RATIONALITY & COMPETITION

CRC TRR 190

Demand and Supply Side Linkages in Exporting Multiproduct Firms

Carsten Eckel (LMU Munich, CESifo, CEPR)

Lisandra Flach (LMU Munich, ifo Institute, CESifo, CEPR)

Ning Meng (Nanjing University, CESifo)

Discussion Paper No. 456

November 17, 2023

Collaborative Research Center Transregio 190 | www.rationality-and-competition.de

Ludwig-Maximilians-Universität München | Humboldt-Universität zu Berlin

Spokesperson: Prof. Georg Weizsäcker, Ph.D., Humboldt University Berlin, 10117 Berlin, Germany

info@rationality-and-competition.de

Demand and Supply Side Linkages in Exporting Multiproduct Firms*

Carsten Eckel† Lisandra Flach‡ Ning Meng§

16th November 2023

Abstract

Products produced by a multiproduct firm can be linked through demand linkages or supply linkages. On the demand side, changes in the price of one product can affect the demand for a firm's other products through shifts in consumer expenditures. This is commonly referred to as the cannibalization effect. On the supply side, joint inputs can create a dependency of one product's marginal costs on the output of other products. The existence of these linkages is important for how firms respond to shocks and has major implications for several performance measures, such as productivity and markups. This paper provides first empirical evidence for the existence of cannibalization linkages in presence of supply linkages, which is implied evidence for market power.

Keywords: Multiproduct firms, cannibalization effect, demand linkages, supply linkages, anti-dumping tariffs, quality, mark-ups.

JEL Classification: D21, D24, F12, F13, F14, L11, L15, L25.

*The authors received valuable feedback from participants of the Fall 2023 Midwest Economic Theory and International Trade Meetings in Atlanta, ETSG in Ghent, 2022 Göttingen Workshop International Economics, and in research seminars in Aarhus, Kiel, Mannheim, Tübingen, ETH Zurich and at the University of Oregon. Financial support from the Deutsche Forschungsgemeinschaft through SFB/TR190 is gratefully acknowledged.

†LMU Munich, CESifo and CEPR

‡LMU Munich, ifo, CESifo and CEPR

§Nanjing University and CESifo

1 Introduction

Products produced by multiproduct firms are connected, both on the supply side and on the demand side. They are connected on the supply side because the production process typically draws on joint inputs, so that changes in the output of one product affect the shadow prices of these inputs (and hence marginal costs) for the other products. They are connected on the demand side because of the so called "cannibalization effect", i.e. the fact that consumers respond to changes in expenditures on one product by reoptimizing their consumption bundle and adjusting their expenditures on all other products, including other products sold by the same firm. Multiproduct firms internalize these linkages across their product range, so that the size of these linkages affects how these firms adjust to shocks, and how consumer and producer rents respond to these adjustments.

In this paper, we investigate the interaction between these two linkages in a multiproduct firm's response to shocks theoretically and how one can isolate and identify these two linkages empirically. The challenge of identification arises because the two types of linkages are not observable directly and impact observable market outcomes (such as prices, outputs, and sales) in a very similar way. Observing the two types of linkages would require access to confidential details of a company's production process, accounting and pricing behavior, which is in general not available to researchers. Instead, we provide a different avenue for identification: We use firm-product-market specific cost shocks and analyze how these cost shocks propagate through a firm's product portfolio in different markets. This strategy allows us to identify how the various products are connected and whether the connection is on the cost side (supply linkages) or via the cannibalization effect (demand linkages).

Specifically, we use antidumping duties as our cost shocks and analyze how these duties affect not only the products that are targeted by these duties (affected products) but also products that are not targeted (non-affected products). One distinctive feature of antidumping policies that is key for our identification strategy is the fact that they target specific products of a specific exporting firm in a specific destination market without directly affecting other products of the same firm in the same destination or in other destinations. Hence, they are a true firm-product-market specific cost shock. We exploit this fact in our empirical strategy by comparing the response of non-affected products in affected and non-affected destinations, using detailed firm-level data on firm-product-market specific outcomes. This way we can eliminate different channels of adjustment and identify the size of the different types of linkages. Our paper is the first to study the interaction between the two types of linkages in theory and to provide empirical evidence for the existence and the size of the different types of shocks.

Our results are important for three reasons: First, the two types of linkages have similar effects on observable market outcomes of firms, but different impacts on performance measures such as productivity or mark-ups. Thus, it is important to understand how the two types of linkages interact to determine how multiproduct firms respond to shocks and how these shocks affect consumers and producers differently. Second, the cannibalization effect can only be present if firms enjoy market power in their respective product markets. If the firms were too small to affect market aggregates, changes in one product would not affect other products. Hence, the identification of the cannibalization effect in a large manufacturing data set is also implied evidence for the existence and importance of market power. And finally, in the case of policy induced cost changes like antidumping duties, the different types of linkages across products create side effects of these policies that need to be understood in order to determine the policies true impact on both allocation and distribution.

Our paper consists of a theory and an empirical part. In the theory part we study how the two types of linkages affect a firm's price setting behavior and how the firm responds to shocks because of these linkages. We model supply linkages as marginal costs that depend on a firm's aggregate output, so that changes in the output of any individual product affect the marginal costs of all other products within the firm's product range. This notion captures the idea of joint inputs. We model demand linkages by assuming that firms take the price-index effect into account, i.e. they internalize the impact that a change in one product has on the revenues generated by other products. This notion captures the idea of the cannibalization effect. We use the theory to derive predictions regarding the impact of an antidumping duty on export revenues, export quantities and export prices of affected and unaffected products, both in the market with the duty as well as in third markets. For the price results we also discuss how endogenous investments in (perceived) quality may affect prices. In line with our empirical strategy we focus on partial equilibrium adjustments.

In the empirical part, we provide evidence for the two types of linkages using Chinese firm-level customs data combined with data on the universe of antidumping (AD) measures imposed against Chinese firms and products. We focus on Chinese firms due to the presence of many different goods that were subject to antidumping investigations, which provides large variation to evaluate firm responses. In the period under analysis (2000-2015), 902 HS 6-digit product categories were targeted by AD measures in 26 different countries. We investigate the impact of an antidumping duty on sales, quantities and prices of other products that the same multiproduct firm sells in the market with the duty and in third markets.

We then employ a number of fixed effects to control for different types of linkages, comparing targeted and non-targeted firms across products and markets. First of all, we use firm-product-country fixed effects to account for time-invariant heterogeneity. Secondly, we employ product-country-year fixed effects to control for all linkages outside the firm, like changes in competition and general equilibrium effects. The remaining changes are then entirely driven by adjustments within firms. To disentagle demand and supply linkages we apply firm-product-year fixed effects to control for a firm's aggregate output of a product, and hence for supply side linkages. The remaining effect of firm-specific shocks for non-affected products is solely due to the cannibalization effect, allowing us to isolate and identify this effect in the presence of cost linkages.

Literature Our paper is related to several theoretical contributions that investigate the effect of trade liberalization on the international activity of multiproduct firms (Feenstra and Ma, 2007; Eckel and Neary, 2010; Bernard et al., 2011; Dhingra, 2013; Nocke and Yeaple, 2014; Mayer et al., 2014; Hottman et al., 2016). These papers demonstrate that firms react to trade shocks by adjusting their product scope. Such reallocations within the firm have been proven to be significant drivers of increases in firm productivity and welfare gains from trade (Bernard et al., 2011; Mayer et al., 2014). However, with the exception of Feenstra and Ma (2007), Eckel and Neary (2010), Dhingra (2013) and Hottman et al. (2016), most of the theoretical literature in international trade does not account for cannibalization effects within the firm.[1] In contrast to the theory in international trade, demand linkages in multiproduct firms models have received more attention in the field of industrial organization (Brander and Eaton, 1984; Shaked and Sutton, 1990; Eaton and Schmitt, 1994; Johnson and Myatt, 2003; Nocke and Schutz, 2018; Armstrong and Vickers, 2022). We contribute to this literature by providing a theoretical framework and empirical evidence that account for both supply and demand linkages within the firm.

On the empirical front, a growing literature provides evidence on how multiproduct firms respond to shocks. Examples are Bernard et al. (2011), Mayer et al. (2014), Hottman et al. (2016), Flach and Irlacher (2018), Albornoz et al. (2021), Bao et al. (2021), and Macedoni (2022). Closest to our work are Hottman et al. (2016) and Bao et al. (2021). Hottman et al. (2016) develop and structurally estimate a model of multiproduct firms that take demand linkages into account. They decompose the firm-size distribution into contributions of firm appeal (quality or taste), differences in product scope, costs, and markups, and provide evidence for cannibalization.[2] Bao et al. (2021) test different hypothesis regarding within-firm product linkages. They provide evidence of supply linkages, which is consistent with models that account for joint inputs in the production process such that the marginal cost of a product is a function of the joint output of the firm. In contrast to these papers, we provide theory and empirical evidence of cannibalization effects taking supply linkages

[1] Whereas in Feenstra and Ma (2007) and Eckel and Neary (2010) cannibalization arise from strategic competition among oligopolistic firms, Dhingra (2013) introduces intra-brand competition in a monopolistic competition setting.

[2] They argue that, although products supplied by the same firm are more substitutable with each other, it is not correct to assume perfect substitutability between products of the same firm, as the cannibalization rate that they find for the typical firm is about 50%.

into account. Demand linkages have received more attention in the empirical literature in industrial organization (Mason and Milne, 1994; Srinivasan et al., 2005; Haynes et al., 2014). However, these papers provide evidence for a specific product or a case study, whereas we leverage shocks to hundreds of products to provide evidence of cannibalization for the universe of products exported by multiproduct firms.

Our paper also relates to a large literature that investigates product-level responses to AD duties using aggregate data.[3] Several papers show empirical evidence of a reduction in trade flows with the targeted country in response to AD duties (Prusa, 2001; Egger and Nelson, 2011). Regarding third-country effects, the literature shows evidence of trade diversion of imports from targeted countries to imports from non-targeted countries (Konings et al., 2001) and of trade deflection, whereby the targeted exporting country increase exports to third countries (Bown and Crowley, 2007).[4] [5] Taking the global perspective, Vandenbussche and Zanardi (2010) provide evidence of a chilling effect of AD duties and suggest that existing studies underestimate their welfare losses as they do not measure the aggregate trade-depressing effects. We contribute to this literature by focusing the analysis on within-firm product responses to AD duties and for the non-targeted products of the firm.

In response to data availability, more recent studies investigate the effects of AD duties using firm-level data.[6] Whereas most of these studies focus on between-firm effects, we are interested in within-firm responses to AD duties. One exception of a paper that investigates within-firm responses across products and destinations and closest to our work, Bao et al. (2021) use Chinese firm-level data to test different channels through which the product range of a multiproduct firm might show interdependencies. First, for the targeted product, they

[3] Blonigen and Prusa (2016) provide an overview of the anti-dumping literature.

[4] Similar results are shown by Felbermayr and Sandkamp (2020) using Chinese firm-level data. They find that AD duties lead to lower exports and trade deflection to third countries. In addition, they provide evidence of large heterogeneity depending on exporter size and on the targeting country.

[5] Whereas Bown and Crowley (2007) find evidence of trade deflection using Japanese product-level data, a follow-up study using Chinese data (Bown and Crowley, 2010) does not find systematic evidence of deflection but rather weak evidence of a chilling effect on Chinese exports to third countries.

[6] Lu et al. (2013), Jabbour et al. (2019), Felbermayr and Sandkamp (2020), and Meng et al. (2020) are examples of studies using Chinese firm-level data to investigate the effect of AD duties.

provide first evidence of a within-firm chilling effect, meaning that firms increase prices and lower sales in other destinations in response to an AD duty. Second, for the other products of the firms, they show that Chinese firms reduce prices and increase sales of its other products across all markets - they call this effect a within-firm cross-product trade deflection, which is implied evidence of supply linkages within the firm. In our study, we focus the analysis on non-affected products and aim to isolate demand linkages within the firm from the supply linkages that Bao et al. (2021) show in their paper. Our results on supply linkages are in accordance with their results, whereby firms decrease prices and increase sales of the other products in third countries.

The remainder of the paper is structured as follows. Section 2 provides a partial equilibrium setting that accounts for supply and demand linkages and show how multiproduct firms respond to shocks. Section 3 presents the data, empirical strategy, and results. Section 4 concludes.

2 Theoretical Framework: Supply and Demand Linkages in Multiproduct Firms

Let the profits $\pi(j)$ of a multiproduct firm j be given by

$$\pi(j) = \int_{d \in D(j)} \int_{\omega \in \delta_d(j)} \{p_d(j,\omega) - \tau_d(\omega) - C_j[\omega, X(j)]\} x_d(j,\omega) \, d\omega dd. \tag{1}$$

Here, $D(j)$ denotes the set of countries/destinations (indexed by d) firm j is selling to, and $\delta_d(j)$ denotes the set of products (indexed by ω) firm j is selling in destination d. For each product ω in destination d, the firm j charges price $p_d(j,\omega)$ and incurs trade costs (transportation costs plus tariffs and duties) $\tau_d(\omega)$. In addition, the firm faces average variable production costs $C_j[\omega, X(j)]$ for each of their product ω, where

$$X(j) \equiv \int_{d\in D(j)} \int_{\omega\in\delta_d(j)} x_d(j,\omega)\, d\omega dd \tag{2}$$

is aggregate firm output.

We refer to $C_j[\omega, X(j)]$ as average variable costs (AVC) and not as marginal costs because we assume that AVC depend on output of all products, so that marginal costs are also a function of outputs. This implies that one product's AVC depend not only on the output of that product, but on the output of all products produced by the firm. The extent to which a firm's AVC of individual products depend on the outputs of other products produced by the firm will be our measure of supply linkages.

In order to obtain explicit solutions we specify a firm's AVC as

$$C_j[\omega, X(j)] \equiv c_j(\omega) + \gamma X(j), \tag{3}$$

where $c_j(\omega)$ is a constant cost term for each product ω in a firm j's product range, and γ measures the extent (and direction) of supply linkages. If γ is positive, AVC for each product are increasing in aggregate output. If γ is negative, AVC are decreasing in aggregate output.

For each product ω in each destination market d demand is derived from a CES utility function with elasticity of substitution $\sigma > 1$:

$$x_d(\omega) = Y_d P_d^{\sigma-1} p_d(\omega)^{-\sigma}. \tag{4}$$

The CES price index is defined as $P_d^{1-\sigma} \equiv \int_{\omega\in\Omega_d} p_d(\omega)^{1-\sigma} d\omega$, and total expenditures in market d are denoted by Y_d. Products are linked on the demand side because demand for one product depends not only on its own price but also on the price index P_d, and thus on all other products' prices. Since not all products in the price index are produced by only one firm, demand linkages exist both within a firm as well as outside the firm.

When calculating price elasticities of demand, we assume that firms take the price-index effect into account, i.e. $dP_d/dp_d(\omega) > 0$ (Yang and Heijdra, 1993).[7] The own-price elasticity is then given by

$$\frac{d \ln x_d(\omega)}{d \ln p_d(\omega)} = (\sigma - 1) s_d(\omega) - \sigma < 0 \tag{5}$$

and the cross-price elasticity by

$$\frac{d \ln x_d(\omega)}{d \ln p_d(\upsilon)} = (\sigma - 1) s_d(\upsilon) \geq 0, \tag{6}$$

where

$$s_d(\omega) \equiv \frac{p_d(\omega) x_d(\omega)}{Y_d} \in [0, 1) \tag{7}$$

is the share of product ω in consumer expenditures in destination market d.

The expenditure share $s_d(\omega)$ is a key parameter for the existence of demand linkages. If products were "atomless" and the expenditure shares $s_d(\omega)$ were perceived as zero, own-price elasticities would reduce to $-\sigma$ and cross-price elasticities to zero.[8] In this case, a change in the price of one product would have an impact only for the demand of this product, but no impact on the demand for other products.[9] But if these expenditure shares are perceived as positive, cross-price elasticities are also positive. And cross-price elasticities are at the core of demand linkages. If they are positive, products are linked via demand.

One should note that changes in prices of one product will change expenditures of all other products, whether they are produced within the same firm or not. Thus, demand linkages exist both within firms as well as across firms. This poses a challenge for identification of

[7] We assume that the income effect (sometimes also referred to as Ford effect, see d'Aspremont et al, 1996) is ignored, i.e. $dY_d/dp_d(\omega) = 0$. This is in line with our focus on partial equilibrium and reflects our presumption that the income effect is not relevant empirically for the overwhelming majority of industries in global markets. Theoretically, ignoring the income effect can be rationalized by assuming a continuum of sectors (Neary, 2003).

[8] Mathematically, expenditure shares of products sold at positive levels are, of course, always also positive. In models of monopolistic competition, the prevalent assumption is that these expenditure shares are so small that they are neglected by firms, effectively reducing the own-price elasticity to $-\sigma$. This is why we refer to this as the "perceived" expenditure share.

[9] Mathematically, $d \ln P_d/d \ln p_d(\omega) = s_d(\omega)$. Thus, $s_d(\omega) = 0$ implies $d \ln P_d/d \ln p_d(\omega) = 0$, and, hence, no effect of a price change on the demand for other products.

within-firm demand linkages, and we will discuss this extensively below.

Firms maximize profits (1) by choosing prices optimally, taking into account technology (3) and demand (4). The profit maximizing price $p_d(j,\omega)$ of product ω produced by firm j and sold in market d is given by (see appendix)

$$p_d(j,\omega) = \underbrace{[1+\mu_d(j)]}_{\text{markups}} \times \underbrace{[c_j(\omega)+\tau_d(\omega)+2\gamma X(j)]}_{\text{marginal costs}}. \tag{8}$$

Prices are charged at a markup over marginal costs. Marginal costs are given by $c_j(\omega) + \tau_d(\omega) + 2\gamma X(j)$ and are *not* equal to AVC plus trade costs, $c_j(\omega) + \tau_d(\omega) + \gamma X(j)$. If $\gamma > 0$, marginal costs are increasing in output and are consequently larger than average variable costs. In this case, supply linkages tend to raise prices because marginal costs are higher compared to a situation without supply linkages. The opposite holds if $\gamma < 0$. If $\gamma = 0$, marginal costs and average variable costs are identical and independent of output. In this case, there are no supply linkages.

Markups are denoted by $\mu_d(j)$ and are equal to (see appendix)

$$\mu_d(j) = \frac{1}{\sigma-1}\frac{1}{1-s_d(j)}, \tag{9}$$

where

$$s_d(j) \equiv \int_{\omega\in\delta_d(j)} s_d(\omega)\,d\omega \tag{10}$$

denotes the aggregate expenditure shares of all products produced by the firm. This is effectively the market share of firm j in destination market d. Hence, markups of firm j in market d depend on two parameters: The elasticity of substitution between products σ and the market share of this firm in this market, $s_d(j)$. Markups are higher if products are more differentiated (lower σ) or if a firm has a higher market share (higher $s_d(j)$). If firms are "atomless", i.e. if $s_d(j) = 0$, markups reduce to the familiar CES markups, $(\sigma-1)^{-1}$. Since all products enter demand symmetrically, markups are identical across products.

The fact that markups, and hence prices, are higher if the market share of a firm is larger is due to the cannibalization effect. Firms take into account that the products they sell in a particular market are linked via demand and internalize these linkages. Larger expenditure shares imply larger cross-price elasticities (see equ. 6), and thus lower marginal revenues. If a firm reduces the price of one of its products, it redirects demand away from its other products towards the now cheaper product. This is commonly referred to as the cannibalization effect, and it is increasing in the market share of a firm. As a consequence, a firm with larger market shares charges higher markups. Therefore, demand linkages tend to increase prices.

Whether supply and demand linkages affect prices in the same or in opposite directions depends on whether $\gamma \gtreqless 0$. Demand linkages tend to raise prices, and the effect of supply linkages depends on whether marginal costs are increasing or decreasing in outputs. Our empirical evidence below suggests that $\gamma > 0$, so that demand and supply linkages work in the same direction. Based on this evidence presented below, we will also focus on the case of $\gamma > 0$ in the theory part.

2.1 Anti-dumping Duties and Exports

In order to seperate supply and demand linkages we will use a product-country-specific cost shock and study how this cost shock affects sales, quantities and unit values in different markets. In the empirics, we will use antidumping duties levied on Chinese exports for our cost shock. In this section, we will derive predictions regarding the effects of these cost shocks that will help us differentiate between demand and supply linkages. In line with our empirical strategy we will conduct the analysis in partial equilibrium and focus on changes at the intensive margin.

Suppose a foreign country levies a duty on product Δ that increases trade costs for this product to this market. How does this cost shock affect export sales, export quantities and export prices of the various products sold by a firm j that is hit by such a duty? In order to differentiate between the various products and markets we use the following terminology:

- *Affected product in affected market:* A product targeted by a duty in a market where the duty is levied.

- *Non-affected product in affected market:* A product not targeted by a duty but sold in the same market where the duty is levied.

- *Affected product in non-affected market:* A product targeted by a duty in one market, but sold in a market without a duty targeted at this firm.

- *Non-affected product in non-affected market:* A product not targeted by a duty, sold in a market without a duty targeted at this firm, but sold by a firm that has at least one product targeted by a duty in a different market.

Using (9) and taking derivatives of (8) yields

$$\frac{d\ln p_d(j,\omega)}{d\ln\tau_d(\Delta)} = \underbrace{\lambda_d^{\tau}(j,\omega)\,\mathbf{1}_{\Delta}(\omega)}_{\text{direct cost effect}} + \underbrace{\lambda_d^{s}(j)\frac{d\ln s_d(j)}{d\ln\tau_d(\Delta)}}_{\text{markup effect}} + \underbrace{\lambda_d^{X}(j,\omega)\frac{d\ln X(j)}{d\ln\tau_d(\Delta)}}_{\text{marginal cost effect}}, \tag{11}$$

where

$$\begin{aligned}
\lambda_d^{\tau}(j,\omega) &\equiv \frac{\tau_d(\omega)}{c_j(\omega)+\tau_d(\omega)+2\gamma X(j)} \in (0,1), \\
\lambda_d^{s}(j) &\equiv \frac{s_d(j)}{1-s_d(j)}\frac{1}{\sigma-(\sigma-1)s_d(j)} > 0, \\
\lambda_d^{X}(j,\omega) &\equiv \frac{2\gamma X(j)}{c_j(\omega)+\tau_d(\omega)+2\gamma X(j)} \in (0,1).
\end{aligned}$$

The term $\mathbf{1}_{\Delta}(\omega)$ symbolizes an indicator function that is equal to one for the product targeted by the duty ($\omega=\Delta$), and zero for all other products ($\omega\neq\Delta$).

The price effects in (11) can be divided into three effects:

1. The direct cost effect: The duty increases the marginal costs of the product targeted by the duty. This effect is unique to the affected product in the affected market and tends to raise the price of this product.

2. The markup effect: The duty changes expenditure shares of all products, and this leads to changes in an affected firm's market share $s_d(j)$ and it's markups $\mu_d(j)$. This effect is based on demand linkages. Since markups are market-specific, this effect can be different between affected markets and unaffected markets.

3. The marginal cost effect: Changes in duties affect aggregate outputs of firms, leading to changes in marginal costs for affected firms. This effect is based on supply linkages. Since aggregate output is firm-specific and not market-specific, this effect is the same across all markets.

The product targeted by the duty is affected by all three effects, all other products are affected only by the markup effect and the marginal cost effect. Naturally, the markup effect and the marginal cost effect impact each other: Increases in markups lead to higher prices and lower outputs, and increases in outputs lead to higher marginal costs and lower markups.

2.1.1 The Markup Effect and the Marginal Costs Effect

Before we begin with the formal analysis we want to use a graphical illustration of our approach and the problem of seperating the two types of linkages. Figure 1 depicts the optimal price $p_d(j,\omega)$ and quantity $x_d(j,\omega)$ of a non-affected product ω of firm j in an affected country d. The figure shows demand D and marginal revenues MR for product ω as well as marginal costs MC for firm j. Marginal costs are increasing in aggregate output which implies that they are increasing in individual outputs as well. Point 0 marks the original intersection of marginal revenues (MR) with marginal costs (MC), leading to price p_0 and output x_0.

[Figure 1]

Now suppose another product of this firm is hit with an antidumping duty and thus generates lower revenues at higher prices. If we abstract from any changes in income and competition, the demand function D for the non-affected product is unaffected by this change, and this non-affected product can only be affected by this shock through intra-firm linkages.

Let us begin with demand linkages: If products are linked on the demand side, a reduction in revenues by another product leads to upward shift of the MR curve to MR'. This upward shift indicates that marginal revenues for non-affected products have gone up because the firm needs to be worried less about cannibalization: With smaller sales of other products, the negative externality of the cannibalization effect on aggregate revenues is also smaller, and, hence, marginal revenues are higher. This can also be seen from inspecting our markup equation (9): If sales of any product decrease, markups of all products are reduced. The new optimal price p_1 and quantity x_1 are determined by point 1 where MR' and MC intersect. The firm expands its output and reduces the price of a non-affected product in response to a duty on another product in its product range.

The problem with identifying demand linkages is that the exact same change (reduction in price and increase in output) can also be generated by supply linkages. If marginal costs of all products depend on aggregate firm output, the antidumping duty on one of its products reduces aggregate output and this effect lowers marginal production costs for all products, including non-affected products. In our diagram this corresponds to a downward shift of the MC curve to MC'. Without any demand linkages, the marginal revenue curve remains at MR, and point 2 now determines the same outcome (p_1 and x_1) as in the case with demand linkages only. The two cases differ in their effects on markups: Demand linkages lower markups (because a smaller cannibalization effect allows firms to lower markups) whereas supply linkages increase markups (because cost reductions are only partially passed on to consumers). However, this difference is not very useful for empirical identification since markups are typically not observed. If both effects are present, the two effects add up (point 3), leading to even lower prices (p_2) and larger outputs (x_2).

Using (2), (4), (7), (8), (9), and (10), we can solve for changes in outputs, markups, prices, and revenues. Detailed calculations are provided in the appendix. In line with our empirical strategy below we implement two simplifications: First, we impose symmetry across products to focus on the different types of linkages across products and markets. This assumption corresponds to our application of firm-product-country fixed effects in our empirics to control for all time invariant heterogeneity. Second, we hold income Y_d and price indices P_d constant in our comparative static analysis to focus on within-firm adjustments. This assumption corresponds to our application of product-country-year fixed effects in our empirics to control for market linkages outside of firms (competition and general equilibrium). We denote affected markets by $d = a$ and non-affected markets by $d = n$.

We obtain the following lemma:

Lemma 1. *An antidumping duty levied on one product in the affected market leads to a reduction of markups in the affected market, an increase in markups in non-affected markets, and a reduction in aggregate output of the firm.*

Proof. We obtain

$$\frac{d\ln s_a(j)}{d\ln \tau_a(\Delta)} = -(\sigma-1)\left(1-(1-\theta)\frac{X_a(j)}{X(j)}\right)\vartheta\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau < 0 \tag{12}$$

$$\frac{d\ln s_n(j)}{d\ln \tau_a(\Delta)} = (\sigma-1)(1-\theta)\vartheta\frac{x_a(j,\Delta)}{X(j)}\lambda^\tau > 0 \tag{13}$$

$$\frac{d\ln X(j)}{d\ln \tau_a(\Delta)} = -\sigma\theta\vartheta\frac{x_a(j,\Delta)}{X(j)}\lambda^\tau < 0 \tag{14}$$

where $\vartheta \equiv (1+(\sigma-1)\lambda^s)^{-1} \in (0,1)$ and $\theta \equiv \left(1+\vartheta\sigma\lambda^X\right)^{-1} \in (0,1)$. See appendix for calculations. □

The antidumping duty increases marginal costs of selling in the affected market. As a consequence, the firm loses market shares in the affected market $s_a(j)$, and aggregate output $X(j)$ decreases. In the non-affected markets, the reduction in aggregate output reduces marginal costs, so that market shares $s_n(j)$ increase. Since markups are positively correlated with market shares [$d\ln\mu_d(j)/d\ln s_d(j) = s_d(j)/(1-s_d(j)) > 0$ from (9)], markups decrease in affected markets and increase in non-affected markets.

All three effects are proportional to the relative size of the cost shock of the antidumping duty, measured by the share of trade costs in overall costs λ^{τ} and the share of the affected product in the firm's aggregate output in the affected market $x_a(j,\Delta)/X_a(j)$. In addition, all three effects depend on the size of the affected market relative to the firm's aggregate global output $X_a(j)/X(j)$. If the affected market is insignificant relative to global sales, the impact on aggregate global sales, marginal costs and markups in unaffected markets goes to zero, while the impact on markups in affected markets is actually larger.

With our analytical results from lemma 1 we can also address the question how the two types of linkages affect each other. Without supply linkages ($\gamma = 0$), $\lambda^X = 0$ and $\theta = 1$, so that $d\ln s_a(j)/d\ln\tau_a(\Delta)|_{\gamma=0} = -\vartheta\lambda^{\tau}x_a(j,\Delta)/X_a(j)$. This expression is clearly smaller than $d\ln s_a(j)/d\ln\tau_a(\Delta)$ in (12), so that the magnitude of the markup effect is larger without supply linkages. Without demand linkages ($s_a(i,\omega) = 0$), $\lambda^s = 0$ and $\vartheta = 1$, and $d\ln X(j)/d\ln\tau_a(\Delta)|_{s_a(i,\omega)=0} = -\frac{\sigma}{\sigma-1}\theta\lambda^{\tau}x_a(j,\Delta)/X(j)$. Again, this expression is clearly smaller than $d\ln X(j)/d\ln\tau_a(\Delta)$ in (14), indicating that the magnitude of the marginal cost effect is also larger without demand linkages. Hence, both types of linkages tend to reduce each other: Supply linkages lead to falling marginal costs, and this reduction in marginal costs softens the decline in markups due to cannibalization. Demand linkages tend to boost outputs of non-affected products, thereby softening the decline in aggregate output that lowers marginal costs. Both linkages spread the initial shock to more products in more markets, thereby increasing the scope of the shock, but this increase in scope also softens the scale of the shock on individual products.

Given these changes we can now calculate how a firm responds to an antidumping duty on one of its products. We can calculate changes in export prices, quantities and sales for affected and non-affected products in affected and non-affected markets. Technically, we first calculate changes in prices using equation (11) combined with the appropriate subset of equations (12) to (14) for affected and non-affected markets. Changes in quantities and revenues can then be derived using demand (4), keeping in mind that both Y_d and P_d are held constant.

2.1.2 Aggregate Effects on Exports with both Types of Linkages

We begin by calculating aggregate effects when both types of linkages are present. Using (11), (12) and (14) we can calculate the changes in prices of affected and non-affected products in the affected market:

$$\frac{d\ln p_a(j,\Delta)}{d\ln\tau_a(\Delta)} = \left(1-(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)} - \vartheta(1-\theta)\frac{x_a(j,\Delta)}{X(j)}\right)\lambda^\tau > 0, \tag{15}$$

$$\frac{d\ln p_a(j,\omega')}{d\ln\tau_a(\Delta)} = -\left((1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)} + \vartheta(1-\theta)\frac{x_a(j,\Delta)}{X(j)}\right)\lambda^\tau < 0, \tag{16}$$

where ω' represents any product within a firm's product range in the affected market other than Δ: $\omega' \in \delta_d(j)\setminus\Delta$. See appendix for calculations. Since $\theta, \vartheta, \lambda^\tau \in (0,1)$ and $x_a(j,\Delta) < X_a(j) < X(j)$ we obtain the following ranking $-1 < \frac{d\ln p_a(j,\omega')}{d\ln\tau_a(\Delta)} < 0 < \frac{d\ln p_a(j,\Delta)}{d\ln\tau_a(\Delta)} < 1$.

We know from (12) and (14) that affected firms experience both a reduction in market shares in the affected market as well as a reduction in aggregate output. This leads to lower markups and lower marginal costs in the affected market. Therefore, both the markup effect and the marginal cost effect push prices down. Hence, the prices of non-affected products clearly fall, since they are entirely determined by these two effects. In contrast, the price of the affected product is also hit by a direct cost effect: Since the antidumping duty is levied (by definition) on the affected product, this product experiences a direct increase in its trade costs and, thus, its marginal export costs. Quantitatively, this effect is given by λ^τ (the trade cost share in marginal costs), and it dominates the two other effects for the affected product. Consequently, the price of the affected product rises.

For affected products we also have to differentiate between consumer prices in the destination market and mill prices, or *fob* prices, without trade costs. Consumer prices (including trade costs) increase as shown, but *fob* prices are not subject to the direct cost effect. They are still affected by the markup effect and the marginal cost effect, so that the change in *fob* prices for affected products is the same as the change in prices for non-affected products: They fall.

Let us now turn to changes in prices of non-affected products in non-affected (third) markets. Using (11), (13) and (14) we obtain the following result:

$$\frac{d \ln p_n (j, \omega)}{d \ln \tau_a (\Delta)} = -\vartheta (1 - \theta) \frac{x_a (j, \Delta)}{X (j)} \lambda^\tau < 0. \tag{17}$$

Again, since $\theta, \vartheta, \lambda^\tau \in (0, 1)$ and $x_a (j, \Delta) < X (j)$ the value of this relative change is between zero and one: $\frac{d \ln p_n (j,\omega)}{d \ln \tau_a (\Delta)} \in (-1, 0)$.

There are no demand linkages across markets, so the driving force behind the price change in non-affected markets is the marginal cost effect. Since aggregate firm output falls when a duty is levied on one of its products (see equ. 14), marginal costs for all products in all markets fall. The reduction in marginal costs leads to lower prices (17) and allows the firm to increase its market shares in non-affected markets (see equ. 13). This, in turn, leads to an increase in markups. As a consequence, the reduction in marginal costs is only partly passed on to consumers.

The fact that the markup effect works against the marginal cost effect in non-affected markets while both work in the same direction in affected markets suggests that the effect on prices is also smaller in non-affected markets:

$$\left| \frac{d \ln p_a (j, \omega')}{d \ln \tau_a (\Delta)} \right| - \left| \frac{d \ln p_n (j, \omega)}{d \ln \tau_a (\Delta)} \right| = (1 - \vartheta) \frac{x_a (j, \Delta)}{X_a (j)} \lambda^\tau > 0 \tag{18}$$

The full ranking of price effects then becomes:

$$-1 < \frac{d \ln p_a (j, \omega')}{d \ln \tau_a (\Delta)} < \frac{d \ln p_n (j, \omega)}{d \ln \tau_a (\Delta)} < 0 < \frac{d \ln p_a (j, \Delta)}{d \ln \tau_a (\Delta)} < 1 \tag{19}$$

The following proposition summarizes our results on prices:

Proposition 1. *In the affected market, prices of affected products* $p_a (j, \Delta)$ *rise and prices of* *non-affected products* $p_a(j,\omega\prime)$ *fall in response to an antidumping duty on the affected product* $\omega = \Delta$. *FOB prices of affected products in affected markets fall. In non-affected markets, prices of non-affected products fall as well, but the magnitude of the decrease is smaller in non-affected markets than in affected markets.*

Proof. See appendix. □

Having established the responses of prices, we can use demand (4) to calculate changes in export quantities $x_d(j,\omega) = \Upsilon p_d(j,\omega)^{-\sigma}$ and export sales $r_d(j,\omega) \equiv p_d(j,\omega)\, x_d(j,\omega) = \Upsilon p_d(j,\omega)^{1-\sigma}$ (keeping in mind that $\Upsilon \equiv Y_d P_d^{\sigma-1}$ is kept constant).

$$\frac{d\ln x_d(j,\omega)}{d\ln\tau_a(\Delta)} = -\sigma\frac{d\ln p_d(j,\omega)}{d\ln\tau_a(\Delta)} \qquad \frac{d\ln r_d(j,\omega)}{d\ln\tau_a(\Delta)} = -(\sigma-1)\frac{d\ln p_d(j,\omega)}{d\ln\tau_a(\Delta)} \tag{20}$$

These calculations are identical for all affected and non-affected products in affected and non-affected markets. Qualitatively, quantities and sales respond inversely to changes in prices since their derivatives have the opposite signs. Quantitatively, assuming that $\sigma > 2$, we can establish the following ranking:

$$\frac{d\ln x_d(j,\omega)}{d\ln\tau_a(\Delta)} > \frac{d\ln r_d(j,\omega)}{d\ln\tau_a(\Delta)} > \left|\frac{d\ln p_d(j,\omega)}{d\ln\tau_a(\Delta)}\right| \tag{21}$$

Based on (20) and (21) we can present the following corollary:

Corollary 1. *In all markets and for all goods, quantities and sales respond inversely to changes in the respective prices. The magnitude of the change in quantities is largest, the change in sales second largest, and in prices smallest.*

2.1.3 Isolating Demand Linkages

As we have seen in the previous subsection, the markup effect and the marginal cost effect impact prices in affected markets in the same way: Both effects lower prices. This makes it impossible to distinguish between the two types of linkages based on observables. In this section, we want to switch off supply side linkages in order to isolate the effect of demand side linkages. In our empirics, we control for firm output by using firm-product-year fixed effects. For our theory, this implies that we hold aggregate firm output fixed. Therefore, in this subsection, we calculate the response to the antidumping duty when $d \ln X = 0$.

Calculating changes in market shares and markups in affected and unaffected markets we obtain:

$$\left.\frac{d \ln s_a(j)}{d \ln \tau_a(\Delta)}\right|_{\bar{X}} = -(\sigma - 1)\vartheta \frac{x_a(j,\Delta)}{X_a(j)} \lambda^{\tau} < 0, \tag{22}$$

$$\left.\frac{d \ln s_n(j)}{d \ln \tau_a(\Delta)}\right|_{\bar{X}} = 0, \tag{23}$$

where the subscript $\bar{X}$ indicates that aggregate firm output is held constant.

First, without supply side linkages, there are no spillovers of the duty into non-affected markets. Since demand linkages are limited by definition to the affected market, and supply side linkages are switched off in this scenario, market shares $s_n(j)$ [and markups $\mu_n(j)$] in non-affected markets remain unchanged. Second, despite the fact that supply side linkages are switched off, market shares in the affected market $s_a(j)$ [and markups $\mu_a(j)$] are still falling. This is now entirely due to demand side linkages.

Turning to prices, price changes of unaffected products are now entirely determined by the markup effect alone:

$$\left.\frac{d \ln p_a(j,\omega\prime)}{d \ln \tau_a(\Delta)}\right|_{\bar{X}} = -(1 - \vartheta) \frac{x_a(j,\Delta)}{X_a(j)} \lambda^{\tau} < 0 \tag{24}$$

$$\left.\frac{d \ln p_n(j,\omega)}{d \ln \tau_a(\Delta)}\right|_{\bar{X}} = 0 \tag{25}$$

Again, we see from (24) that without supply side linkages, outcomes in non-affected markets remain unchanged. In affected markets, however, prices of non-affected products fall (see equ. (25)). These prices fall despite the fact that income Y_a, the price index P_a, and aggregate firm output X (and hence marginal costs) remain unchanged. Hence, neither competition, nor general equilibrium effects, nor linkages on the supply side can be responsible for these changes in prices. They are entirely determined by demand side linkages.

By comparing (24) to (16) we see that the magnitude of the aggregate effect of both types of linkages on prices is clearly larger than the effect of demand linkages alone. In fact, since equation (16) shows the price changes in the presence of both types of linkages, and equation (24) shows the price changes only for demand side linkages, the difference between the two gives the price changes for supply side linkages:

$$\frac{d\ln p_a(j,\omega\prime)}{d\ln\tau_a(\Delta)} - \left.\frac{d\ln p_a(j,\omega\prime)}{d\ln\tau_a(\Delta)}\right|_{\bar{X}} = -\vartheta(1-\theta)\frac{x_a(j,\Delta)}{X(j)}\lambda^{\tau} < 0 \tag{26}$$

This underlines our argument from above: The aggregate effect is the sum of the effects of the two types of linkages, and both affect prices in the same direction.

Finally, we can also see that the magnitude of the demand linkage effect depends positively on the elasticity of substitution σ. Since $\vartheta = (1 + (\sigma - 1)\lambda^s)^{-1}$, the value of $d\ln p_a(j,\omega\prime)/d\ln\tau_a(\Delta)|_{\bar{X}}$ in (24) is increasing in σ. This is not surprising, since demand linkages only exist if products are substitutable, and they are stronger if products are strong substitutes:

Corollary 2. *The magnitude of demand linkages is increasing in the elasticity of substitution between products.*

2.2 Observed Prices and Quality-adjusted Prices

In the previous section we assumed that demand was entirely based on observed prices and not on any other product characteristics. In this chapter, we want to introduce (perceived) quality as an additional characteristic that matters for consumers. One implication of this additional assumption is that we need to differentiate between observed prices and quality-adjusted, or effective, prices. This differentiation will allow us to discuss differences in the responses of observed prices and effective prices that matter in the empirics. Another implication is that we need to model how firms determine what quality to offer, and how their choice of quality is affected by antidumping duties.

The new utility function is

$$U_d \equiv \left(\int_{\omega \in \Omega_d} \left[q_d(\omega) x_d(\omega) \right]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}, \tag{27}$$

where $q_d(\omega)$ represents the (perceived) quality of product ω in market d. We model the demand for quality using a "box-size" formulation where consumers only care about $q_d(\omega) x_d(\omega) \equiv x_d^e(\omega)$, where $x_d^e(\omega)$ represents the effective quantity consumed (in units of quality), and quantity and quality are essentially perfect substitutes in the eyes of consumers (Baldwin and Harrigan, 2011; Kugler and Verhoogen, 2012). Demand (4) now becomes

$$x_d^e(\omega) = p_d^e(\omega)^{-\sigma} \left(P_d^e\right)^{\sigma-1} Y_d, \tag{28}$$

where $p_d^e(\omega) \equiv p_d(\omega)/q_d(\omega)$ is the effective price and $P_d^e \equiv \left(\int_{\omega \in \Omega_d} p_d^e(\omega)^{1-\sigma} d\omega \right)^{1/(1-\sigma)}$ is the index of effective prices. In non-effective terms, the own-quality elasticity and the cross-quality elasticity of demand are $d \ln x_d(j,\omega) / d \ln q_d(j,\omega) = (\sigma - 1)(1 - s_d(j,\omega)) > 0$ and $d \ln x_d(j,\omega) / d \ln q_d(j,\upsilon) = -(\sigma - 1) s_d(j,\upsilon) < 0$. Intuitively, quality is a demand shifter: If a product's quality increases, this product's residual demand goes up, while the residual demand for all other products go down.

We rewrite firm profit as

$$\pi(j) = \int_{d \in D(j)} \int_{\omega \in \delta_d(j)} \left[\left\{ p_d^e(j,\omega) - \tau_d(\omega) - c_j(\omega) - \gamma X^e(j) \right\} x_d^e(j,\omega) - k_d(j,\omega) \right] d\omega dd, \tag{29}$$

where $X^e(j) \equiv \int_{d \in D(j)} \int_{\omega \in \delta_d(j)} x_d^e(j,\omega) \, d\omega dd$ represents effective aggregate firm output, and $k_d(j,\omega)$ represents firm j's expenditures on the quality of product ω in market d.

The variable profits part in (29) is just an expansion of (1) to express revenues and variable costs as a function of effective prices and quantities, $p_d^e(j,\omega)$ and $x_d^e(j,\omega)$. The term $k_d(j,\omega)$ is new and represents a firms expenditure for quality. We assume that firms can invest into the quality of their individual products, and that the effectiveness of their investment is given by the following functional form:

$$q_d(j,\omega) = [\chi k_d(j,\omega)]^{\frac{1}{\chi}}. \tag{30}$$

The parameter $\chi > 0$ measures the inverse elasticity of quality with respect to investments in quality: $\partial \ln q_d(j,\omega) / \partial \ln k_d(j,\omega) = 1/\chi$.

There are two issues we want to point out with respect to the suppy of quality: First, we assume that a higher quality product does not require higher variable production costs $c_j(\omega)$. Hence, our concept of quality is not related to the usage of higher quality inputs, or a more sophisticated production process. Instead, higher quality requires higher market-specific fixed costs $k_d(j,\omega)$. These can be thought of as costs related to marketing, design or packaging. Hence, we refer to quality as "perceived" quality (Eckel et al., 2015). Second, marginal production costs are increasing in *effective* output. The term $\gamma X^e(j)$ in (29) captures the notion that marginal production costs depend on the aggregate effective output of the firm.

In this new environment, firms choose effective prices $p_d^e(j,\omega)$ and quality levels $q_d(j,\omega)$ to maximize profits. Since variable profits and the structure of demand are essentially unchanged, the first order condition for effective prices is a straightforward adaptation of (8) in effective units:

$$p_d^e(j,\omega) = \frac{\sigma}{\sigma-1}\left(1 + \frac{s_d(j)}{\sigma(1-s_d(j))}\right)(c_j(\omega) + \tau_d(\omega) + 2\gamma X^e(j)). \tag{31}$$

The first order condition for quality reflects the fact that firms trade off higher fixed costs $k_d(j,\omega)$ against higher revenues associated with higher quality. The profit-maximizing quality is then given by (see appendix)

$$q_d(j,\omega) = r_d(j,\omega)^{\frac{1}{\chi}}. \tag{32}$$

Clearly, optimal quality is increasing in sales because the gains from quality upgrades are increasing in sales but the fixed costs are not. This implies that if an antidumping duty reduces the sales of the affected producted and increases the sales of unaffected products, expenditures on quality are reduced for affected products and increased for unaffected products. To better compare our results with the results in the previous subsection we focus on the demand side linkages and hold aggregate effective output fixed ($X^e = \bar{X}^e$):

$$\left.\frac{d\ln q_a(j,\Delta)}{d\ln\tau_a(\Delta)}\right|_{\bar{X}^e} = -\frac{\sigma-1}{\chi}\left(1-(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\right)\lambda^\tau < 0 \tag{33}$$

$$\left.\frac{d\ln q_a(j,\omega\prime)}{d\ln\tau_a(\Delta)}\right|_{\bar{X}^e} = \frac{\sigma-1}{\chi}(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau > 0 \tag{34}$$

Clearly, the extent of the quality adjustments depend on the parameter χ. If χ is high, investment in quality is less effective, and quality investments are thus more expensive. As a consequence, firms adjust quality less (and vice versa).

With quality determined endogenously, we can now differentiate between the response of observed prices p_d and effective prices p^e_d. For unaffected products we obtain

$$\left.\frac{d\ln p^e_a(j,\omega\prime)}{d\ln\tau_a(\Delta)}\right|_{\bar{X}^e} = -(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau < 0 \tag{35}$$

$$\left.\frac{d\ln p_a(j,\omega\prime)}{d\ln\tau_a(\Delta)}\right|_{\bar{X}^e} = \left(\frac{\sigma-1}{\chi}-1\right)(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau \gtreqless 0 \tag{36}$$

The response of *effective* prices $p^e_a(j,\omega\prime)$ is clearly negative and corresponds one-to-one to our result in (24). The response of *observed* prices $p_a(j,\omega\prime)$, however, is now ambiguous. The negative effect of the cannibalization effect is counteracted by the positive effect of the boost in quality. Whether the quality effect or the cannibalization effect dominates depends on the responsiveness of quality, and thus on the parameter χ. Observed prices of unaffected products can actually increase in response to an antidumping duty if

$$\chi < \sigma - 1. \tag{37}$$

This result shows that quality investments drive a wedge between observed prices and effective prices, and that this wedge can be large enough so that observed prices of unaffected products can actually be positively correlated with demand. Generally speaking, if one product is hit by an antidumping duty, the cannibalization effect induces firms to lower their effective prices on unaffected products to expand their revenues. But lowering effective prices can be achieved through two measures: Lowering observed prices or increasing investments in perceived quality. Which one of these two measures firms choose depends on our parameter χ relative to $\sigma - 1$.[10] If condition (37) holds, firms respond primarily by investing in quality. As a result, observed prices of unaffected products go up (because their residual demand is shifted outwards by the quality investment), while effective prices are pushed down by the increase in quality.

This leads to the question of what determines the parameter χ. If χ is an exogenous (technological) parameter, condition (37) implies that the quality effect dominates (and observed prices rise) if the products are close substitutes (high σ). However, Eckel et al. (2015) argue that the responsiveness of perceived quality to product-specific investments in quality (the inverse of our χ) is in fact a negative function of the elasticity of substitution.[11] The idea behind this argument is that if products are very close substitutes, the perceived quality of products within a firm's (umbrella) brand is shaped primarily by the quality of the firm's brand itself, and not so much by the quality of individual products, whereas if products are only weak substitutes, the quality of the brand plays a lower role in consumers' perception of quality, and the quality of individual products becomes more important. Mathematically, this implies that $\chi = \chi(\sigma)$ with $\chi'(\sigma) > 0$. In this case, it is possible that the relation between $d \ln p_a(j, \omega\prime) / d \ln \tau_a(\Delta)$ and σ is reversed if $\chi'(\sigma)$ is sufficiently large: If $\partial \ln \chi / \partial \ln \sigma > \sigma / (\sigma - 1)$, then $d \ln p_a(j, \omega\prime) / d \ln \tau_a(\Delta)$ is decreasing in σ, and observed prices can rise when products are only weak substitutes, and fall when they are close substitutes.

[10] By differentiating (32) we obtain $\left|\frac{d \ln q_a(j,\omega\prime)}{d \ln \tau_a(\Delta)}\right| / \left|\frac{d \ln p_a^e(j,\omega\prime)}{d \ln \tau_a(\Delta)}\right| = \frac{\sigma - 1}{\chi}$.

[11] See Eckel et al. (2015), section 2.3 and the literature cited there.

To illustrate this latter point assume that $\chi = \frac{1}{\zeta}(\sigma^2 - 1)$, $\zeta > 0$. Then,

$$\frac{d \ln p_a(j, \omega\prime)}{d \ln \tau_a(\Delta)} = (\zeta - 1 - \sigma) \frac{1 - \vartheta}{\sigma + 1} \frac{x_a(j, \Delta)}{X_a(j)} \lambda^\tau, \tag{38}$$

and $\frac{d \ln p_a(j,\omega\prime)}{d \ln \tau_a(\Delta)} > 0$ if $\sigma < \zeta - 1$ and $\frac{d \ln p_a(j,\omega\prime)}{d \ln \tau_a(\Delta)} < 0$ if $\sigma > \zeta - 1$.

The following proposition summarizes the results of this section:

Proposition 2. *(i) The (perceived) quality of unaffected products in affected markets goes up in response to an antidumping duty, and observed prices of unaffected products can increase. (ii) Whether observed prices rise depends on the elasticity of substitution between products.*

3 Empirical Analysis: Isolating demand and supply linkages

Our goal in the empirical part of the paper is to test the predictions from the model regarding supply and demand linkages in response to AD duties that affect one particular product of a multiproduct exporter. In contrast to most of the antidumping literature, our interest lies in examining the responses of non-affected products of the firm, in affected and non-affected markets (rather than focusing on the affected product of the firm). The comparison group refers to other multiproduct firms that did not have any products affected by an antidumping (AD) duty but export non-affected products. To evaluate firm-product responses to AD duties, we combine Chinese customs data with data on the universe of AD duties imposed against Chinese exporters.

AD duties have been commonly used as instruments of trade policy in the past two decades, in particular against Chinese firms: between 2000 and 2015, roughly 26% of all AD investigations worldwide were conducted against China. The US and the EU alone initiated 209 investigations in this period against Chinese exporters, which corresponds to 22% of the investigations against Chinese firms.

For our specific research question, one important advantage of AD duties over other types of trade policies is their firm-specific nature: AD duties are imposed on products of specific firms that are found to be engaging in "unfair" trade practices, implying that these duties are not only product specific but firm-product specific. Furthermore, there are two additional advantages of using AD data to evaluate demand and supply linkages at the firm-level. First, investigations often hit an important product of a firm and the likelihood of AD duties increases with the value of imports (Bown and Crowley, 2013). Thus, these AD duties are quantitatively important for these exporting firms. Second, an AD duty hits one but not all products of the firm, it hits one but not all destination markets of the firm, and it might hit some but not all firms exporting a specific product. This unique characteristic of AD duties enables us to eliminate other competing channels and to isolate demand linkages, as we outline in our empirical strategy.

3.1 Data

To test the main predictions of the model, we combine firm-level customs data for the universe of Chinese exporters with data on all antidumping measures imposed against Chinese firms between the years 2000 and 2015.

Firm-level data The Chinese Customs Database (CCD) contain values and quantities exported by all Chinese exporters by product (Harmonized System, HS 8-digit) and destination country. We aggregate monthly transactions to annual values to achieve a standard four-dimensional customs data by firm, HS 8-digit product, destination country, and year. We exclude from the sample firms related to processing trade or commercial intermediaries, which do not produce the products. This is possible by matching customs data with Chinese firm census, which contains additional firm characteristics.

Antidumping data The Global Antidumping Database (GAD) created by Chad Bown and maintained by the World Bank (Bown, 2012) include information on all AD cases imposed against China by all trading partners. This is a detailed database that contains, by AD case, information such as the HS product category affected, the names of the firms subject to the AD investigation, and the AD measure imposed (ad valorem duty, specific duty, price undertaking, or suspension agreement). In the context of Chinese exports, the AD data have already been exploited in the literature by Meng et al. (2020), Felbermayr and Sandkamp (2020), Lu et al. (2013), among others. In section 3.3, we describe in more detail how we match firms to an AD case using firm names. In the period under analysis, the dataset includes AD duties imposed by 25 importing countries against Chinese firms.[12] We follow Crowley et al. (2018) and include information on all AD cases at the HS product level by all 25 importing countries against China under the WTO's agreement on antidumping.[13]

One important advantage of using Chinese data for our research question, in comparison to data for other countries, is the large product coverage and the presence of many differentiated goods that were subject to AD investigations. During the period 2000-2015, 902 HS 6-digit and 339 HS 4-digit product categories were targeted by AD measures, which provides large variation to evaluate firm responses.[14] As reported in Table 1, the top sectors (HS 2-digit) affected by AD measures include chemicals, iron and steel, and machinery. This is in contrast to other countries like Brazil, where a significant share of the products undergoing AD investigations belong to the agricultural sector - in this case, the low degree of product differentiation likely imply weak demand linkages.

[12] The AD duties imposed by the European Union are the same for all 28 EU countries and hence we treat the EU as a single market.

[13] Different from Crowley et al. (2018), we do not aggregate the firm-level data across destinations, as sales across destinations help identify supply linkages within the firm. We exploit firm reactions to AD duties imposed by one destination market on sales in other destination markets of exports.

[14] These are only cases that received a final AD duty. AD duties can be at the HS6, HS8 or HS10 (US only) digit level. As products are comparable only at the HS6 digit level (Lu et al., 2013; Bown and Crowley, 2016), we match the two datasets at this level of aggregation.

Table 1: Top sectors subject to AD measures against China during 2000-2015

HS code	Sector	No. of cases	Percent
28	Inorganic chemicals	52	6.74
29	Organic chemicals	77	9.97
38	Chemical products	16	2.07
39	Plastics and articles thereof	34	4.40
40	Rubber and articles thereof	23	2.98
54	Man-made filaments	17	2.20
55	Man-made staple fibres	16	2.07
69	Ceramic products	22	2.85
70	Glass and glassware	24	3.11
72	Iron and steel	53	6.87
73	Iron or steel articles	97	12.56
84	Machinery and mechanical appliances	37	4.79
85	Electrical machinery and equipment	46	5.96
87	Vehicles	16	2.07
Total	–	530	68.64

3.2 Firm-level analysis of non-affected products: demand and supply linkages within the firm

We evaluate responses of multiproduct firms to firm-product-destination-specific shocks that hit one but not all products of the firm in a destination market. The demand and supply linkages that we aim to identify are within-firm linkages specific to multiproduct firms.

To investigate demand and supply linkages of multiproduct firms, we evaluate outcomes of *non-affected products* of the firm in response to antidumping duties. Consider a destination country c that imposed an AD duty on product p of firm f in year $t-1$. Because we are interested in the reaction of the other (non-affected) products of the firm, we drop all products p from the sample that were subject to antidumping investigations. We estimate the following regression:

$$\log y_{fpct} = \beta_1 AD_{fct-1} + \beta_2 NADF_{fct-1} + \rho_{fpc} + \upsilon_{pct} + \mu_{fpt} + \varepsilon_{fpct}, \tag{39}$$

where y_{fpct} refers to the value of exports, quantity or unit value of product p exported to destination c by firm f in year t. AD_{fct-1} is an indicator variable that equals 1 for the "AD-firm" (affected firm), meaning a firm f that had a product subject to an AD duty imposed by country c in year $t-1$. $AD_{fct-1} = 0$ for firms that did not have any products affected by an AD duty and export the same HS products of the "AD-firm". $NADF_{fct-1}$ is an indicator variable that equals 1 for exports of the "AD-firm" f in *non-affected destinations* c (i.e. countries that did not impose antidumping duties).

We control for interacted firm-product-destination country fixed effects ρ_{fpc} to account for time-invariant heterogeneity, product-country-year fixed effects υ_{pct} to account for demand linkages outside the firm in the destination country, such as changes in income, product market competition or other general equilibrium effects,[15] and firm-product-year fixed effects μ_{fpt} to account for supply linkages within the firm.

Demand linkages: In the absence of demand and supply linkages, the estimated coefficient β_1 should not be identified when accounting for the aforementioned fixed effects, as nothing changed for the other products of the firm in the destination country that imposed the AD duty. However, as shown in the model, in the presence of demand linkages, $\beta_1 > 0$ for y_{fpct} being the value or quantity of exports. A decrease in exports of the affected product (in response to the AD duty) implies a lower degree of cannibalization between the products of the firm. This leads to an increase in demand for other (similar) products of the firm, as consumers adjust their expenditure share. Hence, $\beta_1 > 0$, as exports of the non-affected product increase in the country that imposed the duty.

Supply linkages: Demand linkages are only present in the country that imposed AD duties, whereas supply linkages within the firm are not restricted to one market. Hence both coefficients β_1 and β_2 would be identified in the presence of supply linkages. As shown by the model, the direction of supply linkages (γ) can go in both directions. For $\gamma > 0$, marginal costs decrease for all products in all markets when the affected product is sold at lower quantities in the affected market, which leads to lower prices and an increase in sales for all products in non-affected markets.

Exports of the affected firm in non-affected markets ($NADF_{fct-1}$), captured by β_2, reflect

[15] Product-country-year fixed effects are also important to account for a potential correlation between AD duties and trade liberalization. For instance, Moore and Zanardi (2009, 2011) find evidence of a correlation between the use of antidumping and trade liberalization in general. Consequently, if AD duties correlate with tariffs, this could contribute to omitted variable bias. In our baseline firm-level regression, tariffs are controlled for through country-product-time fixed effects. We come back to this issue when we conduct an event study as a robustness check.

only supply linkages. In the presence of demand and supply linkages (and for $\gamma > 0$), $\beta_2 > 0$ and β_1 should be larger than in the case with only demand linkages, as both linkages tend to increase exports and decrease prices. To shut-down supply linkages and isolate demand linkages, we include μ_{fpt} fixed effects.

In Table 2, we estimate eq. 39 and isolate demand linkages by including μ_{fpt} fixed effects. This implies that we no longer identify the coefficient $NADF_{fct-1}$. Table 2 provides first indicative evidence of the presence of demand linkages: firms react to AD duties by increasing the value of exports and quantities of non-affected products in the affected destinations, as shown by the positive coefficients on values and quantities. However, in contrast to our model, prices also increase. We will return to this puzzling effect later in the paper (sections 3.3 and 3.4), when we introduce effective prices and provide an explanation for the price puzzle.

Table 2: Demand linkages: Effect of AD duties on **non-affected products**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0260***	0.0200**	0.00600**
	(0.00806)	(0.00836)	(0.00305)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	2,393,983	2,393,983	2,393,983
R-squared	0.908	0.943	0.983

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

When firm-product-year fixed effects (μ_{fpt}) are excluded from eq. 39, β_1 becomes larger in magnitude and we also identify a positive β_2 in the non-affected market (NAD_{fct-1}), which indicates that $\gamma > 0$ in the model. Supply linkages may occur in the presence of joint inputs, for instance, which creates a positive dependency of all products' marginal cost on the output of any individual product of the firm. In this particular case here, sales of the affected product decrease in response to an AD duty so that marginal costs of all products go down, and non-affected products expand. Within-firm supply linkages have implications for sales both in the affected and non-affected market. Results are shown in Table 3.

Table 3: Demand and supply linkages: Effect of AD duties on **non-affected products in affected and non-affected markets**

	$\log(\text{value}_{fpct})$	$\log(\text{quantity}_{fpct})$	$\log(\text{unit value}_{fpct})$
AD_{fct-1}	0.0405***	0.0378***	0.00271
	(0.00585)	(0.00595)	(0.00207)
NAD_{fct-1}	0.0172*	0.0200*	-0.00281
	(0.0104)	(0.0110)	(0.00345)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	2,393,983	2,393,983	2,393,983
R-squared	0.854	0.910	0.972

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Product similarity: According to our corollary 2, the magnitude of demand linkages depends positively on the elasticity of substitution between products. To further examine the role of the elasticity of substitution, we add an interaction term to AD_{fct-1} in eq. 39, which considers the proximity of the affected product to other products of the firm. Specifically, we include a dummy variable $HS4 = 1$ for non-affected products within the same 4-digit category as the affected product. The idea behind this approach is that products within the same HS4 category exhibit a higher elasticity of substitution than products outside.

As shown in Table 4 by the interaction term AD_{fct-1}*HS4, the demand linkages depicted in Table 2 are captured by products within the same HS 4-digit category. Also in this case, the price effect remains puzzling; we provide an explanation to the price puzzle in sections 3.3 and 3.4.

Single-product firms: The demand linkages discussed in the theoretical model only exist within the firm, implying that they should be solely captured by multiproduct firms. We check the plausibility of this result using data for single-product firms. If our results capture within-firm linkages between products, no effect should be observed for products exported by single-product firms. To do this exercise, we create a sample of single-product firms that export products close to the affected products of the "AD firm", i.e., in the same HS 4-digit category of the affected product. In case demand linkages take place within the firm, single-product firms should not respond to an AD duty that affects a product in the

Table 4: Demand linkages: Effect of AD duties on non-affected products **within the same HS 4-digit category**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0101	0.00245	0.00765***
	(0.00718)	(0.00746)	(0.00265)
AD_{fct-1}*HS4	0.0291**	0.0296**	-0.000489
	(0.0139)	(0.0144)	(0.00521)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	6,123,254	6,123,254	6,123,254
R-squared	0.900	0.936	0.981

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

same category, which is shown in Table 5.

Table 5: Antidumping effects on **single-product firms** exporting the same products of affected multi-product firms' non-affected products in affected and non-affected markets

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	-0.000575	0.00138	-0.00195
	(0.0110)	(0.0115)	(0.00400)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	1,146,706	1,146,706	1,146,706
R-squared	0.911	0.953	0.988

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.3 Firm-specific antidumping duties

AD duties are imposed on a specific product of a firm that is found in an AD investigation to be engaging in unfair practices. The amount of the applied duty varies largely between firms. In this section, instead of the dummy AD_{fct-1}, we exploit information on the exact amount of the firm-specific AD duty, which is made available by Bown (2010). During the period 2000-2015, the vast majority of AD measures imposed on Chinese firms are ad valorem duties and specific duties, which are the cases of interest. We drop firms affected by other

AD measures (duty if price falls under a given level, price undertaking, etc).[16] We identify in the sample 2472 firms that were subject to ad valorem and specific duties, 51% of them refer to AD cases initiated by the US and 17% by the EU. Using firm names available in the Global Antidumping Database and in the Chinese Customs Database, we have successfully matched 92% (2290) of firms subject to AD duties from all countries, 87% of firms for the US cases, and 90% of firms for the EU cases. As discussed by Nita and Zanardi (2013), duties imposed by the EU on Chinese firms are, on average, higher than on other countries.

We conduct the following exercise:

$$\log y_{fpct} = \beta_1 AD\_duty_{fct-1} + \beta_2 NADF\_duty_{fct-1} + \rho_{fpc} + \upsilon_{pct} + \mu_{fpt} + \varepsilon_{fpct}, \qquad (40)$$

where $AD\_duty_{fct-1} = AD_{fpct-1} * \log(1 + duty_{fpct-1})$ refers to the duty $(duty_{fpct-1})$ imposed against a Chinese firm f in country c, instead of a dummy as in eq. 39.

Tables 6 and 7 show the results using the exact amount of the firm-specific duty, which more precisely estimate the strength of demand and supply linkages: the larger the amount of the duty, the larger the cannibalization effects between products of the firm. The results shown below for values and quantities are in accordance with the baseline findings presented in Tables 2 and 3. When using firm-specific duties, the puzzling positive price effect observed in the baseline results disappears. However, they do not fall as the model suggests; we go back to this puzzle in the next section.

To be able to compare the coefficients and ensure that results are not driven by sample selection, we replicate the baseline results from Tables 2 and 3 using the same sample utilized for Tables 2 and 3. Results are shown in the Appendix Tables B1 and B2.

[16] 43% and 33% of the AD measures imposed on Chinese firms are ad valorem duties and specific duties, respectively. The remaining measures refer to a duty if price falls under a given level or price undertakings. AD investigations in the EU against China may result in the imposition of negotiated price undertakings (Bown and Crowley, 2016; Crowley and Song, 2015). However, the share of such cases in AD proceedings in the EU against all exporters has decreased by half between the 1980's and 2012 (see Felbermayr and Sandkamp (2020)). As in Felbermayr and Sandkamp (2020), regarding imports from China, only 9% of investigations resulted in the impositions of price undertakings between 2002 and 2012. These cases are excluded from the sample.

Table 6: Demand linkages: Effect of AD duties on non-affected products

	$\log(\text{value}_{fpct})$	$\log(\text{quantity}_{fpct})$	$\log(\text{unit value}_{fpct})$
$ADduty_{fct-1}$	0.0324***	0.0357***	-0.00334
	(0.00828)	(0.00851)	(0.00342)
$NADduty_{fct-1}$	0.00174	0.00516	-0.00342
	(0.0160)	(0.0161)	(0.00627)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	1,410,692	1,410,692	1,410,692
R-squared	0.913	0.949	0.986

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Table 7: Demand and supply linkages: Effect of AD duties on non-affected products in affected and non-affected markets

	$\log(\text{value}_{fpct})$	$\log(\text{quantity}_{fpct})$	$\log(\text{unit value}_{fpct})$
$ADduty_{fct-1}$	0.0425**	0.0491***	-0.00660
	(0.0183)	(0.0185)	(0.00841)
$NADduty_{fct-1}$	0.0202	0.0287	-0.00848
	(0.0219)	(0.0227)	(0.00991)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	1,410,692	1,410,692	1,410,692
R-squared	0.862	0.921	0.977

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.4 The Price Puzzle

According to proposition 1 of the theoretical framework, prices of non-affected products should decrease in response to AD measures. However, the baseline empirical results indicate a puzzling increase in prices,[17] which can be rationalized by the extension of the model shown in section 2.2 and proposition 2. The extension of the model accounts for endogenous investments in quality. In the theory, we highlight the importance of perceived quality, based on packaging and design, and show that investments in perceived quality can drive a wedge between effective prices (in units of quality) and observed prices (in units of output). The problem with this wedge is that effective prices are the relevant prices for consumers, but quality is a very complex concept that is difficult to measure.

In our framework where perceived quality refers to packaging and design, we can capture essential elements of box-size adjustments by focusing on products that are measured in units of weight, length, area, or volume. Prices posted in these units are essentially effective prices with respect to packaging and do not depend on the size of packaged units. This way, we can more precisely calculate changes in demand based on effective prices. As shown in Tables 8 and 9, once we account for effective prices, results go in the direction suggested by the model: because of demand linkages within the firm, prices of the non-affected products decrease in response to AD duties (Table 8). Once supply linkages are also taken into consideration, the negative effect is even larger, as suggested by the model (Table 9). As before, the results on values and quantities are positive and larger in magnitude once both supply and demand linkages are taken into account.

[17] This positive coefficient is no longer significant once we account for the size of the duty imposed against Chinese firms (see section 3.3).

Table 8: Demand linkages: Effect of AD duties on non-affected products **using effective prices**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0338***	0.0394***	-0.00562*
	(0.00819)	(0.00840)	(0.00337)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	1,124,629	1,124,629	1,124,629
R-squared	0.858	0.887	0.939

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Table 9: Demand and supply linkages: Effect of AD duties on non-affected products in affected and non-affected markets **using effective prices**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0395***	0.0555***	-0.0160***
	(0.00764)	(0.00789)	(0.00330)
NAD_{fct-1}	0.00969	0.0200	-0.0103
	(0.0154)	(0.0158)	(0.00630)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	1,124,629	1,124,629	1,124,629
R-squared	0.839	0.870	0.926

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.5 Robustness checks

3.5.1 Isolating supply linkages in non-affected markets

In the non-affected market, only supply linkages can exist - firms only internalize demand linkages in the market affected by the AD duty, as sales of the affected product decrease. To isolate supply linkages, we conduct an analysis keeping only non-affected products in non-affected markets (NAD_{fct-1}). Results shown in Table 10 reinforce the presence of supply linkages within the firm.

Table 10: Supply linkages: Effect of AD duties **only non-affected markets**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
NAD_{fct-1}	0.0594***	0.0664***	-0.00699
	(0.0185)	(0.0197)	(0.00805)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	801,235	801,235	801,235
R-squared	0.903	0.944	0.983

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.5.2 Circumvention effect

Firms might undertake circumvention activities to avoid the payment of antidumping or countervailing duties imposed on a product. For instance, firms might slightly modify a product such that the new product nomenclature is no longer subject of duties, or do certain assembly operations in the importing country or third countries, or the firm could trade a good through a third country or through another producer with a lower duty rate. The presence of such practices would bias our results, as the effect of the duty is undermined and/or our group of non-affected products might be wrongly assigned.[18]

To tackle this issue, we conduct robustness checks excluding Chinese firms involved in anti-circumvention (AC) inquiries targeting **product circumvention**. Among all AD measures

[18] For instance, if in response to the AD duty, the firm starts exporting a product in parts that will be assembled in the destination country, and these parts are other products of the firm that are not subject to duties, we would wrongly attribute our results to demand linkages within the firm.

imposed against China between 2000 and 2015, 107 AC investigations were filed by 8 different countries, including Turkey (29), EU (28), US (17), Australia (7), Brazil (7), India (6), Argentine (4) and Mexico (4), between the years 2004 and 2021. Among these AC cases, 64% of them accused Chinese firms of re-exporting from third countries and 26% of them accused Chinese exporters of product circumvention. In total, 197 HS 6-digit products were involved in AC investigations and 165 HS 6-digit products received affirmative decisions. Overall, we exclude 6,440 firms that were accused of product circumvention.

Results excluding firms that were accused of product circumvention are shown in Tables 11 and 12. In comparison to the baseline results shown in Tables 2 and 3, results are of similar magnitudes, which indicate that our results are no driven by circumvention activities.[19]

Table 11: Demand linkages: Effect of AD duties on non-affected products **excluding AC firms**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0229***	0.0163*	0.00660**
	(0.00838)	(0.00867)	(0.00318)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	2,262,047	2,262,047	2,262,047
R-squared	0.910	0.945	0.984

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.5.3 Chilling effect

Vandenbussche and Zanardi (2010) provide evidence of a "chilling effect" of AD duties, i.e., the fact that AD laws are associated with substantial decreases in aggregate trade flows in the countries that are traditional users of AD actions. This is in contrast with earlier views that the aggregate effect of AD measures on trade flows is negligible, as the amount of trade affected by AD laws is rather small. Vandenbussche and Zanardi (2010) describe different

[19] Though we can not directly compare the coefficients due to different sample sizes, we find that the results accounting for circumvention issues are slighly smaller in magnitude, which could indicate a small increase in sales of non-affected products due to circumvention activities in Tables 2 and 3.

Table 12: Demand and supply linkages: Effect of AD duties on non-affected products in affected and non-affected markets **excluding AC firms**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0269***	0.0241***	0.00276
	(0.00540)	(0.00552)	(0.00214)
NAD_{fct-1}	0.00361	0.00671	-0.00309
	(0.00890)	(0.00928)	(0.00361)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	2,262,047	2,262,047	2,262,047
R-squared	0.857	0.913	0.973

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

channels through which AD reduce imports, in particular of frequent users of AD measures. For instance, trade might decrease because of reputation and learning effects: trade partners become more cautious when exporting products to countries that are frequent users of AD. Another channel may take place due to a threatening effect: they show that trade diversion may occur not only in the targeted product-sector, but also in sectors not directly subject to AD duties because of a threatening effect. Other channels refer to strategic considerations by countries that lead to retaliation and the anticompetitive nature of AD laws.

If this channel was present within firms, we should observe targeted firms reducing exports of non-affected products because of the threat of being caught. Moreover, to avoid additional AD complaints, firms would increase prices and lower exports, as firms become more prudent when shipping their goods. However, in our results, firms consistently increase exports of non-affected products and decrease prices (once we account for effective prices). Hence, within the firm, we find no evidence of a chilling effect. Our results are in accordance with recent evidence from Bao et al. (2021) using Chinese firm-level data. Whereas they find evidence of a chilling effect for the affected product, for the other products of the firm they also find that firms lower prices and increase sales.

3.5.4 Tariff evasion and the auditing strength of a country

We have shown that product circumvention is an activity used by firms to evade or avoid the payment of antidumping duties. Such practices are less likely to be identified and punished in countries with poorly functioning institutions. In additional robustness checks, we account for the auditing strength in the destination country. We use data from the Global Competitiveness Report from the World Economic Forum,[20] which is a survey-based index between 1 (lowest auditing quality) to 7 (highest auditing quality). We then add an interaction terms in the regression corresponding to the tertiles of auditing strength in the destination country of exports ($audit_c^{tertile\_x}$, for the tertiles $x = 1, 2, 3$). Results in Table 13 do not indicate a clear relation between the strength of audit in the destination country and the outcomes of interest. The coefficient for values and quantities in the affected market are positive and significant across all tertiles and do not provide a clear pattern. A similar result holds when we isolate demand linkages, as shown in the appendix Table B3. In this case, the coefficients are only significant for the second tertile $audit_c^{tertile\_2}$.

3.5.5 Market share of the firm

The evidence of demand linkages in our framework indicate cannibalization effects, which is implied evidence of market power, as firms only internalize these linkages in the presence of market power. If this is the case, demand linkages should be stronger for firms that have a larger market share in the destination country.

We use the results from Table 2 as a baseline and add an interaction term, which refers to the market share of the targeted firm in the destination country. As shown in Table 14, the positive effect on the value of exports indicates that larger market shares are associated with stronger demand linkages. For quantities the effect is less precisely estimated.

[20] See: World Economic Forum (2016), The Global Competitiveness Report 2015-16, Insight Report, available at `https://www3.weforum.org/docs/gcr/2015-2016/Global_Competitiveness_Report_2015-2016.pdf`.

Table 13: Demand and supply linkages: Effect of AD duties on non-affected products in affected and non-affected markets **accounting for auditing strength**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
$AD_{fct-1} * audit_c^{tertile\_1}$	0.0281***	0.0253***	0.00275
	(0.00945)	(0.00982)	(0.00394)
$AD_{fct-1} * audit_c^{tertile\_2}$	0.0473***	0.0447***	0.00259
	(0.00911)	(0.00921)	(0.00302)
$AD_{fct-1} * audit_c^{tertile\_3}$	0.0393***	0.0364***	0.00294
	(0.0111)	(0.0113)	(0.00403)
$NAD_{fct-1} * audit_c^{tertile\_1}$	-0.00728	-0.0127	0.00541
	(0.0123)	(0.0129)	(0.00514)
$NAD_{fct-1} * audit_c^{tertile\_2}$	0.0194	0.0276*	-0.00819
	(0.0168)	(0.0166)	(0.00658)
$NAD_{fct-1} * audit_c^{tertile\_3}$	0.0489**	0.0533**	-0.00442
	(0.0236)	(0.0253)	(0.00682)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	2,393,983	2,393,983	2,393,983
R-squared	0.854	0.910	0.972

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Table 14: Demand linkages: Effect of AD duties depending on the firm's market share

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.00718	-0.00133	0.00851***
	(0.00689)	(0.00705)	(0.00289)
$AD_{fct-1}*share_{fhct-1}$	0.0358**	0.0443**	-0.00856
	(0.0167)	(0.0173)	(0.00631)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	2,528,266	2,528,266	2,528,266
R-squared	0.900	0.939	0.982

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.5.6 Firm-level analysis of affected products

Within-firm demand linkages are only present if the targeted product indeed observe a decrease in sales. In this case, firms internalize these linkages due to a lower degree of cannibalization among their products.

To to check the plausibility of our results, we investigate the effect of AD duties on the output of the targeted products, which have until now being omitted in our analysis. We estimate the following equation to investigate if the output of the affected product decreases in the destination that imposed the duty:

$$\log y_{fpct} = \beta_1 ADF_{fct-1} + \beta_2 NADF_{fct-1} + \rho_{fpc} + \upsilon_{sct} + \mu_{fpt} + \varepsilon_{fpct}, \tag{41}$$

where ADF_{fct-1} is an indicator variable that equals 1 if firm f had a product subject to an AD duty imposed by country c in year $t-1$, and zero otherwise. $NADF_{fct-1}$ refers to affected firms f in non-affected markets c. y_{fpct} are either value of exports, quantity or unit value of product p exported to destination c by firm f in year t. The empirical strategy includes (1) countries c that impose the AD duty and countries that did not impose duties, (2) products p that were subject to the AD-duty and non-affected products, and (3) multiproduct and single-product firms that were affected by the AD duty or not.We include in the estimations a set of fixed effects that accounts for time-invariant heterogeneity that affect a firm-product-country observation (ρ_{fpc}) such as differences in marginal costs, product quality, or markups charged by a firm in different destinations. We also include factors common to a country, year, and HS 4-digit sector (υ_{sct}) such as sectoral trends and sector-specific demand shocks in a country,[21] and for firm-product-time fixed effects (μ_{fpt}) to account for firm-product shocks that affect all destinations.

As in previous papers (see for instance Lu et al. (2013) and Felbermayr and Sandkamp (2020) for analyzes using Chinese data), we expect $\beta_1 < 0$ for $y_{fpct} = value_{fpct}$, as AD

[21] In eq. 41, we include only υ_{sct} fixed effects instead of the υ_{pct} fixed effects included for the analysis of non-affected products in eq. 39. This is because in eq. 41 the relevant level of variation is at the product, country, and year.

duties reduce firm-level exports of the affected product. Results reported in Table 15 are in accordance with the literature: in response to AD duties, firms decrease sales of the affected product.

We also compare the effects for multiproducts and single-product firms using interaction terms with an indicator $MPF_{fc} = 1$ if firm f is a multiproduct exporter in destination country c, and zero otherwise. We show that the negative effect of the duty is dampened for multiproduct firms, meaning that they react less than incumbent single-product firms in the affected market.

Table 15: Antidumping effects on firms' **affected** products in affected (AD) and non-affected (NAD) markets

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	-0.119***	-0.115***	-0.00325
	(0.0254)	(0.0259)	(0.00791)
NAD_{fct-1}	-0.0105	-0.00344	-0.00708*
	(0.0140)	(0.0144)	(0.00428)
AD_{fct-1}*MPF_{fc}	0.0804***	0.0871***	-0.00666
	(0.0250)	(0.0254)	(0.00773)
NAD_{fct-1}*MPF_{fc}	0.0212	0.0193	0.00190
	(0.0151)	(0.0155)	(0.00487)
Firm-product-country	Yes	Yes	Yes
HS4-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	8,193,045	8,193,045	8,193,045
R-squared	0.861	0.909	0.968

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

3.5.7 Event study

Given the nature of AD duties, one important concern refers to pre-trends and anticipation effects, which would bias our results. To overcome this concern, we conduct an event study as follows:

$$\log value_{fpct} = \sum_{max}^{t} {}_{k=t_{min}} \beta_k \times AD_{fck} + \rho_{fpc} + \upsilon_{pct} + \mu_{fpt} + \varepsilon_{fpct}, \tag{42}$$

Figure 2 shows the estimates for an event of an AD duty imposed against Chinese firms.

The coefficients are plotted with their 95% confidence intervals. As shown in the figure, an AD duty is accompanied by a sustained increase in exports of non-affected produts to the affected destination. More importantly, the dynamic behavior of exports prior to the duty does not show clear pre-trends in the activity of the affected firm, meaning that firms do not systematically increase sales of non-affected products before the duty. The point estimates for the year -3 to 0 before are not statistically significant at the level of 5%.

[Figure 2]

4 Conclusion

We present a model with demand and supply linkages that help explain firm responses to shocks that affect specific products of a multiproduct firm. The model provides testable predictions that we test using Chinese firm-level data. To evaluate the impact of cost shocks at the firm and product level, we use data on all AD duties imposed against Chinese exporters between 2000 and 2015. AD duties have been a commonly used instrument of trade policy, in particular against Chinese firms. In this period, roughly 26% of the AD investigations worldwide were conducted against China, and they affected 902 different HS 6-digit product categories, including a large range of differentiated goods. The firm and product-specific nature of AD duties make them particularly suitable for the analysis of demand and supply linkages within the firm: AD duties are imposed by a destination country on specific firms that are found to be engaging in unfair trade practices, they commonly hit an important product of the firm, and they hit one but not all products of the firm in one particular market.

The results presented in the empirical analysis provide evidence for demand linkages and supply linkages that are specific to multiproduct firms and allow us to isolate cannibalization effects within the firm. Multiproduct firms react to an AD duty that hit one but not all their products by increasing exports of non-affected products in the country that imposed the duty. This effect is stronger for products that share greater similarity and are not driven by product misclassification or anti-circumvention activities of firms.

References

Albornoz, F., I. Brambilla, and E. Ornelas (2021). Firm export responses to tariff hikes. CEPR Discussion Papers 16455.

Armstrong, M. and J. Vickers (2022, April). Multiproduct cost passthrough: Edgeworth's paradox revisited. CEPR Discussion Paper No. DP17202.

Bao, X., B. Blonigen, and Z. Yu (2021). Cross-product and cross-market adjustments within multiproduct firms: Evidence from antidumping actions. NBER Working Papers 29521.

Bernard, A. B., S. J. Redding, and P. K. Schott (2011). Multiproduct firms and trade liberalization. Quarterly Journal of Economics 126, 1271–1318.

Blonigen, B. A. and T. J. Prusa (2016). Dumping and antidumping duties. In Handbook of commercial policy, Volume 1, pp. 107–159. Elsevier.

Bown, C. and M. Crowley (2016). Chapter 1 - the empirical landscape of trade policy. Volume 1 of Handbook of Commercial Policy, pp. 3–108. North-Holland.

Bown, C. P. (2012). Temporary trade barriers database, available at http://econ.worldbank.org/ttbd/.

Bown, C. P. and M. A. Crowley (2007). Trade deflection and trade depression. Journal of International Economics 72(1), 176–201.

Bown, C. P. and M. A. Crowley (2010). China's export growth and the china safeguard: threats to the world trading system? Canadian Journal of Economics 43(4), 1353–1388.

Brander, J. A. and J. Eaton (1984). Product line rivalry. The American Economic Review 74(3), 323–334.

Crowley, M. A., N. Meng, and H. Song (2018). Tariff scares: Trade policy uncertainty and foreign market entry by chinese firms. Journal of International Economics 114, 96–115.

Dhingra, S. (2013). Trading away wide brands for cheap brands. American Economic Review 103(6), 2554–84.

Ding, X. (2021). Intangible economies of scope: Micro evidence and macro implications. Working Paper.

Eaton, B. C. and N. Schmitt (1994). Flexible manufacturing and market structure. The American Economic Review 84(4), 875–888.

Eckel, C., L. Iacovone, B. Javorcik, and J. P. Neary (2015). Multi-product firms at home and away: Cost- versus quality-based competence. Journal of International Economics 95(2), 216–232.

Eckel, C. and J. P. Neary (2010). Multi-product firms and flexible manufacturing in the global economy. The Review of Economic Studies 77(1), 188–217.

Egger, P. and D. Nelson (2011). How bad is antidumping? evidence from panel data. Review of Economics and Statistics 93(4), 1374–1390.

Feenstra, R. and H. Ma (2007). Optimal choice of product scope for multiproduct firms under monopolistic competition. NBER Working Papers 13703.

Felbermayr, G. and A. Sandkamp (2020). The trade effects of anti-dumping duties: Firm-level evidence from china. European Economic Review 122, 103367.

Flach, L. and M. Irlacher (2018). Product versus process: Innovation strategies of multi-product firms. American Economic Journal: Microeconomics 10(1), 236–77.

Haynes, M., S. Thompson, and P. W. Wright (2014). New model introductions, cannibalization and market stealing: Evidence from shopbot data. The Manchester School 82(4), 385–408.

Hottman, C. J., S. J. Redding, and D. E. Weinstein (2016, August). Quantifying the sources of firm heterogeneity. The Quarterly Journal of Economics 131(3), 1291–1364.

Jabbour, L., Z. Tao, E. Vanino, and Y. Zhang (2019). The good, the bad and the ugly: Chinese imports, european union anti-dumping measures and firm performance. Journal of International Economics 117, 1–20.

Johnson, J. P. and D. P. Myatt (2003, June). Multiproduct quality competition: Fighting brands and product line pruning. American Economic Review 93(3), 748–774.

Konings, J., H. Vandenbussche, and L. Springael (2001). Import diversion under european antidumping policy. Journal of Industry, Competition and Trade 1(3), 283–299.

Lu, Y., Z. Tao, and Y. Zhang (2013). How do exporters respond to antidumping investigations? Journal of International Economics 91(2), 290–300.

Macedoni, L. (2022). Large multiproduct exporters across rich and poor countries: Theory and evidence. Journal of Development Economics 156, 102835.

Mason, C. H. and G. R. Milne (1994). An approach for identifying cannibalization within product line extensions and multi-brand strategies. Journal of Business Research 31(2), 163–170. Special Issue: Strategy Evaluation Research.

Mayer, T., M. J. Melitz, and G. I. Ottaviano (2014). Market size, competition, and the product mix of exporters. American Economic Review 104(2), 495–536.

Meng, N., C. Milner, and H. Song (2020). Antidumping and heterogeneous quality adjustment of multi-product firms: Evidence from chinese exporters. Economic Modelling 92, 147–161.

Nita, A. C. and M. Zanardi (2013). The first review of european union antidumping reviews. World Economy 36(12), 1455–1648.

Nocke, V. and N. Schutz (2018). Multiproduct-firm oligopoly: An aggregative games approach. Econometrica 86(2), 523–557.

Nocke, V. and S. Yeaple (2014). Globalization and multiproduct firms. International Economic Review 55(4), 993–1018.

Prusa, T. J. (2001). On the spread and impact of anti-dumping. Canadian Journal of Economics 34(3), 591–611.

Shaked, A. and J. Sutton (1990). Multiproduct firms and market structure. The RAND Journal of Economics 21(1), 45–62.

Srinivasan, S., S. Ramakrishnan, and S. E. Grasman (2005, January). Identifying the effects of cannibalization on the product portfolio. Marketing Intelligence Planning 23(4), 359–371.

Vandenbussche, H. and M. Zanardi (2010). The chilling trade effects of antidumping proliferation. European Economic Review 54(6), 760–777.

A Theoretical Appendix

A.0.8 First Order Condition

Firms maximize profits (1) by choosing prices optimally, taking into account technology (3) and demand (4).

Marginal revenues are given by

$$\frac{dR(j)}{d\ln p_d(j,i)} = -(\sigma-1)\,p_d(j,i)\,x_d(j,i) + (\sigma-1)\,s_d(j,i)\,R_d(j) \tag{43}$$

where $R_d(j) \equiv \int_{\omega\in\delta_d(j)} p_d(j,\omega)\,x_d(j,\omega)\,d\omega$ and $R(j) \equiv \int_{d\in D(j)} R_d(j)\,dd$.

Marginal costs are given by

$$\frac{dTC(j)}{d\ln p_d(j,i)} = -\sigma\left(c_j(i) + \tau_d(i) + 2\gamma X(j)\right)x_d(j,i) + (\sigma-1)\,s_d(j,i)\,\Gamma_d(j) \tag{44}$$

where $TC(j) \equiv \int_{d\in D(j)} \int_{\omega\in\delta_d(j)} \{c_j(\omega) + \tau_d(\omega) + \gamma X(j)\}\,x_d(j,\omega)\,d\omega dd$ stands for Total Costs, and $\Gamma_d(j) \equiv \int_{\omega\in\delta_d(j)} \{c_j(\omega) + \tau_d(\omega) + 2\gamma X(j)\}\,x_d(j,\omega)\,d\omega$.

Setting marginal costs equal to marginal revenues yields the first order condition (FOC):

$$p_d(j,i)\,x_d(j,i) - \frac{\sigma}{\sigma-1}\left(c_j(i) + \tau_d(i) + 2\gamma X(j)\right)x_d(j,i) = s_d(j,i)\left(R_d(j) - \Gamma_d(j)\right) \tag{45}$$

Integrating over all products within Ω_d yields

$$(1 - s_d(j))\,R_d(j) = \left(\frac{\sigma}{\sigma-1} - s_d(j)\right)\Gamma_d(j) \tag{46}$$

where $s_d(j) \equiv \int_{\omega\in\delta_d(j)} s_d(\omega)\,d\omega$. Substituting (46) into (45) and rearranging yields (8) and (9).

A.1 Comparative Statics

Equations (2), (4), (7), (8), (9), and (10), can be reduced to a system of three equations:

$$p_d(j,\omega) = \frac{\sigma}{\sigma-1}\left(1+\frac{s_d(j)}{\sigma(1-s_d(j))}\right)(c_j(\omega)+\tau_d(\omega)+2\gamma X(j)) \tag{47}$$

$$s_d(j) = P_d^{\sigma-1}\int_{\omega\in\delta_d(j)} p_d(j,\omega)^{1-\sigma}\, d\omega \tag{48}$$

$$X(j) = \int_{d\in D(j)} Y_d P_d^{\sigma-1}\int_{\omega\in\delta_d(j)} p_d(\omega)^{-\sigma}\, d\omega dd \tag{49}$$

When taking derivatives of these equations we need to take a few things into account:

- Prices are product- and market-specific. Thus, we have to differentiate between prices of affected and unaffected products in affected markets, and prices in unaffected markets.

- Markups are market-specific. Therefore, we have to differentiate between markups in affected and unaffected markets.

- Firm-product-country fixed effects in the empirics imply that we control for all ex ante heterogeneity. Thus, in the theory we assume that all products are symmetric: $\lambda_d^s(j) = \lambda^s$, $\lambda_d^\tau(j,\omega) = \lambda^\tau$ and $\lambda_d^X(j,\omega) = \lambda^X$. This also implies that $s_a(j,\Delta)/s_a(j) = x_a(j,\Delta)/X_a(j)$.

- Product-country-year fixed effects in the empirics imply that we control for all linkages outside of firms (competition, GE). Thus, in the theory we assume that a market's price index P_d is exogenous.

Given these considerations, we obtain a system of six equations:

$$\begin{aligned}
\frac{d\ln p_a(j,\Delta)}{d\ln\tau_a(\Delta)} &= \lambda^s\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)} + \lambda^X\frac{d\ln X(j)}{d\ln\tau_a(\Delta)} + \lambda^\tau, \\
\frac{d\ln p_a(j,\omega')}{d\ln\tau_a(\Delta)} &= \lambda^s\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)} + \lambda^X\frac{d\ln X(j)}{d\ln\tau_a(\Delta)},
\end{aligned}$$

$$
\begin{aligned}
\frac{d\ln p_n(j,\omega)}{d\ln\tau_a(\Delta)} &= \lambda^s\frac{d\ln s_n(j)}{d\ln\tau_a(\Delta)}+\lambda^X\frac{d\ln X(j)}{d\ln\tau_a(\Delta)},\\
\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)} &= -(\sigma-1)\int_{\omega\in\delta_a(j)}\frac{s_a(j,\omega)}{s_a(j)}\frac{d\ln p_a(j,\omega)}{d\ln\tau_a(\Delta)}d\omega,\\
\frac{d\ln s_n(j)}{d\ln\tau_a(\Delta)} &= -(\sigma-1)\int_{\omega\in\delta_n(j)}\frac{s_n(j,\omega)}{s_n(j)}\frac{d\ln p_n(j,\omega)}{d\ln\tau_a(\Delta)}d\omega,\\
\frac{d\ln X(j)}{d\ln\tau_a(\Delta)} &= -\sigma\int_{\omega\in\delta_a(j)}\frac{x_a(j,\omega)}{X(j)}\frac{d\ln p_a(j,\omega)}{d\ln\tau_a(\Delta)}d\omega\\
&\quad -\sigma\int_{d\in D_n(j)}\int_{\omega\in\delta_d(j)}\frac{x_d(j,\omega)}{X(j)}\frac{d\ln p_n(j,\omega)}{d\ln\tau_a(\Delta)}d\omega dd,
\end{aligned}
$$

where $d=a$ and $d=n$ stand for affected and nonaffected markets, $\omega=\Delta$ stands for the affected product, and $\omega'\in\delta_d(j)\setminus\Delta$ stands for all unaffected products in firm j's product range in the affected market.

This system reduces to

$$
\begin{aligned}
\left(\frac{1}{\sigma-1}+\lambda^s\right)\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)}+\lambda^X\frac{d\ln X(j)}{d\ln\tau_a(\Delta)} &= -\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau\\
\left(\frac{1}{\sigma-1}+\lambda^s\right)\frac{d\ln s_n(j)}{d\ln\tau_a(\Delta)}+\lambda^X\frac{d\ln X(j)}{d\ln\tau_a(\Delta)} &= 0\\
\frac{X_a(j)}{X(j)}\lambda^s\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)}+\left(1-\frac{X_a(j)}{X(j)}\right)\lambda^s\frac{d\ln s_n(j)}{d\ln\tau_a(\Delta)}+\left(\frac{1}{\sigma}+\lambda^X\right)\frac{d\ln X(j)}{d\ln\tau_a(\Delta)} &= -\frac{x_a(j,\Delta)}{X(j)}\lambda^\tau
\end{aligned}
$$

with solutions (12) to (14).

Having determined $\frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)}$, $\frac{d\ln s_n(j)}{d\ln\tau_a(\Delta)}$ and $\frac{d\ln X(j)}{d\ln\tau_a(\Delta)}$, we can plug the solutions into the equations for $\frac{d\ln p_a(j,\Delta)}{d\ln\tau_a(\Delta)}$, $\frac{d\ln p_a(j,\omega')}{d\ln\tau_a(\Delta)}$ and $\frac{d\ln p_n(j,\omega)}{d\ln\tau_a(\Delta)}$ and we obtain the solutions (15) to (17). Finally, equations (22) to (25) can be determined in the same way, but assuming that $d\ln X(j)=0$.

A.2 Perceived Quality

Firms maximize profits

$$
\pi(j)=\int_{d\in D(j)}\int_{\omega\in\delta_d(j)}\left[\left\{p_d^e(j,\omega)-\tau_d(\omega)-c_j(\omega)-\gamma X^e(j)\right\}x_d^e(j,\omega)-k_d(j,\omega)\right]d\omega dd \tag{50}
$$

subject to the following constraints:

$$\begin{aligned} x_d^e(j,\omega) &= p_d^e(j,\omega)^{-\sigma}(P_d^e)^{\sigma-1}Y_d \\ X^e(j) &= \int_{d\in D(j)}\int_{\omega\in\delta_d(j)} x_d^e(j,\omega)\,d\omega dd \\ k_d(j,\omega) &= \frac{1}{\chi}q_d(j,\omega)^{\chi} \end{aligned}$$

With respect to the effective price $p_d^e(j,\omega)$, the problem is isomorphic to the one without quality. Hence, the optimal effective price is given by (31).

The FOC for profit maximization with respect to quality $q_d(j,\upsilon)$ is

$$\begin{aligned} q_d(j,\upsilon)^{\chi} &= \sigma\left(p_d^e(j,\upsilon)-\tau_d(\upsilon)-c_j(\upsilon)-2\gamma X^e(j)\right)x_d^e(j,\upsilon) \\ &\quad -(\sigma-1)\,s_d(j,\upsilon)\int_{\omega\in\delta_d(j)}\left(p_d^e(j,\omega)-\tau_d(\omega)-c_j(\omega)-2\gamma X^e(j)\right)x_d^e(j,\omega)\,d\omega \end{aligned} \tag{51}$$

Combining this with the FOC for prices yields (32).

We now have a system of three equations (assuming that $X^e(j)$ is held constant):

$$\begin{aligned} p_d^e(j,\upsilon) &= \frac{\sigma}{\sigma-1}\left(1+\frac{s_d(j)}{\sigma(1-s_d(j))}\right)(c_j(\upsilon)+\tau_d(\upsilon)+2\gamma X^e(j)) \\ s_d(j) &= (P_d^e)^{\sigma-1}\int_{\omega\in\delta_d(j)} p_d^e(j,\omega)^{1-\sigma}\,d\omega \\ q_d(j,\upsilon)^{\chi} &= p_d^e(j,\omega)^{1-\sigma}(P_d^e)^{\sigma-1}Y_d \end{aligned}$$

In changes, we obtain the following results (assuming, as above, symmetry of products and exogeneity of market wide parameters in line with our fixed effects)

$$\begin{aligned} \frac{d\ln s_a(j)}{d\ln\tau_a(\Delta)} &= -(\sigma-1)\,\vartheta\frac{x_a(j,\Delta)}{X_a(j)}\lambda^{\tau}<0 \\ \frac{d\ln p_a^e(j,\Delta)}{d\ln\tau_a(\Delta)} &= \left(1-(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\right)\lambda^{\tau}>0 \end{aligned}$$

$$\frac{d\ln p_a^e(j,\omega\prime)}{d\ln\tau_a(\Delta)} = -(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau < 0$$
$$\frac{d\ln q_a(j,\Delta)}{d\ln\tau_a(\Delta)} = -\frac{(\sigma-1)}{\chi}\left(1-(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\right)\lambda^\tau < 0$$
$$\frac{d\ln q_a(j,\omega\prime)}{d\ln\tau_a(\Delta)} = \frac{(\sigma-1)}{\chi}(1-\vartheta)\frac{x_a(j,\Delta)}{X_a(j)}\lambda^\tau > 0$$

The result for observed (non-effective) prices can be obtained from $p_d^e(j,\omega) = p_d(j,\omega)/q_d(j,\omega)$ and thus $d\ln p_a(j,\omega\prime) = d\ln p_a^e(j,\omega\prime) + d\ln q_a(j,\omega\prime)$.

If $\chi = \chi(\sigma)$, and $\chi(\sigma)/(\sigma-1)$ is to be increasing in σ, then $\chi'(\sigma)(\sigma-1) - \chi(\sigma) > 0$, or $\chi'(\sigma)\frac{\sigma}{\chi(\sigma)} > \frac{\sigma}{\sigma-1} > 1$. A possible functional form satisfying this condition is $\chi = \frac{1}{\zeta}(\sigma^2-1)$, $\zeta > 0$. In this case, $\frac{d\ln p_a(j,\omega\prime)}{d\ln\tau_a(\Delta)} > 0$ if $\sigma < \zeta - 1$ and $\frac{d\ln p_a(j,\omega\prime)}{d\ln\tau_a(\Delta)} < 0$ if $\sigma > \zeta - 1$.

B Empirical Appendix

Table B1: Demand linkages: Effect of AD duties on **non-affected products** using the sample from Table 6

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0286*	0.00784	0.0208***
	(0.0153)	(0.0160)	(0.00626)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	1,414,483	1,414,483	1,414,483
R-squared	0.912	0.949	0.986

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Table B2: Demand and supply linkages: Effect of AD duties on non-affected products **in affected and non-affected markets** using the sample from Table 7

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
AD_{fct-1}	0.0382***	0.0357***	0.00252
	(0.00703)	(0.00722)	(0.00293)
NAD_{fct-1}	0.0116	0.0221*	-0.0105**
	(0.0121)	(0.0127)	(0.00512)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Observations	1,414,483	1,414,483	1,414,483
R-squared	0.862	0.921	0.977

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

Table B3: Demand linkages: Effect of AD duties on non-affected products **accounting for the auditing strength**

	log(value$_{fpct}$)	log(quantity$_{fpct}$)	log(unit value$_{fpct}$)
$AD_{fct-1} * audit_c^{tertile\_1}$	0.00546	-0.000883	0.00634
	(0.0132)	(0.0138)	(0.00532)
$AD_{fct-1} * audit_c^{tertile\_1}$	0.0345***	0.0233*	0.0112**
	(0.0117)	(0.0122)	(0.00466)
$AD_{fct-1} * audit_c^{tertile\_1}$	0.0136	0.000583	0.0130**
	(0.0139)	(0.0144)	(0.00540)
Firm-product-country	Yes	Yes	Yes
Product-country-year	Yes	Yes	Yes
Firm-product-year	Yes	Yes	Yes
Observations	2,393,983	2,393,983	2,393,983
R-squared	0.908	0.943	0.983

Notes: Robust standard error in parentheses, clustered at the firm-country level; ***, **, * denote significance at the 1%, 5% and 10% level.

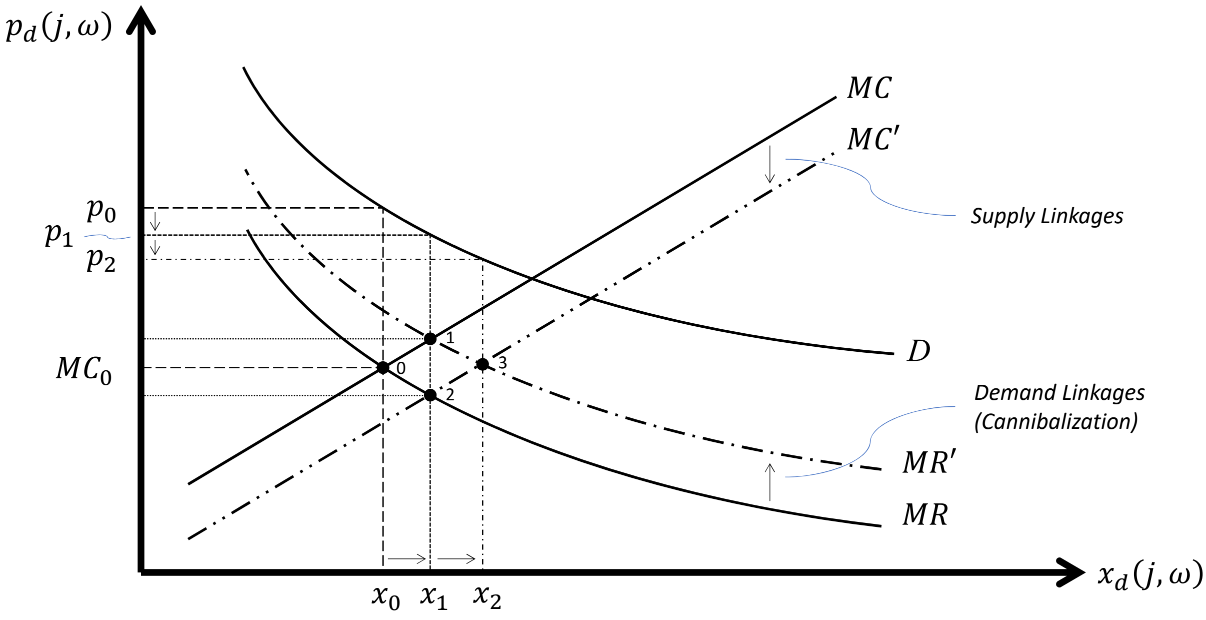

Figure 1

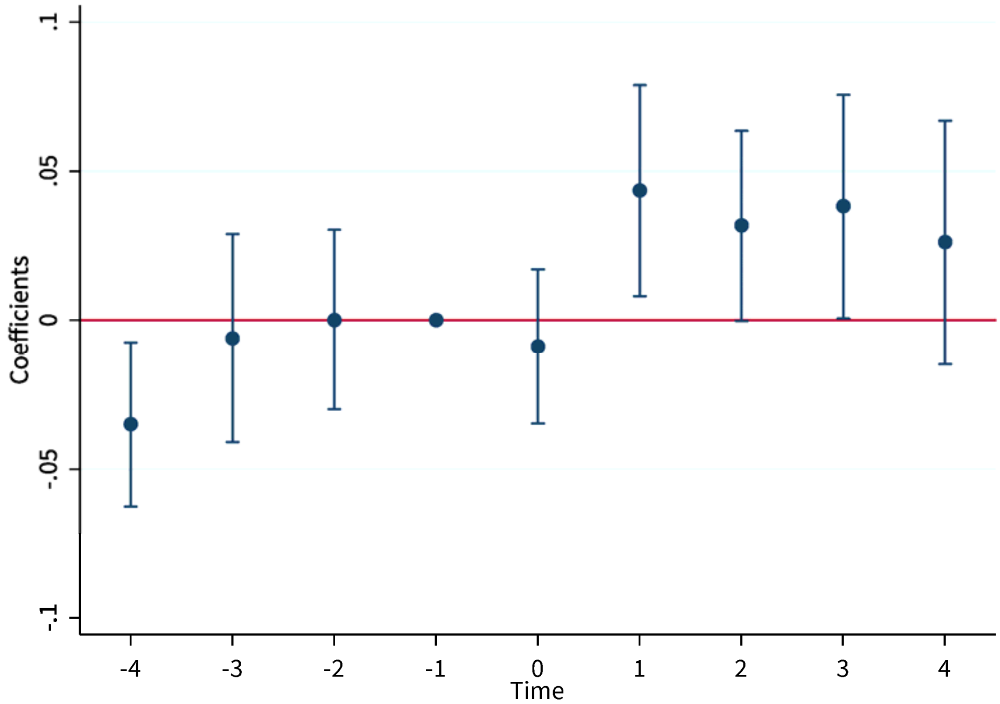

Figure 2