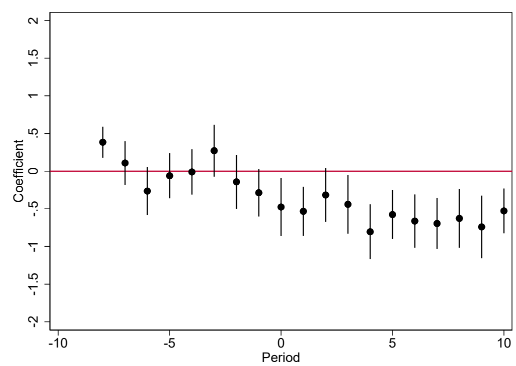
b) Country × HS10 product fixed effects and country × time (year–quarter) fixed effects



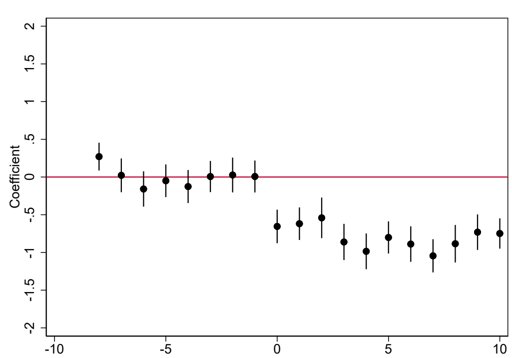
c) Country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS2 sector × time (year–quarter)



d) Country × HS10 product fixed effects and country × HS4 industry × time (year–month) fixed effects



e) Country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS10 product × time (year–quarter) fixed effects

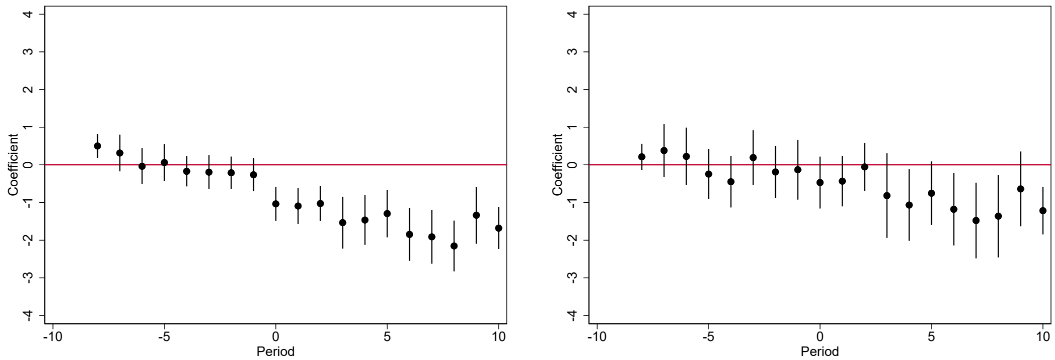


Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.12: Retaliatory tariffs and US exports to China: Alternative fixed effects

a) HS10 product fixed effects and time (year–quarter) fixed effects

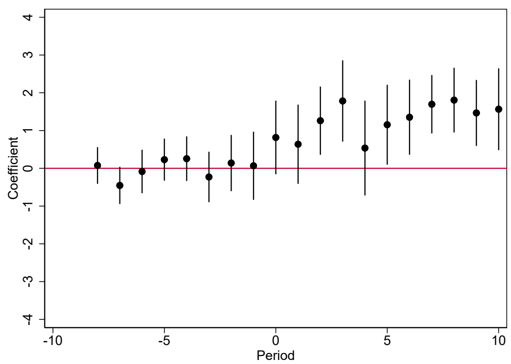
b) HS10 product fixed effects and HS4 industry × time (year–month) fixed effects



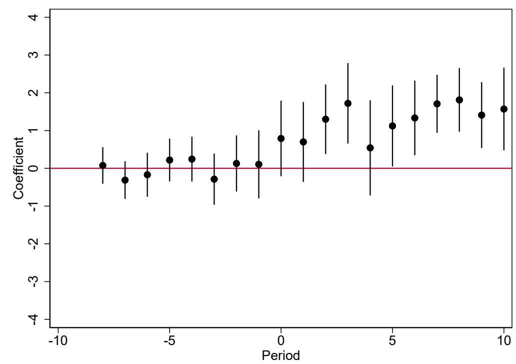
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.13: China's retaliatory tariffs and US exports to ROW: Alternative fixed effects

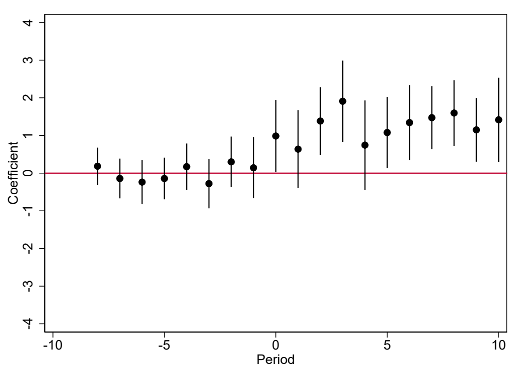
a) Country × HS10 product fixed effects and time (year–quarter) fixed effects



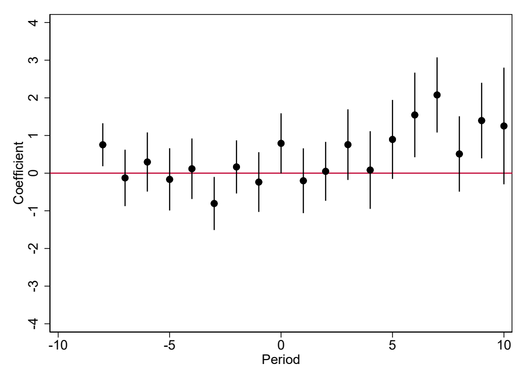
b) Country × HS10 product fixed effects and country × time (year–quarter) fixed effects



c) Country × HS10 product fixed effects and country × time (year–quarter) fixed effects and HS2 sector × time (year–quarter)



d) Country × HS10 product fixed effects and country × HS4 industry × time (year–month) fixed effects



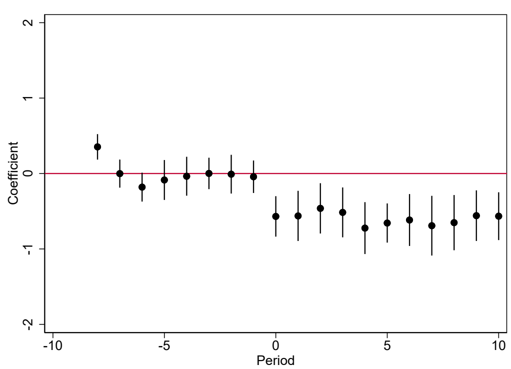
Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

A.3.2 Alternative clustering

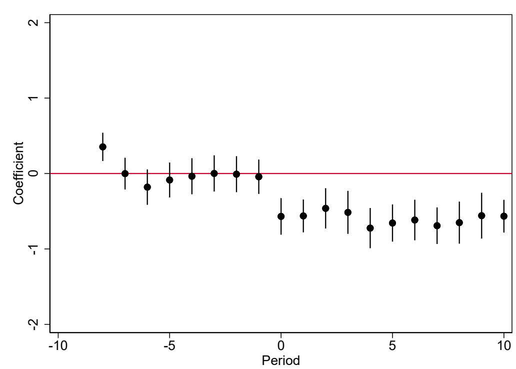
Here, we show that the results in Section 4 are robust to alternative ways of clustering standard errors. In the baseline analysis in the main text, standard errors are clustered by HS6 product. In Appendix Figures A.14 and A.15 below we cluster standard errors by i) HS4 product, ii) HS6 product and country, using multiway clustering or iiii) HS4 product and country, using multiway clustering. Figure A.14 corresponds to the direct effect of retaliatory tariffs and is equivalent to Figures 2a and 2b in the main text. Figure A.15 corresponds to export reallocation in response to Chinese retaliatory tariffs and is equivalent to Figure 4a in the main text. The results are statistically significant in all cases.

Figure A.14: Retaliatory tariffs and US exports: Alternative clustering

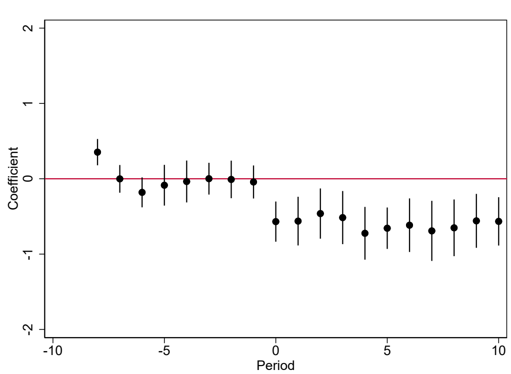
a) Exports to World; Clustering by HS6 and country



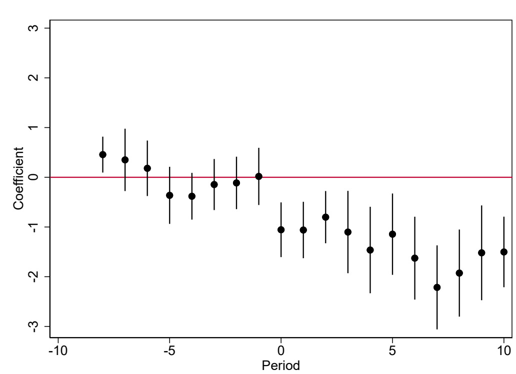
b) Exports to World; Clustering by HS4



c) Exports to World; Clustering by HS4 and country



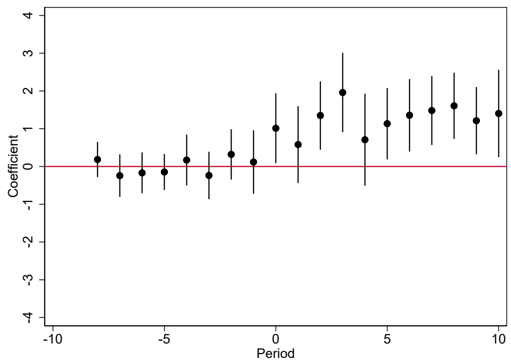
e) Exports to China; Clustering by HS4



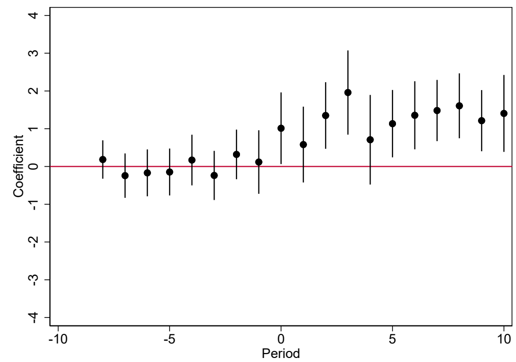
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.15: China's retaliatory tariffs and US exports to ROW: Alternative clustering

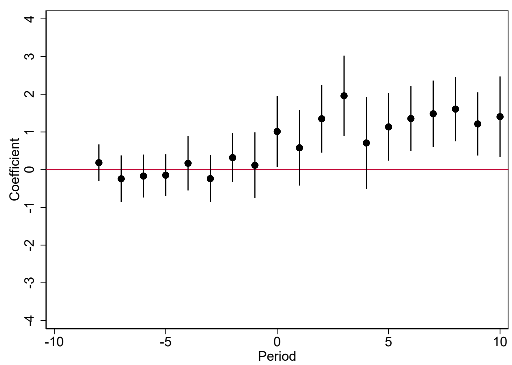
a) Clustering by HS6 and country



b) Clustering by HS4



c) Clustering by HS4 and country



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

A.3.3 Export reallocation in response to other retaliatory tariffs

In Section 4.1 (as well as in Section 5), we document export reallocation toward the rest of the world in response to Chinese tariffs. Here, we extend the same approach and study export reallocation in response to other retaliatory tariffs. We focus on the retaliatory tariffs imposed by Canada, the European Union, and Mexico.[40]

We extend equation (10) to include terms capturing the response of exports to the rest of the world to retaliatory tariffs imposed by Canada, the European Union, and Mexico.

$$
\begin{aligned}
\log \mathrm{Y}_{cpt} = & \sum_{k=--\underline{T}}^{\overline{T}} \beta_k \left(I_{cpk} \times \ln\left(\frac{1+\tau_{cpk}}{1+\tau_{cp0}} \right) \right) + \sum_{k=--\underline{T}}^{\overline{T}} \gamma_k^{CHN} \left(I_{pk}^{CHN} \times \ln\left(\frac{1+\tau_{pk}^{CHN}}{1+\tau_{p0}^{CHN}} \right) \times \mathrm{S}_{p0}^{CHN} \right) \\
& + \sum_{k=--\underline{T}}^{\overline{T}} \gamma_k^{CAN} \left(I_{pk}^{CAN} \times \ln\left(\frac{1+\tau_{pk}^{CAN}}{1+\tau_{p0}^{CAN}} \right) \times \mathrm{S}_{p0}^{CAN} \right) + \sum_{k=--\underline{T}}^{\overline{T}} \gamma_k^{EU} \left(I_{pk}^{EU} \times \ln\left(\frac{1+\tau_{pk}^{EU}}{1+\tau_{p0}^{EU}} \right) \times \mathrm{S}_{p0}^{EU} \right) \\
& + \sum_{k=--\underline{T}}^{\overline{T}} \gamma_k^{MEX} \left(I_{pk}^{MEX} \times \ln\left(\frac{1+\tau_{pk}^{MEX}}{1+\tau_{p0}^{MEX}} \right) \times \mathrm{S}_{p0}^{MEX} \right) \eta_{cp} + \delta_{cst} + \epsilon_{cpt} \,, \qquad (78)
\end{aligned}
$$

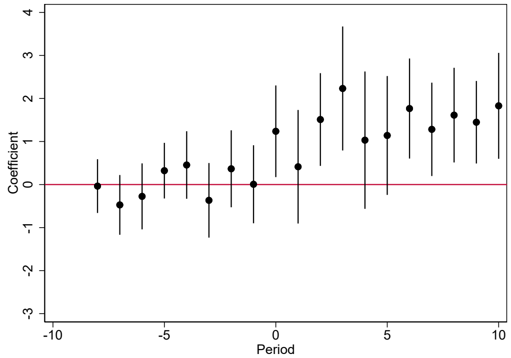
In one approach, we restrict the sample to all export destinations excluding China, Canada, the European Union, and Mexico. The results are shown in Figure A.16. First, we see that the retaliatory tariffs of Canada, the European Union, and Mexico did not lead to a significant amount of export reallocation. This is perhaps to be expected given the relatively small amount of products targeted by these tariffs. Second, the figure shows that the export reallocation effect in response to Chinese tariffs that we document in the main text persists under this augmented approach that also considers other retaliatory tariffs.

In a second approach, we include all export destinations. The results are shown in Figure A.17. They confirm the previous message, with little signs reallocation in response to Canadian, European and Mexican tariffs and substantial reallocation in response to Chinese tariffs.

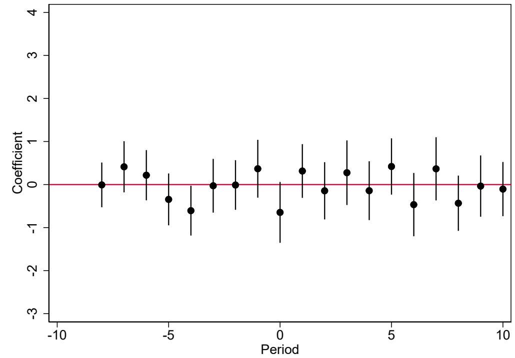
[40] Retaliatory tariffs imposed by other countries were very minor relative to these.

Figure A.16: Retaliatory tariffs and US export reallocation

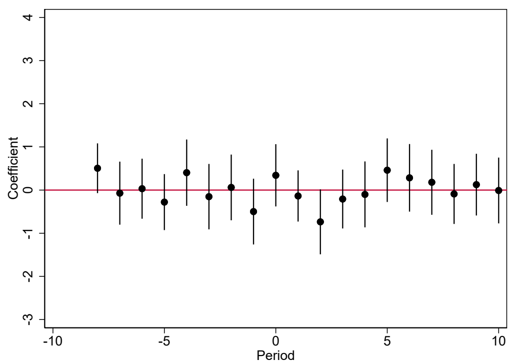
a) Reallocation in response to China's tariffs



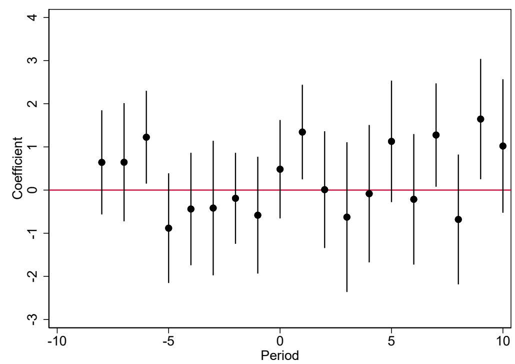
b) Reallocation in response to Canada's tariffs



c) Reallocation in response to the European Union's tariffs



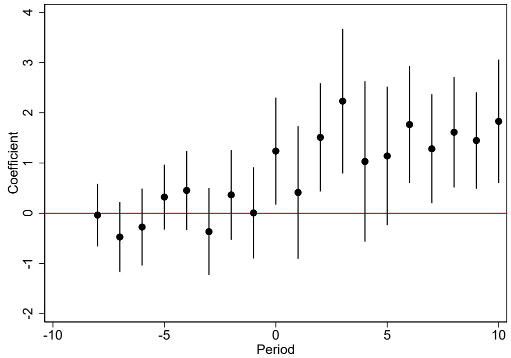
d) Reallocation in response to the Mexico's tariffs



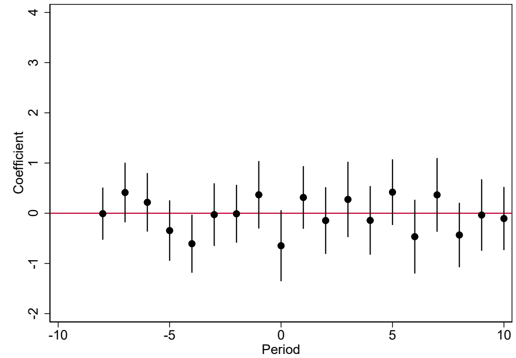
Notes: This figure plots the coefficients obtained from the estimation of equation (78). Vertical bars represent 90% confidence intervals. The sample considers exports to all destinations excluding China, Canada, and the European Union.

Figure A.17: Retaliatory tariffs and US export reallocation

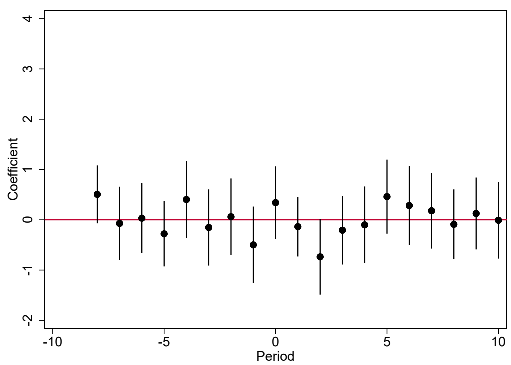
a) Reallocation in response to China's tariffs



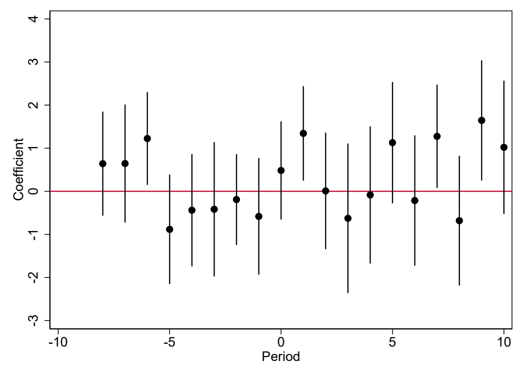
b) Reallocation in response to Canada's tariffs



c) Reallocation in response to the European Union's tariffs



c) Reallocation in response to Mexico's tariffs



Notes: This figure plots the coefficients obtained from the estimation of equation (78). Vertical bars represent 90% confidence intervals. The sample considers all destinations.

A.3.4 Using the De Chaisemartin and d'Haultfoeuille [2020] estimator

We estimate regressions with two–way fixed effects (for products and time or destination–product and time). De Chaisemartin and d'Haultfoeuille [2020] show that in the two period and two group case, these regressions match the difference in difference interpretation and the assumption required to obtain an unbiased estimate of the average treatment effect is the parallel trends assumptions. De Chaisemartin and d'Haultfoeuille [2020] establish that in more general settings including multiple periods, variation in treatment timing, and non-binary treatment (among other features) an additional assumption is required. This second assumption is that the treatment effect is constant across groups and over time. Because this assumption is unlikely to hold, they propose an alternative estimator.

Our setting has these more general features. For this reason, here we report results using the DID_M estimator proposed by De Chaisemartin and d'Haultfoeuille [2020], that is valid when the treatment effect is heterogeneous across groups and/or time. The DID_M estimator estimates the average treatment effect across groups and time based on changes in treatment between periods $t-1$ and t. We focus on exports to China and report the results in Table A.2. In line with the results shown in the main text (Figure 2b), we find a substantial decline in exports to China in response to Chinese tariffs, with a similar magnitude to the effect of the tariff on impact on that figure.

Table A.2: China's Retaliatory Tariffs and US Exports to China: DID_M estimator

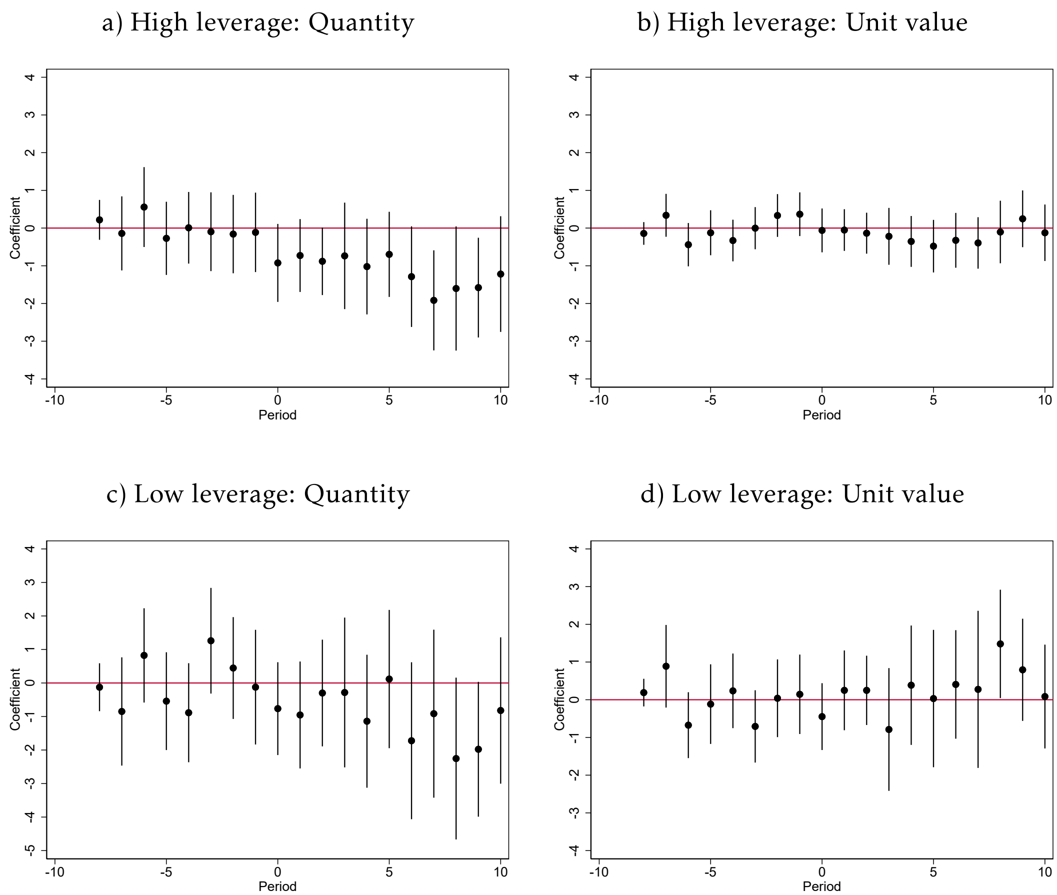
	(1)
ATE	-0.788*
	(0.412)
Observations	20949

Notes: This table reports the results of using the DID_M estimator of De Chaisemartin and d'Haultfoeuille [2020] for equation (9) on the sample of exports to China including HS10 product and time fixed effects. ***, **, and * indicate statistical significance at the 1%, 5% and 10% level.

A.4 Appendix to Section 5

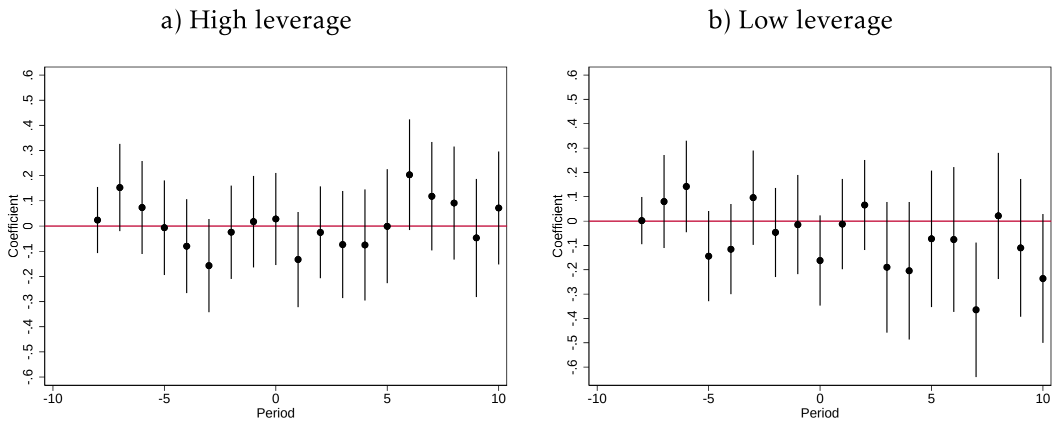
A.4.1 Additional results: Leverage

Figure A.18: China's retaliatory tariffs and US exports to China in high and low leverage industries: Quantities and unit values



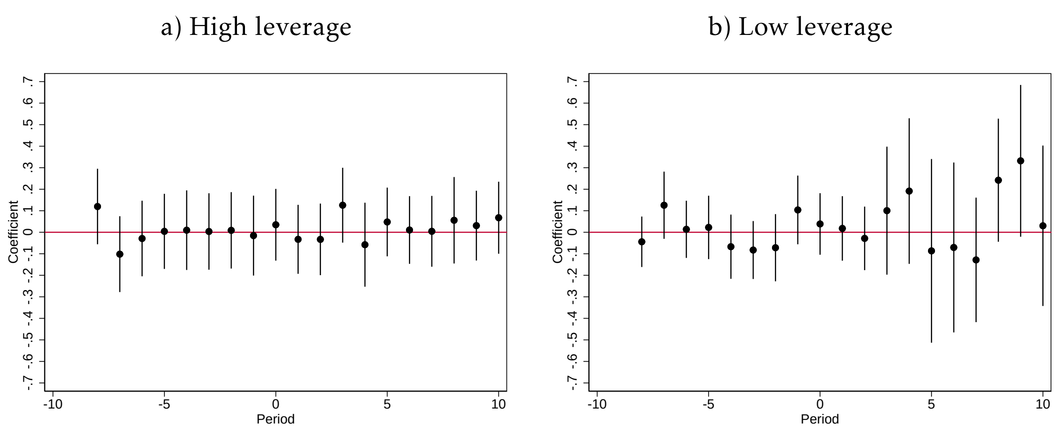
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.19: China's retaliatory tariffs and US exports to China in high and low leverage industries: Extensive margin



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

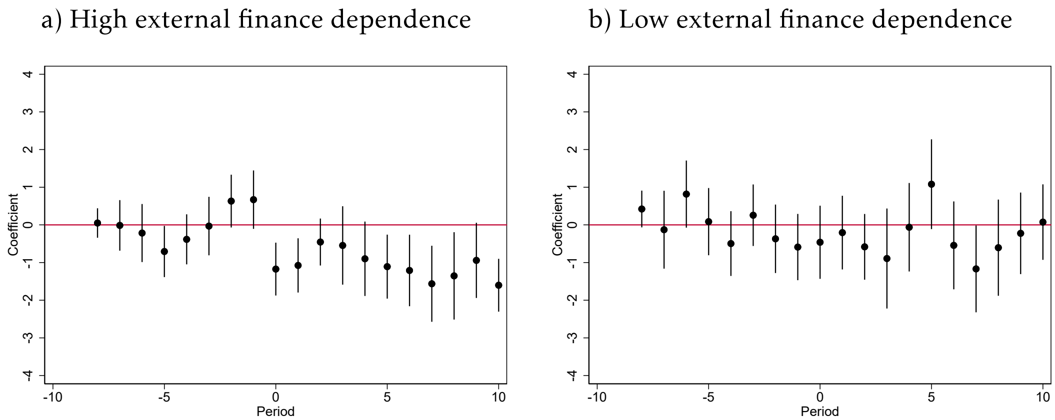
Figure A.20: China's retaliatory tariffs and US exports to ROW in high and low leverage industries: Extensive margin



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

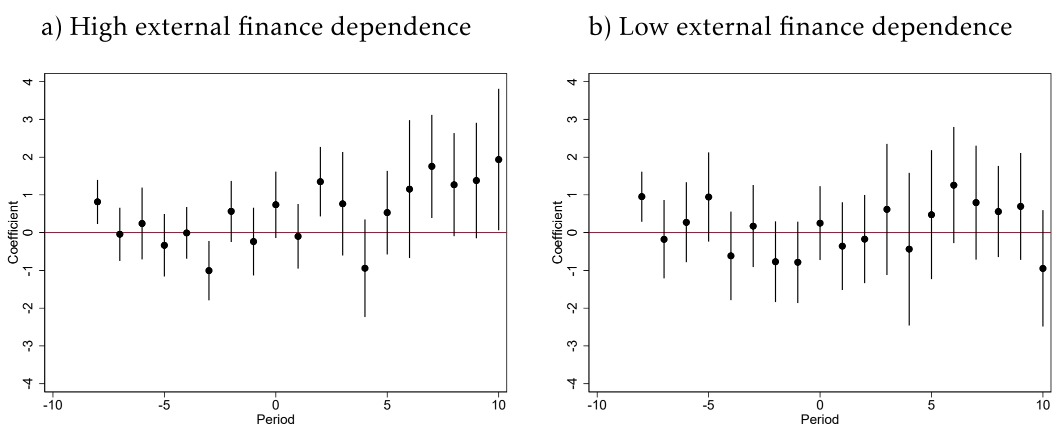
A.4.2 Additional financial measures

Figure A.21: China's retaliatory tariffs and US exports to China: External finance dependence



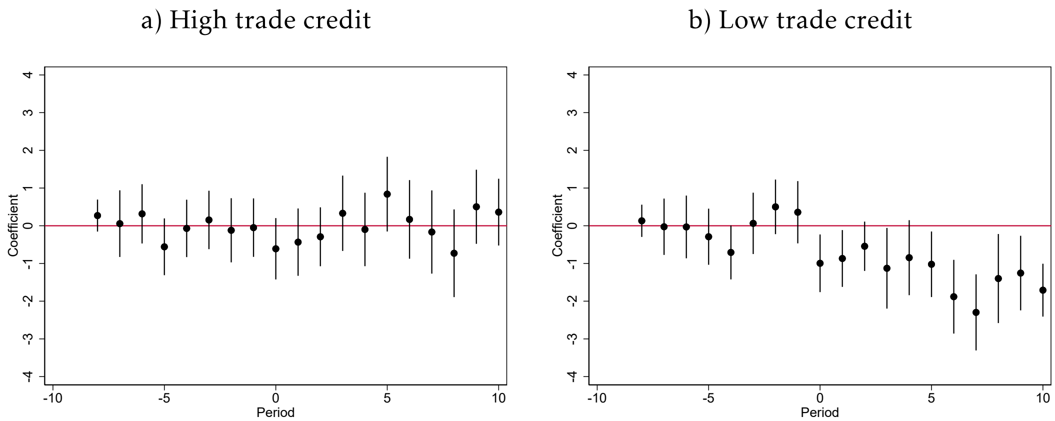
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.22: China's retaliatory tariffs and US exports to ROW: External finance dependence



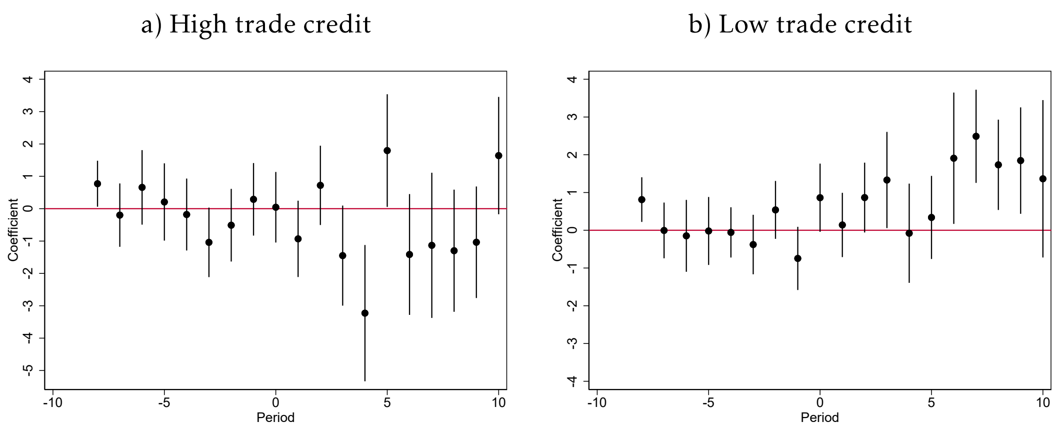
Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

Figure A.23: China's retaliatory tariffs and US exports to China: Trade credit



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

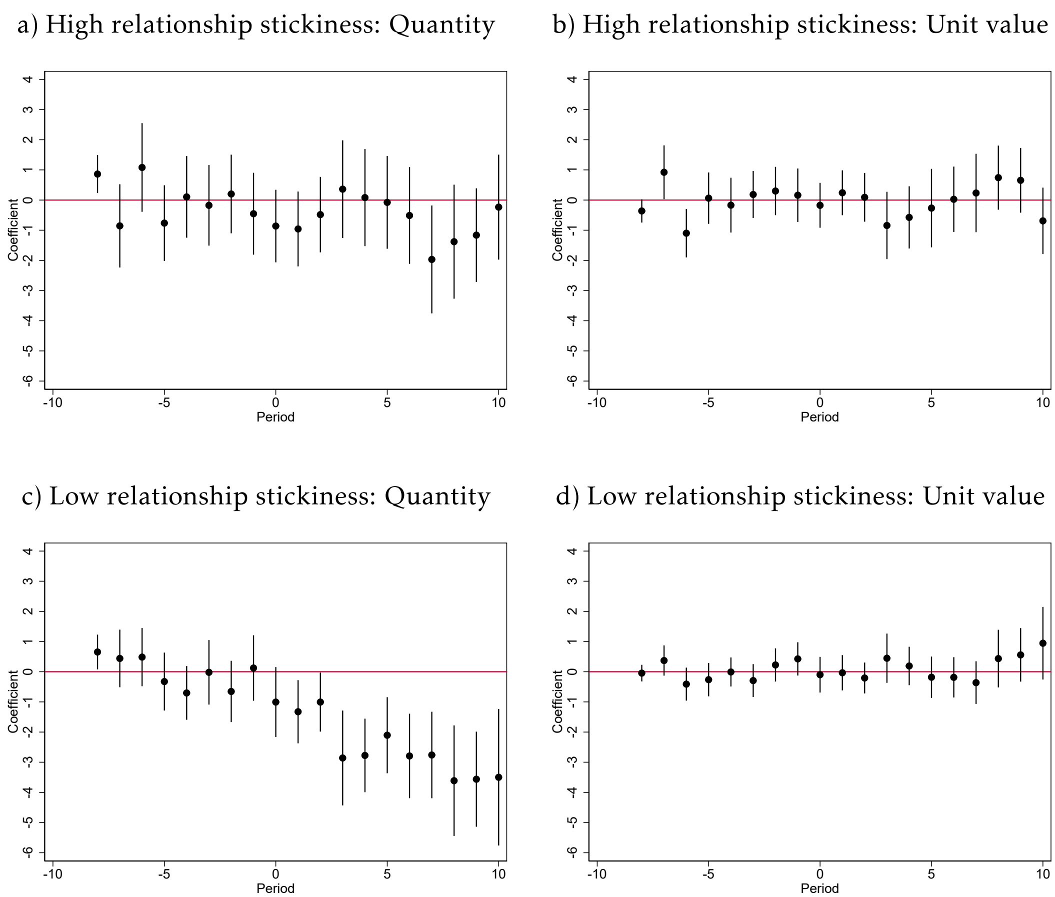
Figure A.24: China's retaliatory tariffs and US exports to ROW: Trade credit



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

A.4.3 Additional results: Relationship stickiness

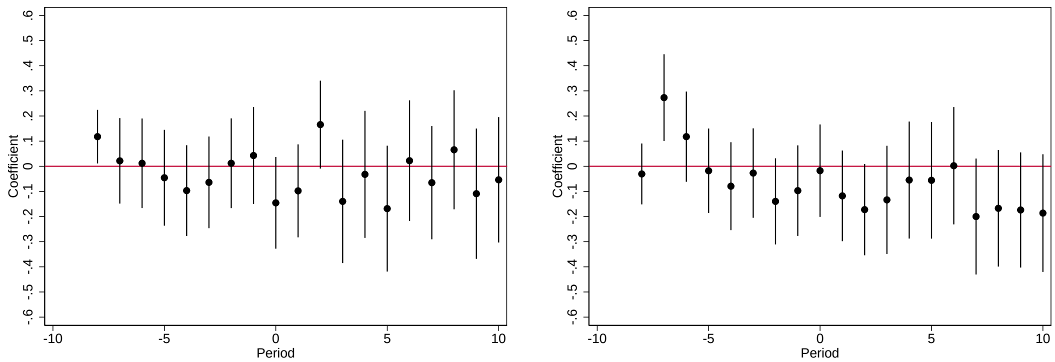
Figure A.25: China's retaliatory tariffs and US exports to China in industries with high and low relationship stickiness: Quantities and unit values



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.26: China's retaliatory tariffs and US exports to China in industries with high and low relationship stickiness: Extensive margin

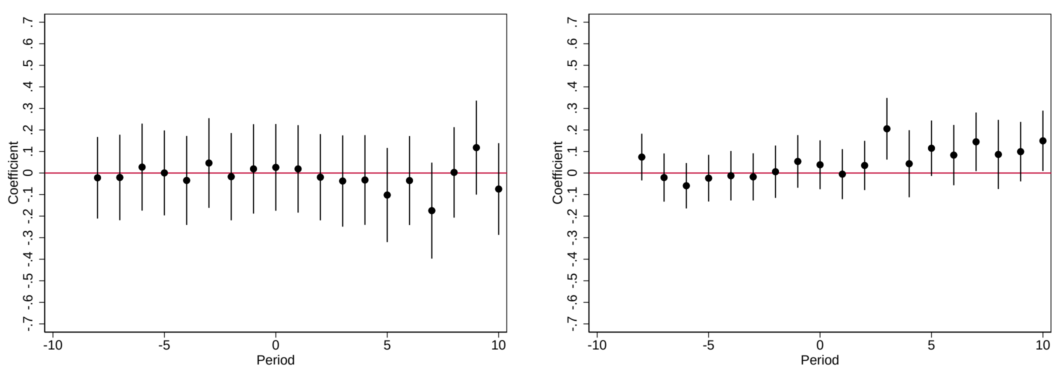
a) High relationship stickiness b) Low relationship stickiness



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.27: China's retaliatory tariffs and US exports to ROW in industries with high and low relationship stickiness: Extensive margin

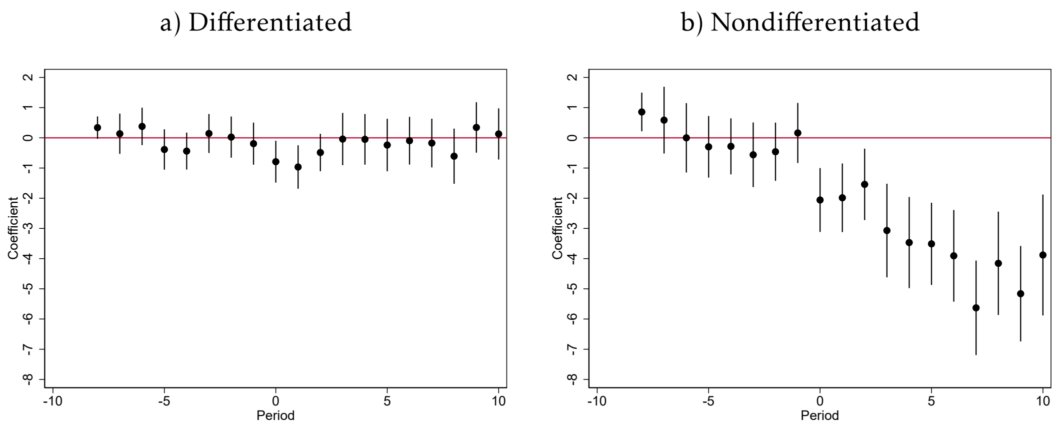
a) High relationship stickiness b) Low relationship stickiness



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.

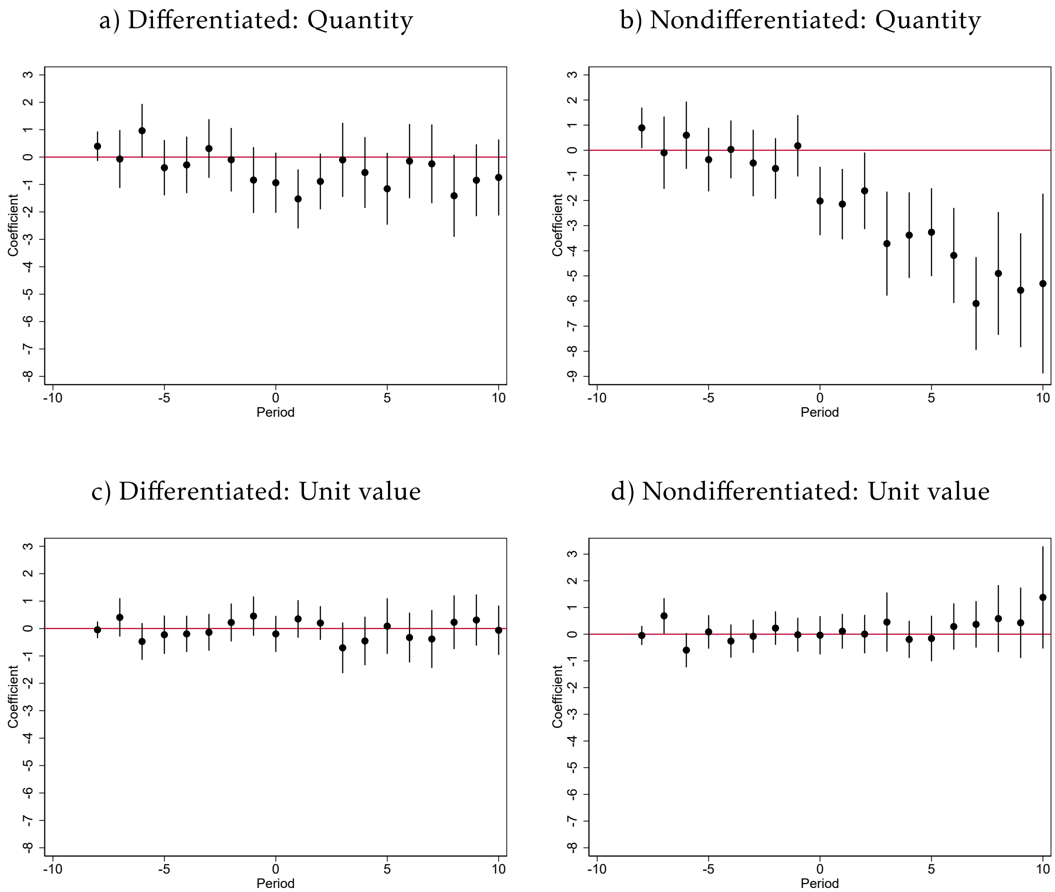
A.4.4 Additional results: Product differentiation

Figure A.28: China's retaliatory tariffs and US exports to China: Product differentiation



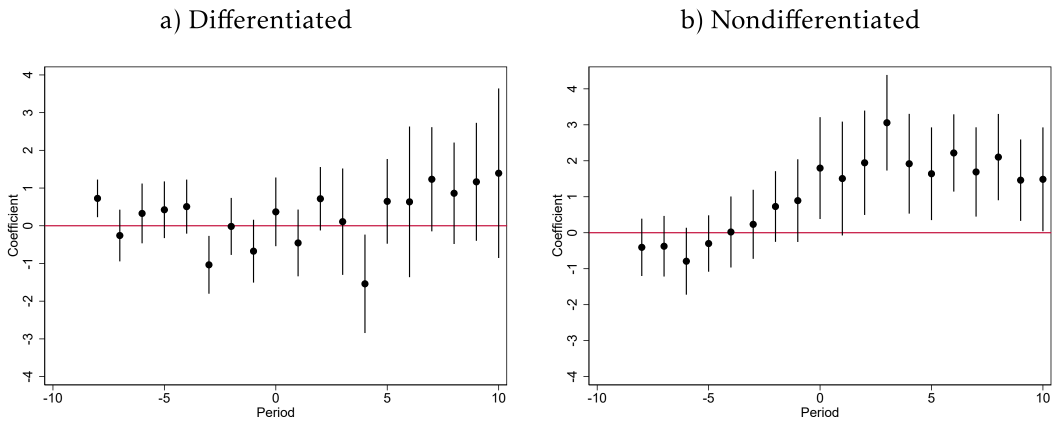
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.29: China's retaliatory tariffs and US exports to China: Product differentiation



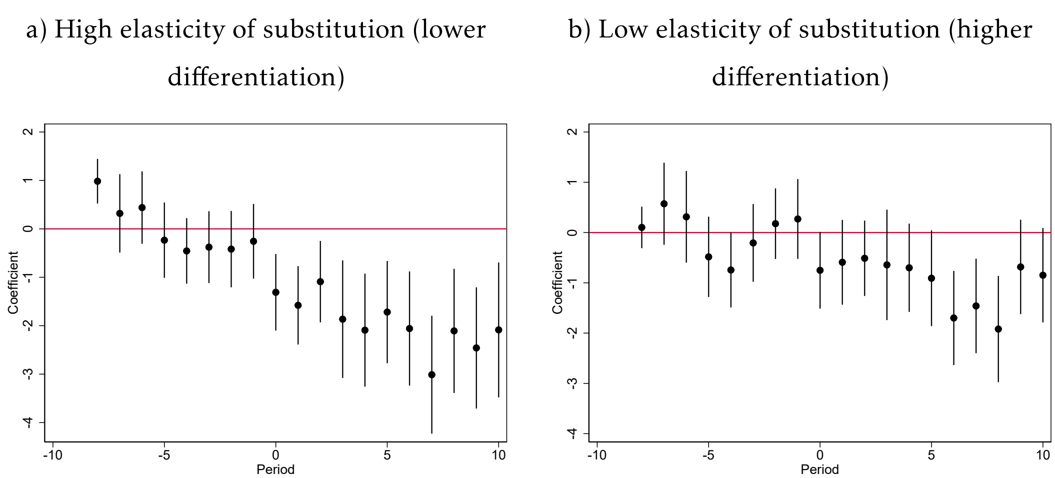
Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.30: China's retaliatory tariffs and US exports to ROW: Product differentiation



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

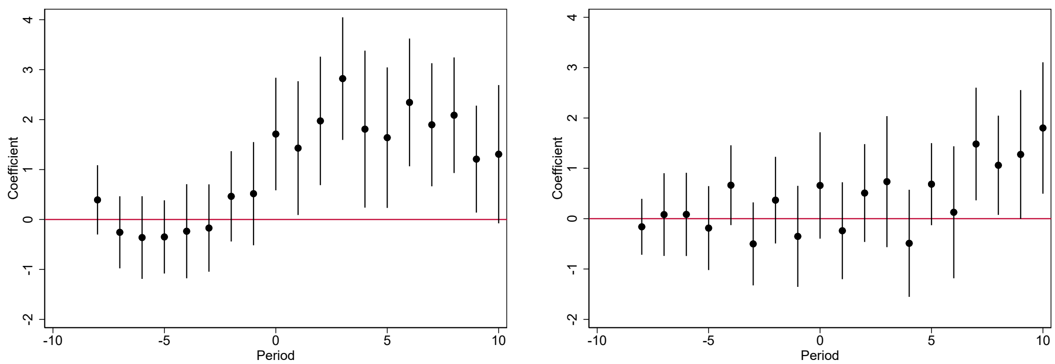
Figure A.31: China's retaliatory tariffs and US exports to China: High vs. low elasticities of substitution



Notes: This figure plots the coefficients obtained from the estimation of equation (9). Vertical bars represent 90% confidence intervals.

Figure A.32: China's retaliatory tariffs and US exports to ROW: High vs. low elasticity of substitution

a) High elasticity of substitution (lower differentiation) b) Low elasticity of substitution (higher differentiation



Notes: This figure plots the coefficients obtained from the estimation of equation (10). Vertical bars represent 90% confidence intervals.