The Structural Drivers of Price and Quantity Adjustment: Insights from Tariff and Exchange Rate Pass-through

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May 2023

Abstract

Why is there complete long-run pass-through of both tariffs and exchange rates in US exports, despite evidence of flexible markups? To answer this question, I develop a methodology to leverage tariffs and exchange rates to uncover the structural drivers of pass-through, the markup elasticity and the marginal cost scale elasticity. I derive and quantify the scale channel of pass-through, which can be decomposed into a bilateral scale and the novel "shock span" scale effect. The shock span channel arises because different correlation patterns across customers enters prices via the scale channel. Because exchange rates are correlated across trading partners, compared to tariffs they have greater capacity for shock-span effects of scale economies. Quantifying the bilateral and shock span components of the scale channel, the paper demonstrates that scale economies can rationalize the discrepancy between markup flexibility and observed pass-through.
JEL Codes: F41.

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1 Introduction

Why is there complete tariff and exchange rate pass-through in United States exports, even in the long-run? Fajgelbaum and Khandelwal (2022) pose this question with respect to the recent trade war, calling it "the complete pass-through puzzle." This result, which I document for both tariffs and exchange rates, is particularly surprising in light of evidence in the literature of flexible markups (e.g. Atkeson and Burstein (2008), Nakamura and Zerom (2010), Amiti, Itskhoki, and Konings (2019)), which would suggest incomplete pass-through. Namely, in models with markup flexibility, any cost shock is partially absorbed into the markup, generating pass-through less than unity. With complete pass-through, either both markups and marginal costs must be constant, rejecting those models; or marginal costs act to offset markup flexibility.

To answer this question, I estimate the underlying structural components governing firms' pricing decisions - the markup elasticity and the marginal cost scale elasticity. The markup elasticity is the derivative of the markup with respect to the price, and governs how much markups evolve with cost shocks; it is the curvature of the demand function. The marginal cost scale elasticity determines whether or not there are increasing, decreasing, or constant returns-to-scale in production. Estimating these parameters enables me to quantify the scale channel of tariff and exchange rate pass-through, which I show can rationalize the discrepancy between flexible markups and complete pass-through. In particular, in the face of a cost shock, scale economies increase marginal costs, and the overall change in marginal costs is absorbed into the markup, generating pass-through of unity in total.

Researchers and policymakers are interested in how foreign cost shocks affect prices because their pass-through determines shock transmission into the broader economy. While these pass-throughs have been measured in the aggregate, not much is understood about the underlying parameters driving firms to adjust - or not adjust - prices in the face of these shocks. Work such as Amiti et al (2014, 2019, 2022), Gopinath and Rigobon (2008), Gopinath, Itshoki, and Rigobon (2010), and Gopinath and Itskhoki (2011) have quantified pricing pressures contributing to pass-through such as imported inputs, competitor pricing, and nominal rigidities. However, the underlying structural parameters governing how firms incorporate these channels into pricing - namely, the adjustment elasticities of marginal costs and markups - are more difficult to measure and have not been widely established.

As the markup elasticity (introduced by Klenow and Willis (2006)) is the curvature of the demand function and the optimal markup is a function of the demand elasticity, this markup elasticity is a key component into pass-through and informs both the nature of demand and also markup adjustment (Arkolakis and Morlacco (2017)). Work such as Nakamura and Zerom (2010) and Amiti, Itskhoki, and Konings (2019) have documented strong degrees of markup flexibility, implying incomplete pass-through. These facts are difficult to reconcile with evidence of complete pass-through even in the long-run, which I document and as in Amiti, Redding, and Weinstein (2020).

In this work, I show that increasing returns-to-scale can rationalize the discrepancy between long-run complete pass-through and markup flexibility. In particular, aggregate quantity adjustment can affect prices in the face of non-constant returns (e.g. when the scale elasticity - the elasticity of marginal cost with respect to aggregate quantity - is nonzero). The aggregate quantity response is in part dependent on the bilateral demand elasticity, but may not increase linearly with bilateral quantities if there is reallocation or correlated shocks across destinations. This effect will differ across exchange rates and tariffs because the two shocks have different correlation patterns across trading partners.

Increasing returns-to-scale in particular can answer the complete pass-through puzzle because in this case, marginal costs are decreasing in output. When goods become more expensive due to a tariff or exchange rate shock and quantities contract, production becomes more expensive, raising prices further. Thus in such a mode of production pass-through can rise to completion despite some costs being absorbed into markups. I document that markup flexibility lowers prices by 14%, but that increasing returns-to-scale raises marginal costs sufficiently to generate complete pass-through.

To quantify the scale channel, I show that it can be broken down into two components - the bilateral scale channel and the shock span channel. Bilateral scale effects arise from a change in bilateral quantities sold to an importer, and how that impacts prices via scale economies. My model is informative of a novel channel of pass-through, which I term shock span. Namely, shock span is the correlation patterns of a shock; whether or not a shock is linked with the shocks of other trading partners. An example of how an exchange rate shock could differ in its correlation patterns is that it could be caused by monetary policy, which would induce a fluctuation affecting all destinations; another example would be that it could be due to financial speculation from a trading partner, a bilateral fluctuation. These two determinants of a single exchange rate fluctuation would have very different implications for firms' pricing decisions, and the measurements in this paper will help understand that execution. For tariffs, they can be imposed on one or many trading partners, which would for example have different implications for reallocation and aggregate quantities. Thus, my structural model paired with my empirical estimates will enable me to uncover the scale channel of pass-through, both for bilateral effects and rest-of-world shock span effects.

Existing pass-through estimates tend to ignore the scale channel, or (implicitly) assume constant returns-to-scale. While this may not jeopardize reduced-form estimation, it implies that structural implications of those estimates may be biased. For example, ignoring marginal cost effects when quantifying the "complete pass-through puzzle" would imply a markup elasticity of zero (constant markup), rejecting literature on flexible markups. Furthermore, as I discuss later in the paper, welfare estimates of cost shocks may be biased if the researcher assumes constant returns.

In sum, the goal of this project is to explain the long-run complete tariff and exchange rate pass-through results by (1) estimating the structural components of a firm's pricing decision and (2) quantifying the markup and scale channels of pass-through. I discuss related literature in the next section, then I introduce the model, then I discuss estimation and provide concluding remarks.

2 Literature Review

This paper contributes to five strands of literature. First, it contributes to literature interested in estimating the structural drivers of pass-through, the markup elasticity and the marginal cost scale function. It also contributes to literature estimating cost channels of pass-through, by estimating the scale channel of pass-through. Third, it contributes to literature interested in comparing tariff and exchange rate pass-through. Fourth, it contributes to literature interested in implications of scale economies, both with the estimates but also via its application to shock response. Finally, it contributes to literature exploring the drivers of complete pass-through.

The first chunk of literature has focused on the markup elasticity, which is the curvature of the demand function. It has become a workhorse in international macroeconomics models estimating impacts of cost shocks on prices. It is difficult to measure because it often requires information on marginal costs; there have been a few such attempts in the literature. Nakamura and Zerom (2010) employ a Berry, Levinsohn, and Pakes (1994) strategy to estimate the markup elasticity. Amiti, Itskhoki, and Konings (2019) employ an instrumental variables strategy to uncover this object. In this work, I follow Atkeson and Burstein (2008) and impose a nested-CES demand structure and estimate the markup elasticity and demand elasticity with observable structural components.[1]

Pass-through literature has been less focused on the marginal cost scale elasticity, even though it is a key component in standard pricing models. Fajgelbaum, Goldberg, Kennedy, Khandelwal, and Taglioni (2021) aim to quantify scale economies at the country level, and are able to sign the supply curve of a number of countries in their data. An advantage of my approach relative to theirs is that I can quantify the scale economies in pricing. An additional paper which estimates scale economies is Bartelme, Costinot, Donaldson, and Rodriguez-Clare (2021), estimating these elasticities at industry-level heterogeneity using a demand-based instrumental variables strategy. The approach in my paper more directly applies to pass-through.

[1]As an alternative approach in the Appendix, I estimate the markup elasticity with a fixed-effects approach, though I discuss that this does not properly control for scale effects.

The second strand of literature is the literature estimating various pass-through channels. The contribution of this paper is to quantify the scale channel of pass-through, for both tariffs and exchange rates. A large literature has estimated effects of nominal rigidities, such as Gopinath et al (2008, 2010, 2011). Other work has quantified effects of imported inputs (exchange rates: Amiti, Itskhoki, and Konings (2014); tariffs: Amiti and Konings (2007)); other work has quantified effects of dominant currencies (Gopinath et al (2020); Amiti, Itskhoki, and Konings (2022)). Another example is market power (Alviarez, Fioretti, Kikkawa, and Morlacco (2022)) or strategic complementarities (Amiti, Itskhoki, and Konings (2019)). Less has estimated the scale channel of pass-through, possibly because of the difficulty of estimating the scale elasticity. Thus that is a contribution of this paper.

A third strand of literature is that comparing tariffs to exchange rates with respect to trade flows. Fitzgerald and Haller (2018) estimate that exchange rates have much smaller export revenue effects than tariffs. Cavallo, Gopinath, Neiman, and Tang (2021) document that exchange rate pass-through is much lower in US imports than tariff pass-through. They speculate that imported inputs and persistence drives the discrepancy. In this paper, I answer this question by leveraging my structural estimation to show that the incidence of scale economies varies by shock, in particular due to the shocks' correlation patterns across destinations.

A fourth strand of literature is quantifying impacts of scale economies on trade models. Antras et al (2022) argue that scale economies in downstream relative to upstream sectors can be rationale for tariff escalation. Kucherayvyy and Lyn (2023) embed scale economies into a trade model to estimate how gains from trade change; Kucherayvyy et al (2023) incorporate intermediate inputs in this framework. Bartelme, Costinot, Donaldson, and Rodriguez-Clare (2021) leverage scale economies as a rationale for industrial policy. I contribute to this general line of literature by applying my estimation to show how scale economies can impact pass-through.

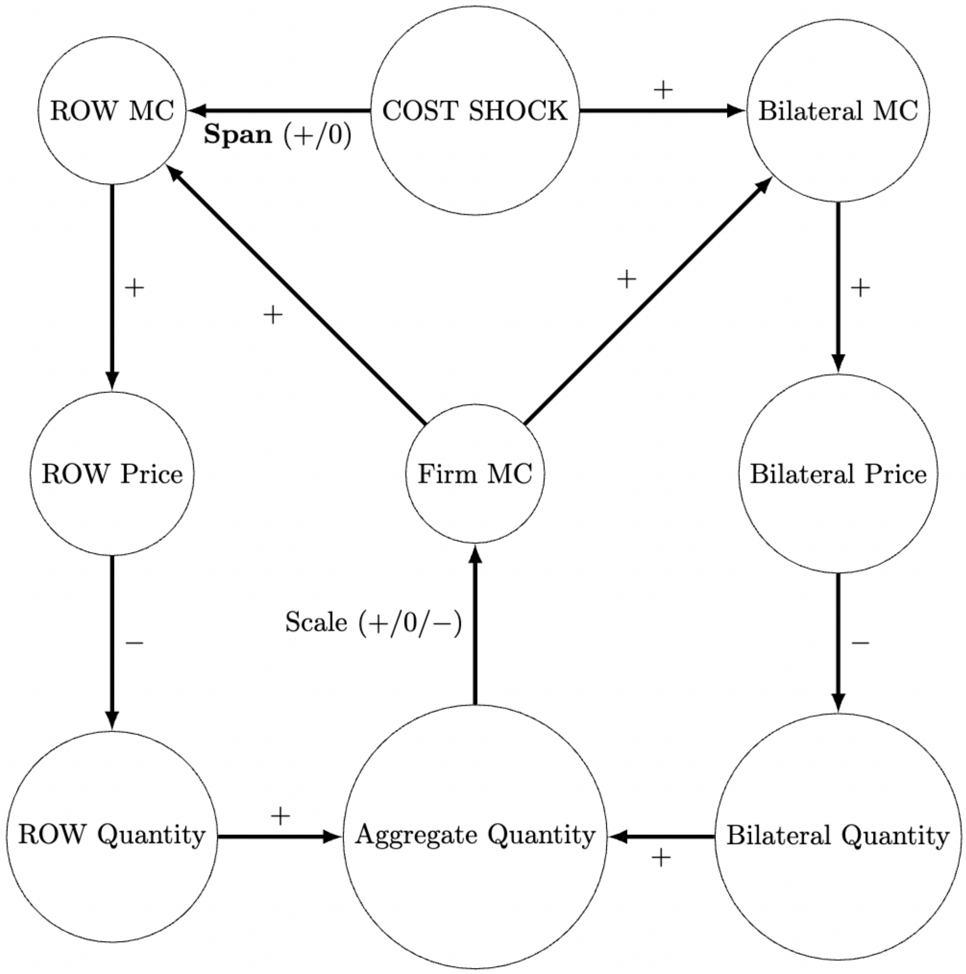
A final set of papers documents and explores why there was complete Trump tariff pass-through, namely Amiti, Redding, and Weinstein (2019, 2020), Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020), and Fajgelbaum and Khandelwal (2022). My paper answers this question by arguing that increasing returns rationalize the gap between flexible markups and the complete pass-through result.

In sum, there are five major contributions of this paper. First, I contribute to the literature interested in estimating the structural drivers of pass-through, the markup elasticity and the marginal cost scale function, by generating a novel methodology that only requires pass-through shocks and can jointly estimate both objects. I contribute to the literature estimating various channels of pass-through by quantifying the scale channel of pass-through. Third, I leverage my estimation to introduce a new means by which tariff and exchange rate pass-through may differ - shock span. Fourth, I contribute to the literature interested in implications of scale economies. Finally, I provide an answer to the complete pass-through of the Trump tariffs: scale economies paired with flexible markups generate one-hundred-percent pass-through in the long-run.

3 Structural Model of Pass-through

In this section I introduce my structural model. Figure 1 maps the dynamics of the scale channel. When a cost shock occurs, it shifts bilateral marginal costs, and total marginal costs endogenously evolve via the scale channel. Rest-of-world marginal costs also evolve via the shock span channel. In this section, I derive this dynamic leveraging the demand structure from Costinot, Donaldson, Kyle, and Williams (2019) and the pricing structure from Amiti, Itskhoki, and Konings (2019).

Figure 1: Scale Channel Dynamics



Note: Figure 1 maps the dynamics of the scale channel of pass-through. The mathematical symbols denote whether or not an object increases or decreases its destination. "Span" refers to **shock span.** A bilateral cost shock directly increases marginal costs and then indirectly adjusts them via the scale channel (unless there are constant returns). Rest-of-world marginal costs follow. **Shock span** governs whether or not rest-of-world also receives the bilateral shock.

3.1 Pricing Framework

I begin with a setup similar to the Amiti, Itskhoki, and Konings (2019) pricing framework. The accounting identity for exporter i's price for product p sold to country j at time t is given by

$$p_{ipjt} = mc_{ipjt} + \mu_{ipjt}, \tag{1}$$

where lowercases denote logs. This identity is a log markup μ_{ipjt} over log marginal cost mc_{ipjt}. Here, marginal cost is firm-product-specific, but may vary to each destination if there is an exchange rate or tariff shock. The markup is flexible and varies along the curvature of demand, where firms may absorb part of any cost shocks into the markup. As in Amiti et al (2019), totally differentiating this expression yields

$$dp_{ipjt} = dmc_{ipjt}\frac{d\mu_i(p_{ipjt};\zeta_{ipjt})}{dp_{ipjt}}dp_{ipjt} + \sum_{k\neq i}\frac{dM_i(p_{ipjt};\xi_{ipjt})}{dp_{kpjt}}dp_{kpjt} + \sum_{k=1}^{N}\frac{dM_i(p_{ipjt};\xi_{ipjt})}{d\xi_{kpjt}}d\xi_{kpjt}. \quad (2)$$

Then, the fixed point solution to the log price differential decomposition is given by

$$dp_{ipjt} = \frac{1}{1+\Gamma_{ipjt}}dmc_{ipjt} + \frac{\Gamma_{-ipjt}}{1+\Gamma_{ipjt}}dp_{-ipjt} + \epsilon_{ipjt}, \quad (3)$$

[2]

In the above equation, the definition of Γ_{ipjt} is

$$\Gamma_{ipjt} = -\frac{\partial M_{ijpt}(\mathbf{p}_{ipjt};\xi_{ipjt})}{\partial p_{ipjt}}, \quad (4)$$

where M_{ijpt} is the level markup and ξ_{ipjt} is the product-destination demand shock.

[3]

The price P_{ipjt} is a function of bilateral cost shifters and firm-specific marginal costs, and is of the form of Equation 3. Firm-specific marginal costs are given by

$$MC_{ipt} = C_{ipt}Q_{ipt}^{\nu_{ip}}. \quad (8)$$

In Equation 8, C_{ipt} is the firm's unit cost and ν_{ip} governs returns-to-scale. Bilateral marginal costs are given by

$$MC_{ipjt} = (1+t_{ipjt})\varepsilon_{ijt}MC_{ipt}. \quad (9)$$

Equation 8 requires the assumption that within marginal costs, unit cost and scale is firm-specific rather

[2] where as in Amiti et al (2019) the residual $\epsilon_{ipjt} = \frac{1}{1+\Gamma_{ipjt}}\sum_{k=1}^{N}\frac{\partial M_i(\mathbf{p}_{ipjt};\xi_{ipjt})}{\partial \xi_{kpjt}}d\xi_{kpjt}$ is the effective demand shock.

[3] Following Amiti et al (2019) I define the index of competitor price changes as

$$dp_{-ipjt} = \sum_{k\neq i}\omega_{fkpjt}dp_{kpjt}, \quad (5)$$

where

$$\omega_{fkpjt} = \frac{\partial M_{ipjt}(\mathbf{p}_{ipjt};\xi_{ipjt})/\partial p_{kpjt}}{\sum_{m\neq i}\partial M_{ipjt}(\mathbf{p}_{ipjt};\xi_{ipjt})/\partial p_{mpjt}}. \quad (6)$$

Define

$$\Gamma_{-ipjt} = -\sum_{k\neq i}\frac{\partial M_{ijpt}(\mathbf{p}_{ipjt};\xi_{ipjt})}{\partial p_{kpjt}}. \quad (7)$$

than destination-specific. This assumption implies that the marginal cost function I estimate will be a firm's average marginal cost function across all destinations.

I follow Amiti et al (2019) and write unit cost C_{ipt} as

$$C_{ipt} = \frac{V_{ipt}^{\phi_{ipt}} W_{ipt}^{1-\phi_{ipt}}}{A_{ipt}}, \tag{10}$$

where V_{ipt} is the imported input price index, W_{ipt} is the domestic input price index, ϕ_{ipt} is the share of expenditure on foreign intermediates, and A_{ipt} is firm productivity. I assume that the exchange rate and tariff is only correlated with the unit cost via the imported input price index V_{ipt}.

3.2 Demand Function

Aggregate firm quantities of a firm in country i, Q_i, are given by

$$Q_{ipt} = \sum_j Q_{ipjt} = Q_{ipjt} + \sum_{k \neq j} Q_{ipkt}, \tag{11}$$

Let bilateral quantities be function of country-specific demand shifters D_{ijp} and prices P_{ijp} and P_{jp}, the latter subject to a downward sloping function $D()$:

$$Q_{ipjt} = D_{ijp} D(\frac{P_{ipjt}}{P_{jpt}}). \tag{12}$$

Log linearizing Equation 12, we have

$$dq_{ipt} = \sum_j \alpha_{ipjt} \big(dt_{ijpt} + de_{ijt} + dc_{ipt} + \Gamma_{-ipjt} dp_{-ipjt} \big), \tag{13}$$

where

$$\alpha_{ipjt} = \underbrace{\frac{1}{1 - \sum_j \frac{\psi_{ipjt}\nu_{ip}(\sigma_{ipjt}+1)}{1+\Gamma_{ipjt}}}}_{General} \times \underbrace{\frac{\psi_{ipjt}(\sigma_{ipjt}+1)}{1+\Gamma_{ipjt}}}_{j-Specific}, \tag{14}$$

and

$$\sigma_{ipjt} = \frac{d \ln D(z)}{dz} \Big|_{z=\frac{P_{ijpt}}{P_{jpt}}}, \tag{15}$$

where I denote ψ_{ipjt} as country j's share in exporter i's sales of product p. The derivation is in the Appendix.

Imposing a system variable markups and a nested-CES demand structure, following Amiti, Itskhoki, and

Konings (2019), Krugman (1987), and Atkeson and Burstein (2008) implies the following functional form for the demand elasticity:

$$\sigma_{ipjt} = \left[\frac{1}{\eta} S_{ipjt} + \frac{1}{\rho}(1 - S_{ipjt})\right]^{-1}, \tag{16}$$

where S_{ipjt} is exporter i's market share in destination j's purchases of product p. In the above expression, η is the cross-industry and ρ is the within-industry elasticity of substitution, with $\eta \geq 1$ and $\rho > \eta$. Defining the markup as $\frac{\sigma_{ipjt}}{\sigma_{ipjt}-1}$, this gives the following definition of the markup elasticity:

$$\Gamma_{ipjt} = \frac{(\rho - 1)S_{ipjt}}{1 + \frac{\rho(\eta-1)}{(\rho-\eta)(1-S_{ipjt})}}. \tag{17}$$

Note that for $\eta = 1$ as in Cobb-Douglas this collapses to $\Gamma_{ipjt} = (\rho - 1)S_{ipjt}$.

3.3 Scale Channel Pass-through

Finally, I derive the pass-through regression equations. Substituting the definition of marginal costs into the pricing equation, denoting lowercases as logs, we have

$$dp_{ipjt} = \frac{1}{1+\Gamma_{ipjt}} dt_{ipjt} + \frac{1}{1+\Gamma_{ipjt}} de_{ijt} + \frac{1}{1+\Gamma_{ipjt}} dc_{ipt} + \frac{\nu_{ip}}{1+\Gamma_{ipjt}} dq_{ipt} + \frac{\Gamma_{-ipjt}}{1+\Gamma_{ipjt}} dp_{-ipjt} + \epsilon_{ipjt}, \tag{18}$$

where as in Amiti et al (2019) the error term ϵ_{ipjt} contains product-destination demand shocks ξ_{ipjt} (defined in Footnote 2 on Equation 3).

In the Appendix I include the motivating derivation of the scale channel of pass-through, substituting Equation 13 into Equation 18 above. Assuming imported input- and competitor-scale channels of tariff and exchange rate pass-through are second-order, (and noting that I am using product-, not firm-level data), I focus on the following decomposition of the scale channel of pass-through:

$$Scale^{e}_{ipt} = \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\alpha_{ipjt}}_{Bilateral} + \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\sum_{k\neq j}\alpha_{ipkt}\frac{de_{kt}}{de_{ijt}}}_{ShockSpan}, \tag{19}$$

and

$$Scale^{t}_{ipt} = \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\alpha_{ipjt}}_{Bilateral} + \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\sum_{k}\alpha_{ipkt}\frac{de_{kt}}{dt_{ijpt}}}_{ShockSpan}. \tag{20}$$

In the subsequent analysis I will estimate the structural components of these formulae, enabling me to quantify the bilateral, shock span, and overall scale channels of pass-through.

4 Data

The main data setting I employ is the Trump tariffs, from years April 2015 - April 2019. The base dataset I employ is from Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020), which estimates pass-through and quantity effects of those tariffs for imports and exports. This data also includes producer price and import price indices. I focus on the retaliatory tariffs, so that I can estimate the structural parameters for US exporting firms. I pair this data with monthly exchange rate information from Bloomberg. Altogether, this data enables me to estimate price and quantity effects of both tariffs and exchange rates.

I run my estimation at a 2-year horizon, estimating long differences in exchange rates and weighting the tariff shocks by time enacted. In the Appendix I include a figure of the tariff variation I exploit, originally drawn from Fajgelbaum et al (2020).

I employ the sectoral producer price index (PPI_{st}) as a proxy for C_{ipt}. This variable is originally drawn from the Bureau of Labor Statistics (BLS) database.[4] In the estimation section I discuss the market share data I employ to compute the markup elasticities.

Finally, I employ the following exports-to-sales correction: I employ data from the NBER-CES manufacturing database, which has information on NAICS-6 level sales. I construct a sales-to-exports weight from 2018 year data, and multiply aggregate quantities by this value to determine total sales. The correction is as follows:

$$Sales_{ipt} = \frac{Sales_{s,2018}}{Exports_{s,2018}} Exports_{ipt}. \tag{21}$$

In the main estimation, to minimize noise I impose a common weight of the mean of the sales-to-exports ratio, which is 1.43. However, in the Appendix I obtain a similar point estimate when using the raw weights.

In the next section, I discuss the motivational pass-through facts, and the structural estimation follows.

5 Pass-through

To motivate my analysis, I estimate long-run (two-year) tariff and exchange rate pass-through in US exports. To do so, I need to isolate exchange rates and tariffs from the demand shocks in the error term.

[4] I extract the data from the Fajgelbaum et al (2020) replication package.

Namely, I assume that within partner-sector and within product-time, the exchange rate is uncorrelated with the demand shocks in the error term. This assumption follows Amiti at al (2014) and Fajgelbaum et al (2020) and implies inclusion of partner-sector and product-time fixed effects in the pass-through regressions. Identification is based on measuring average price changes with respect to the exchange rate relative to partner-sector and product-time means. Following Equation 43 and Equation 44, the exchange rate pass-through regression takes the form

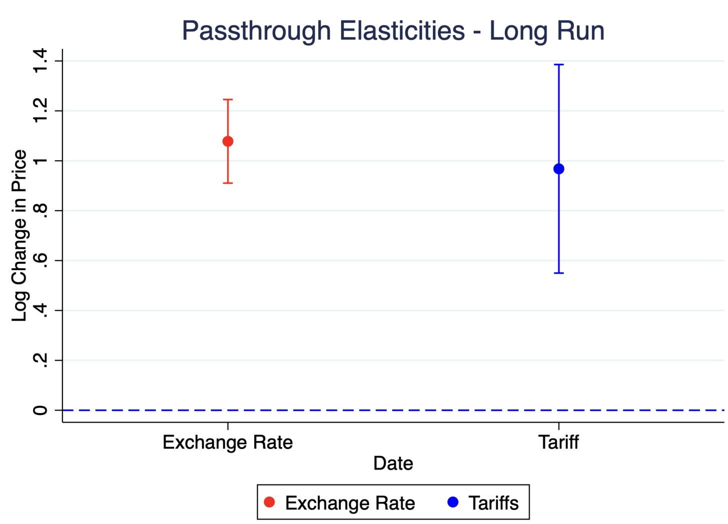
$$dp_{ipjt} = \eta^{e}_{ipjt} de_{ijt} + \xi_{ijs} + \xi_{ipt} + \bar{\varepsilon}_{ipjt}, \tag{22}$$

Next, I assume that within partner-sector, product-time, and partner-time, tariffs are uncorrelated with the demand shocks in the error term. This follows Fajgelbaum et al (2020) and implies inclusion of partner-sector, product-time, and partner-time fixed effects in the pass-through regressions. Identification is based on measuring average price changes with respect to tariffs relative to these means. Then the desired pass-through regression is

$$dp_{ipjt} = \eta^{t}_{ipjt} dt_{ipjt} + \xi_{ijt} + \xi_{ipt} + \xi_{ijs} + \tilde{\varepsilon}_{ipjt}, \tag{23}$$

With this estimation strategy, I find the following results for tariff and exchange rate pass-through:

Figure 2: 2-year Tariff and Exchange Rate Pass-through, US Exports



Note: 2-year exchange rate (left, red) and tariff (right, blue) pass-through in US Exports. Estimation sample 2013m4-2019m4 at 2-year intervals. Tariff shocks weighted by duration in effect. Regression equations 22 and 23.

I find evidence of complete pass-through of both tariffs and exchange rates at the 2-year horizon. As discussed earlier, this fact is puzzling in light of the literature's evidence of positive markupelasticities (and therefore flexible markups). In the next section, I will estimate the structural components of pass-through, the markup elasticity and the scale elasticity, then quantify the markup and scale components of pass-through to answer this puzzle.

6 Estimation

To extract the markup elasticity and scale elasticity, I employ a two-step estimation process. In the first step, I measure the markup elasticity using an Atkeson-Burstein model structure, and data on market shares. I employ this approach because I can then compute product-destination specific markupelasticities. Given these values, in the second step I isolate the scale function and estimate the scale elasticity via an instrumental-variables approach. I describe each step in detail in the next two sections. For robustness, in the Appendix I alternatively estimate a pooled markup elasticity using a fixed-effects approach, then estimate the scale elasticity in the same way.

6.1 Step 1: Atkeson-Burstein

Following Krugman (1987), Atkeson and Burstein (2008), and Amiti, Itskhoki, and Konings (2019), I impose a nested-CES demand structure, with oligopolistic competition and flexible markups. In such a framework, firms compete within a narrow industry where goods are highly substitutable (elasticity ρ) as a part of a broader industry where goods are less substitutable (elasticity $\eta < \rho$). Defining the market share of exporter i of firm j's purchases of product p as S_{ipjt}, we have a functional form for the demand elasticity:

$$\sigma_{ipjt} = \left[\frac{1}{\eta}S_{fpjt} + \frac{1}{\rho}(1 - S_{ipjt})\right]^{-1}, \tag{24}$$

and for the markup elasticity:

$$\Gamma_{fpjt} = \frac{(\rho - 1)S_{ipjt}}{1 + \frac{\rho(\eta-1)}{(\rho-\eta)(1-S_{ipjt})}}. \tag{25}$$

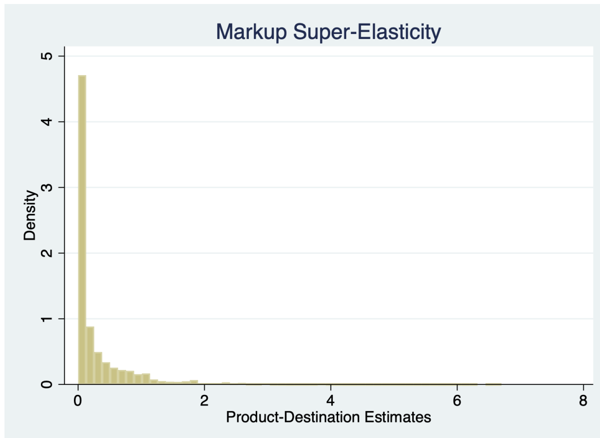
To compute market shares, I employ Atlas of Economic Complexity data for global product-level imports. I compute the US's share in each destination's product-level purchases, and correct for total purchases using the imports-to-GDP ratio from the World Bank.

$$S_{ipjt} = \frac{Imports_{ijpt}}{Imports_{ijpt}} \times \frac{Imports_{ijt}}{GDP_{ijt}} \tag{26}$$

Next, following Amiti, Itskhoki, and Konings (2019) I assume the broader environment is Cobb-Douglas, so $\eta = 1$. Given this and the optimal markup $M_{ipjt} = \frac{\sigma_{ipjt}}{\sigma_{ipjt}-1}$, I compute the necessary ρ to match the mean markup from De Loecker (2016), which is 1.6. This method implies a $\rho = 3.25$.

Given this calibration, I find the following distribution of markup elasticities:

Figure 3: Markup Elasticity



In this computation, the average markup elasticity is 0.16, implying marginal cost pass-through of 86%. In the next section, I employ these values to isolate the scale function and estimate the scale elasticity.

I note that in the Appendix I include the distribution of demand elasticities. I find the average demand elasticity is $\sigma_{ipjt} = -2.8$. Also in the Appendix I include the distribution of the markup elasticities with counterfactual values of ρ. Increasing the value of ρ increases the implied super-elasticity and lowers the realized pass-through rate.

6.2 Step 2: Scale Elasticity

A challenge with estimating the scale elasticity is that aggregate quantities are endogenous to prices. Accordingly, from Equation 13 I employ the sales-share-weighted sum of tariff shocks as an instrument for total quantities. The advantage and exclusion restriction of this approach is that the rest-of-world shocks do not directly affect bilateral prices except through their impact on total output. I follow Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020) in including the bilateral tariff as an instrument for prices.

In practice, given this instrumental variables strategy I estimate a modified $\hat{dp}_{ipjt}$ which is given by

$$\hat{dp}_{ipjt} = (1 + \Gamma_{ipjt})dp_{ipjt} - de_{ijt} - dt_{ipjt} - dc_{ipt}. \tag{27}$$

This enables me to directly estimate the scale elasticity off of the instrumental variables approach described above. The regression equation is given by

$$\hat{dp}_{ipjt} = \nu_{ip} dq_{ipt} + \zeta_{ijt} + \zeta_{ijs}. \tag{28}$$

Thus in this two-step approach I can extract both the markup elasticity and the marginal cost scale elasticity. The estimated scale elasticity is given in Table 1 below.[5] I estimate a scale elasticity of -0.65, implying strong increasing returns-to-scale.

Table 1: Estimation - 2 year horizon

	(1)
	dp_{ipjt}
ν_{ip}	-0.651**
	(0.298)
Country-Time FE	Y
Country-Sector FE	Y
R^2	0.02
N	130347

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Robust standard errors in parentheses, clustered by product and destination. Estimation of Equation 28. Regression of product-destination prices weighted by the markup super-elasticity and cost shocks on product-level quantities, instrumented using the sales share-weighted sum of global tariff shocks. Estimation at 2-year horizon from 2013m4 to 2019m4. Tariff shocks weighted by duration in effect.

In the Appendix I include estimates for shorter-run horizons, namely 1-month and 6-month intervals. In that analysis, I find that scale economies increase over time: in the very short-term, there are decreasing returns-to-scale but as time passes production develops into increasing returns. Intuitively, in the short-run there may be fixed costs of production generating decreasing returns, but that over time firms learn and improve production processes as output increases.

Also in the Appendix I include the values of the scale elasticity generated by the counterfactual values of ρ. As discussed in the previous section, increasing the substitutability of goods in the narrow sector raises the markup elasticity, implying greater scale elasticities.

7 Quantification

In this section, I leverage my structural model to quantify the scale- and markup channels of pass-through. This exercise is of interest, to determine how much each channel contributes to pricing decisions. I first note that I find evidence of flexible markups but also complete long-run pass-through. The scale effects must therefore account for this discrepancy.

As derived in the model in Section 3, the scale channel can be decomposed into a bilateral scale component and a shock span scale component.

[5] I note that Equation 28 calls for exporter-importer-time and exporter-importer-sector fixed effects, but the estimation table reports country-time and country-sector fixed effects because there is only one exporter in the sample (the US).

$$Scale_{ipjt} = \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\alpha_{ipjt}}_{Bilateral} + \underbrace{\frac{\nu_{ip}}{1+\Gamma_{ipjt}}\sum_{k\neq j}\alpha_{ipkt}\frac{de_{ikt}}{de_{ijt}}}_{ShockSpan} \tag{29}$$

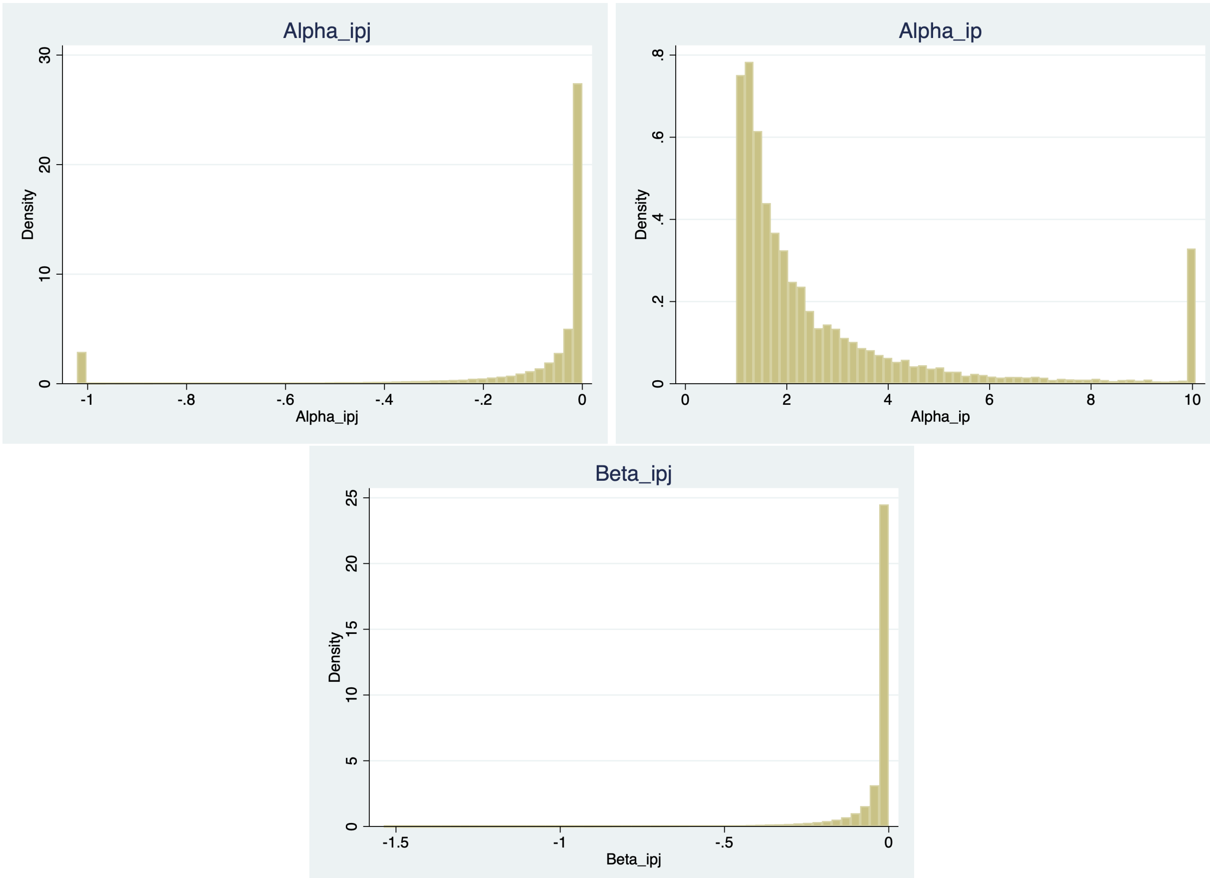
I employ the estimates of Γ_{ipjt} and ν_{ip} to quantify this number. The next step is to estimate α_{ipjt} for each importer j. Recall the definition:

$$\alpha_{ipjt} = \underbrace{\frac{1}{1-\sum_j \frac{\psi_{ipjt}\nu_{ip}(\sigma_{ipjt}+1)}{1+\Gamma_{ipjt}}}}_{\alpha_{ipt}=General} \times \underbrace{\frac{\psi_{ipjt}(\sigma_{ipjt}+1)}{1+\Gamma_{ipj}}}_{\beta_{ipjt}=j-Specific}, \tag{30}$$

where again ψ_{ipjt} is the sales share of importer j in exporter i's sales of product p. This is observable in the trade data, with the same correction for domestic sales. σ_{ipjt} can be quantified using the Atkeson-Burstein formulation from Equation 24. Given this process, the average $\alpha_{ipjt} = -0.10$. Intuitively, an 100% increase in an individual cost shock lowers aggregate quantities by 10%.

I plot the distribution of α_{ipjt} below. Note that as in Equation 30 this parameter can be broken up into a general exporter-product term (α_{ipt}) and a destination-specific term (β_{ipjt}). This decomposition will be later useful to quantify the shock span component of scale effects.

Figure 4: Distributions of α_{ipjt}, α_{ipt}, and β_{ipjt}



Note: Distributions of α_{ipjt}, α_{ipt}, and β_{ipjt}. Values winsorized at 5% tails.

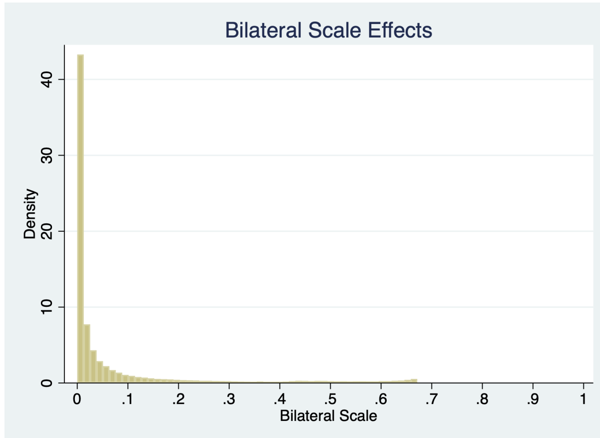
7.1 Bilateral Scale Effects

The bilateral scale component of pass-through is given by

$$BilateralScale_{ipjt} = \frac{1}{1 + \Gamma_{ijpt}} \nu_{ip} \alpha_{ipjt} \tag{31}$$

Using the distributions of the structural objects from the previous section, I estimate the following distribution of bilateral scale effects in pass-through:

The average bilateral scale contribution to pass-through is 6%. Recalling that the estimated markup elasticities imply an average marginal cost pass-through of 86%, the estimated bilateral scale effects bring the quantification to 92%, closer to complete. The shock span estimation in the previous section will then fully rationalize estimated pass-through with the structural objects.



7.2 Shock Span

The shock span term of pass-through is given by

$$ShockSpan_{ipjt} = \frac{\nu_{ip}}{1+\Gamma_{ipjt}} \sum_{k \neq j} \alpha_{ipkt} \frac{de_{ikt}}{de_{ijt}}. \tag{32}$$

Estimating this object requires the regression of each rest-of-world shock on the bilateral shock. In practice, this is very difficult to estimate due to dimensionality, so following the breakdown in Equation 30 I redefine the pricing equation as follows:

$$dp_{ipjt} = \frac{1}{1+\Gamma_{ipjt}} \Big[de_{ijt} + dt_{jpt} + dc_{ft} + \Gamma_{-ipjt} dp_{-ipjt} \Big] + \\ \frac{\nu_{ip}}{1+\Gamma_{ipjt}} \alpha_{ipt} \sum_{j} [\beta_{ipjt} de_{ijt} + \beta_{ipjt} dt_{ijpt} + \beta_{ipjt} dc_{ipt} + \beta_{ipjt} \Gamma_{-ipjt} dp_{-ipjt}] \tag{33}$$

By the laws of covariance and the omitted variable bias formula, the objects to estimate are $\frac{Cov(de_{ijt}, \sum_k \beta_{ipk} de_{ikt})}{Var(de_{ijt})}$ and $\frac{Cov(dt_{ijpt}, \sum_k \beta_{ipk} dt_{ijkt})}{Var(dt_{ijpt})}$. This simply the regression of the weighted sum of shocks on the bilateral shock. The implied shock span formulas are given by

$$ShockSpan^{t}_{ipjt} = \frac{1}{1+\Gamma_{ipjt}} \nu_{ip} \alpha_{ipt} \frac{Cov(dt_{ipjt}, \sum_k \beta_{ipk} dt_{ipkt})}{Var(dt_{ipjt})}, \tag{34}$$

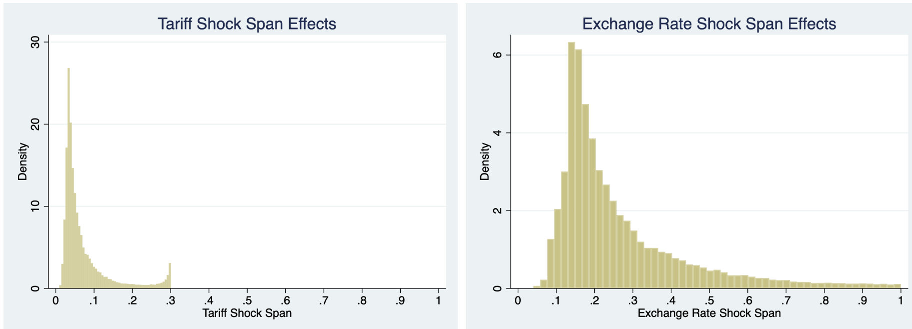
and

$$ShockSpan^{e}_{ipjt} = \frac{1}{1+\Gamma_{ipjt}} \nu_{ip} \alpha_{ipt} \frac{Cov(de_{ijt}, \sum_k \beta_{ipk} de_{ikt})}{Var(de_{ijt})}. \tag{35}$$

The weighted sum regression for the tariff term is approximately -0.04, and for exchange rates -0.2.

This gives the following shock span distributions:

Figure 5: Shock Span, Tariffs and Exchange Rates



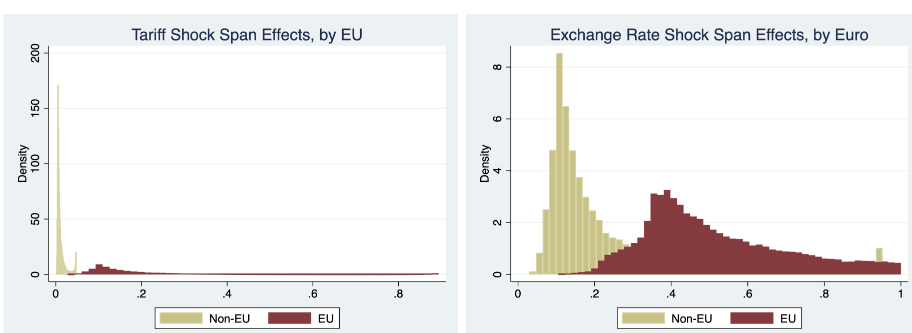
Note: Shock span distributions for tariffs (left) and exchange rates (right), calculated using equations **??** and **??**.

The average tariff shock span is 5% and exchange rates is 23%. Incorporating the markup effects, this implies total tariff pass-through of 97% and exchange rate pass-through of 115%. Given I estimate approximate complete pass-through, my estimation closely matches the tariff value and slightly over-approximates the exchange rate value. However, as in Fitzgerald and Haller (2018) it is possible that exchange rates have smaller effects on quantities, so that with an adjusted demand elasticity my estimates match the 100% value.

7.2.1 Heterogeneity: European Union

The European Union (EU) is an interesting test case because (1) the EU imposes a common tariff, in particular a common retaliatory tariff against the United States and (2) the Eurozone is a common currency. Thus, shocks against one EU country is highly correlated with other shocks to European countries. As an exercise, I test whether EU countries have higher shock span than other countries. Indeed, that is what I find; in Figure 6 below I estimate that the EU has higher tariff and exchange rate shock span, driven by higher levels of correlation in the shocks.

Figure 6: Shock Span - EU Heterogeneity



Note: Tariff (left) and exchange rate (right) shock span estimated for EU (red) and non-EU (yellow) countries. The tariff EU sample contains EU-member countries, and the exchange rate EU sample contains Eurozone countries.

8 Conclusion

In this paper, I first document the puzzling facts that over a 2-year horizon, both tariff and exchange rate pass-through are complete in US exports. This is puzzling because earlier work has found evidence of flexible markups, which would suggest pass-through less than one. I show that increasing returns-to-scale in marginal costs can pair with markup flexibility to bring pass-through to completion. I develop the scale channel of pass-through, decomposing it into bilateral and rest-of-world "shock span" scale effects. Altogether, scale economies rationalize the complete pass-through puzzle.[6]

After documenting the complete pass-through facts, I turn to estimating the structural components of a firm's pricing decision: the markup elasticity and the marginal cost scale elasticity. I estimate the former with an Atkeson-Burstein (2008) approach, employing a nested-CES demand structure and data on market shares. Armed with a distribution of this parameter, I estimate a general scale elasticity, finding evidence of strong increasing returns. Then, given this, I quantify the scale channel of pass-through for tariffs and exchange rates, finding a microfoundation for complete pass-through.

I document that shock span, how the correlation patterns of shocks enter pass-through via scale economies, is a key component into prices. Simply focusing on bilateral scale effects would understate the scale channel. Furthermore, because exchange rate shocks tend to be more correlated across trading partners than tariffs (e.g. from a monetary shock versus tariffs on only China), exchange rates tend to have larger shock span effects than tariffs. Finally, I document that countries in the European Union and the Eurozone, given a common tariff and a common currency, have higher shock span effects than other countries given the high correlation of shocks.

My estimates lend themselves to computing a welfare analysis of the Trump tariffs and US-China trade war. Namely, Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020) document a 7.2 billon dollar equivalent-variation loss in welfare due to the retaliatory tariffs by computing the effective change in the export price index. However, this number assumes constant markups and constant returns. I estimate that marginal costs increased 13%, so that the true loss from the retaliatory tariffs was approximately 8.15 billion, and 0.045 percent of GDP. This exercise suggests that quantifying the underlying structural pricing parameters has important implications for welfare analysis.

In sum, in this paper I document surprising complete pass-through facts in light of evidence of flexible markups, then estimate the structural pricing components to quantify the markup and scale channels of pass-through. I show that scale economies can rationalize markup flexibility with complete pass-through, and introduce a novel channel of pass-through (shock span). There is rich potential for future work understanding

[6] A term coined by Fajgelbaum and Khandelwal (2022).

how structural pricing components apply to trade and international macroeconomics questions.

References

[1] Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2014. ”Importers, Exporters, and Exchange Rate Disconnect.” American Economic Review, 104 (7): 1942-78.

[2] Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2019. The Review of Economic Studies, 86(6): 2356–2402.

[3] Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2022. “Dominant Currencies: How Firms Choose Currency Invoicing and Why it Matters.” National Bureau of Economic Research. https://doi.org/10.3386/w27926

[4] Arkolakis, Costas, and Monica Morlacco. 2017. ”Variable demand elasticity, markups, and pass-through.” Manuscript, Yale University.

[5] Berry, Steven, James Levinsohn, and Ariel Pakes. 1995. ”Automobile prices in market equilibrium.” Econometrica: Journal of the Econometric Society 841-890.

[6] Cavallo, Alberto, Gita Gopinath, Brent Neiman, and Jennifer Tang. 2021. “Tariff Pass-through at the Border and the Store: Evidence from US Trade Policy.” American Economic Review: Insights, forthcoming.

[7] Chow, Melissa, Christopher Goetz, Nathan Goldschlag, James Lawrence, Elisabeth Ruth Perlman, Martha Stinson, and T. Kirk White. 2021. “Redesigning the Longitudinal Business Database.” CES Working Paper 21-08.

[8] Costinot, Donaldson, Kyle, and Williams. 2019. “The More We Die, The More We Sell? A Simple Test of the Home-Market Effect.” The Quarterly Journal of Economics, 134(2): 843-894.

[9] Pablo Fajgelbaum, Pinelopi Goldberg, Patrick Kennedy, Amit Khandelwal, and Daria Taglioni. “Global Reallocations in the 2018-19 Trade War.” Working paper.

[10] Gopinath, Gita, and Oleg Itskhoki. 2011. “In Search of Real Rigidities.” NBER Macroeconomics Annual 2010. Vol 25. Chicago: University of Chicago Press.

[11] Gopinath, Gita, Pierre-Olivier Gourinchas, Chang-Tai Hsieh, and Nicholas Li. 2011. “International Prices, Costs, and Mark-up differences.” American Economic Review 101 (6): 2450-86.

[12] Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon. 2010. “Currency Choice and Exchange Rate Pass-through.” American Economic Review 100 (1): 304-336.

[13] Gopinath, Gita, and Oleg Itskhoki. 2010. “Frequency of Price Adjustment and Pass-through.” Quarterly Journal of Economics 125 (2): 675-727.

[14] Gopinath, Gita, and Roberto Rigobon. 2008. “Sticky Borders.” Quarterly Journal of Economics 123 (2): 531-575.

[15] Klenow, Peter J., and Jonathan L. Willis. ”Real rigidities and nominal price changes.” FRB of Kansas City Working Paper No. RWP06-03 (2006).

[16] Nakamura, Emi, and Dawit Zerom. ”Accounting for incomplete pass-through.” The Review of Economic Studies 77.3 (2010): 1192-1230.

A Derivations

This section contains derivations from the main text. Section A.1 derives Equation 13 from Section 3.2; Section A.2 derives the scale channel of pass-through from Section 3.3.

A.1 Equation 13 [Section 3.2]

Log linearizing Equation 12, we have

$$\begin{aligned}\ln Q_{ipjt} = \ln D_{ijp} - \ln D + &\\ \sigma_{ipjt}\Big(\ln(1+t_{ijpt}) + \ln e_{ijt} + \mu_{ipjt} + \ln C_{ipt} + \nu_{ip}\ln Q_{ipt} - \ln(1+t) - \ln e\Big) + &\\ \ln(1+t_{ij}) - \ln(1+t) + \ln e_{ij} - \ln e + \ln C_i + \nu_{ip}\ln Q_i. &\end{aligned} \tag{36}$$

I note that the markup is flexible so the price adjustment is a function of the markup elasticity; I substitute Equation 2 to adjust for the markup:[7]

$$\begin{aligned}\ln Q_{ipjt} = \ln D_{ijp} - \ln D + &\\ \frac{1}{1+\Gamma_{ipjt}}\Bigg(\sigma_{ipjt}\Big(\ln(1+t_{ijpt}) + \ln e_{ijt} + \ln C_{ipt} + \nu_{ip}\ln q_{ipt} + \Gamma_{-ipjt}dp_{-ipjt} - \ln(1+t) - \ln e\Big) + &\\ \ln(1+t_{ij}) - \ln(1+t) + \ln e_{ij} - \ln e + \ln C_i + \nu_{ip}\ln Q_i + dp_{-ipjt}\Bigg). &\end{aligned} \tag{37}$$

Estimating in changes, letting lowercases represent logs, and approximating $dq_{ipt} = \sum_j \psi_{ipjt} dq_{ipjt}$, where $\psi_{ipjt} = \frac{Q_{ipjt}}{Q_{ipt}}$, I can rewrite Equation 37 as

$$\begin{aligned}dq_{ipt} = \sum_j \psi_{ipjt}\frac{1}{1+\Gamma_{ipjt}}\Bigg(\sigma_{ipjt}\big(dt_{ijpt} + de_{ijt} + dc_{ipt} + \nu_{ip}dq_{ipt} + \Gamma_{-ipjt}dp_{-ipjt}\big) + &\\ dt_{ijpt} + de_{ijt} + dc_{ipt} + \nu_{ip}dq_{ipt} + \Gamma_{-ipjt}dp_{-ipjt}\Bigg), &\end{aligned} \tag{38}$$

where σ_{ipjt} is

[7] I assume that strategic complementarities are second-order.

$$\sigma_{ipjt} = \frac{d \ln D(z)}{dz}\Big|_{z=\frac{P_{ipjt}}{P_{pjt}}}, \tag{39}$$

and I assume the demand shifter is constant as are the steady-state terms. Rearranging, we have

$$dq_{ipt}(1 - \sum_{ipj} \frac{\psi_{ipjt}}{1+\Gamma_{ipjt}} \nu_{ip}(\sigma_{ipjt}+1)) = \sum_{jp} \psi_{ipjt} \frac{1}{1+\Gamma_{ipjt}} \Big(\sigma_{ipjt}\big(dt_{ipjt}) + de_{ijt} + dc_{ipt} + \Gamma_{-ipjt} dp_{-ipjt}\big) + \\ dt_{ijpt} + de_{ijt} + dc_{ipt} + \Gamma_{-ipjt} dp_{-ipjt} \Big). \tag{40}$$

The solution is given by

$$dq_{ipt} = \sum_j \alpha_{ipjt} \big(d \ln(1 + t_{ipjt} + de_{ijt} + dc_{ipt} + \Gamma_{-ipjt} dp_{-ipjt} \big), \tag{41}$$

where

$$\alpha_{ipjt} = \underbrace{\frac{1}{1 - \sum_j \frac{\psi_{ipjt}\nu_{ip}(\sigma_{ipjt}+1)}{1+\Gamma_{ipjt}}}}_{General} \times \underbrace{\frac{\psi_{ipjt}(\sigma_{ipjt}+1)}{1+\Gamma_{ipjt}}}_{j-Specific}, \tag{42}$$

where ψ_{ipjt} is the sales share of destination j in exporter i's sales of product p.

A.2 Deriving Scale Channel of Pass-through

Substituting the derivation in Section 3.2 into Equation 18, we have

$$dp_{ipjt} = \frac{1}{1+\Gamma_{ipjt}} dt_{ipjt} + \frac{1}{1+\Gamma_{ipjt}} de_{ijt} + \frac{1}{1+\Gamma_{ipjt}} dc_{ipt} + \frac{\nu_{ip}}{1+\Gamma_{ipjt}} \Bigg(\sum_j \alpha_{ipjt} \big(d \ln t_{ijpt} + de_{ijt} + dc_{ipt} + \Gamma_{-ipjt} dp_{-ipjt} \big) \Bigg) + \frac{\Gamma_{-ipjt}}{1+\Gamma_{ipjt}} dp_{-ipjt} + \epsilon_{ipjt}. \tag{43}$$

Differentiating Equation 43 with respect to exchange rates and tariffs yields:

$$\frac{dp_{ipjt}}{de_{ijt}} = \frac{1}{1+\Gamma_{ipjt}} + \frac{1}{1+\Gamma_{ipjt}} \frac{dc_{ipt}}{de_{ijt}} + \frac{\nu_{ip}}{1+\Gamma_{ipjt}} (\alpha_{ipjt} + \sum_{k \neq j} \alpha_{ipkt} \frac{de_{kt}}{de_{ijt}} + \sum_j \alpha_{ipjt} \frac{dc_{ipt}}{de_{ijt}} + \sum_j \alpha_{ipjt} \Gamma_{ipjt} \frac{dp_{-ipjt}}{de_{ijt}}) + \frac{\Gamma_{-ipjt}}{1+\Gamma_{ipjt}} \frac{dp_{-ipjt}}{de_{ijt}} + \frac{d\varepsilon_{ipjt}}{de_{ijt}}, \tag{44}$$

where I assume $\frac{dt_{ijpt}}{de_{ijt}} = 0$, and

$$\frac{dp_{ipjt}}{dt_{ijt}} = \frac{1}{1+\Gamma_{ipjt}} + \frac{1}{1+\Gamma_{ipjt}} \frac{dc_{ipt}}{dt_{ijpt}} + \frac{1}{1+\Gamma_{ipjt}} \frac{de_{ijt}}{dt_{ijpt}} + \frac{\nu_{ip}}{1+\Gamma_{ipjt}} (\alpha_{ipjt} + \sum_k \alpha_{ipkt} \frac{de_{kt}}{dt_{ijpt}} + \sum_k \alpha_{ipkt} \frac{dc_{ipt}}{dt_{ijpt}} + \sum_j \alpha_{ipjt} \Gamma_{ipjt} \frac{dp_{-ipjt}}{dt_{ijpt}}) + \frac{\Gamma_{-ipjt}}{1+\Gamma_{ipjt}} \frac{dp_{-ipjt}}{dt_{ijpt}} + \frac{d\varepsilon_{ipjt}}{dt_{ijpt}}. \tag{45}$$

B Tariff Variation

Table 2: Table I - Fajgelbaum, Goldberg, Kennedy, and Khandelwal (202)

	(1)	(2)	(3)	(4)	(5)	(6)
panel A: US Tariffs						
Tariff Wave	Date Enacted	Products	2017 Imports (Millions)	2017 Import Share	Tariff Rate 2017	Tariff Rate 2018
Solar Panels	Feb 7, 2018	8	5782 0.2	0	30	
Washing Machines	Feb 7, 2018	8	2105	0.1	1.3	32.2
Aluminum	Mar-Jun, 2018	67	17685	0.7	2	12
Iron and Steel	Mar-Jun, 2018	753	30523	1.3	0	25
China 1	Jul 6, 2018	1672	33510	1.4	1.3	26.2
China 2	Aug 23, 2018	433	14101	0.6	2.7	27
China 3	Sep 24, 2018	9102	199264 8.3	3.3	12.9	
Total		**12,043**	**302,970**	**12.7**	**2.6**	**16.6**
panel B: Retaliatory Tariffs						
Country	Date Enacted	Products	2017 Exports (Millions)	2017 Export Share	Tariff Rate 2017	Tariff Rate 2018
China	Apr-Sep, 2018	7474	92518	6	8.4	18.9
Mexico	Jun 5, 2018	232	6746 0.4	9.6	28	
Turkey	Jun 21, 2018	244	1554	0.1	9.7	31.8
European Union	Jun 22, 2018		303	8244 0.5	3.9	29.2
Canada	Jul 1, 2018	325	17818	1.2	2.1	20.2
Russia	Aug 6, 2018	163	268	0	5.2	36.8
Total		**8,073**	**127,149**	**8.2**	**7.3**	**20.4**

Notes from Fajgelbaum, Goldberg, Kennedy, and Khandelwal (2020): Panels display unweighted monthly HS-10 country average statutory tariff rates. 2017 tariff rates are computed as the annual average; 2018 tariff rates are computed using data from December 2018. Total tariff rates are computed as the trade-weighted average of table row values. The denominator for import (export) share is the total 2017 annual US$ value of all U.S. imports (exports). The U.S. government announced import tariffs on aluminum and steel products on March 23 but granted exemptions for Canada, Mexico, and the European Union; those exemptions were lifted on June 1. The dates of Chinese retaliations are April 6, July 2, August 23, and September 24.

C Alternative Estimation

C.1 Step 1: Markup Elasticity

As an alternative to the Atkeson-Burstein approach, I extract the markup elasticity using tariff and exchange rate pass-through. I assume that within country-sector and within year, the exchange rate is orthogonal to the demand shocks in the error term (following Amiti et al (2014)). I also assume that within country-sector, country-time, and product-time, the tariff is orthogonal to demand shocks in the error term (following Fajgelbaum et al (2020)). Furthermore, following the model in Section 3 I assume that after controlling for the fixed effects the pass-through coefficients for tariffs and exchange rates are the same. Accordingly, I restrict the two shocks to have the same coefficient (and a singular markup elasticity). The estimation design is as follows:

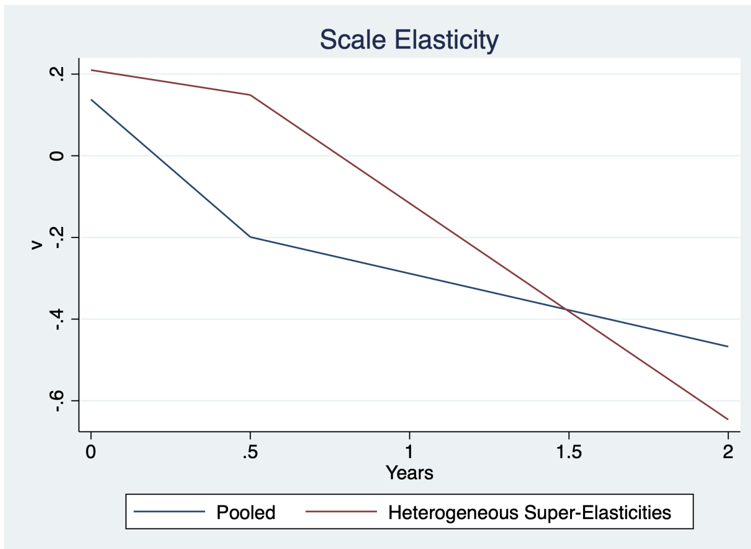
$$dp_{ipjt} = \frac{1}{1+\Gamma_{ipjt}}\left(de_{ijt} + dt_{ipjt}\right) + \zeta_{ipt} + \zeta_{ijt} + \zeta_{ijs}. \tag{46}$$

The fixed effect ζ_{ipt} effectively controls for unit costs c_{ipt} and scale Q_{ipt}. Thus Equation 46 extracts the Γ_{ipjt} coefficient, which informs the estimation of the scale elasticity ν_{ip} in the next step.

D Dynamics

I plot the dynamics of these parameters, using both the method in the main text and also the alternative method from the previous section. I find that, using both methods, economies of scale are increasing over time. Namely, in the short-run, there are decreasing returns, but in the long-run, there are increasing returns.

Figure 7: Marginal Cost Scale Elasticity ν_{ip}



Note: Marginal cost scale function ν_{ip} estimated using the methodology from Section 6 (red) and Appendix Section C (blue). Estimation tables can be found in the Appendix.

It implies that in the short run, falling quantities as a result of cost shocks with decreasing returns-to-scale implies cheaper production and lower prices. In the long run, with increasing returns the falling quantities reduces economies of scale, pushing up prices.

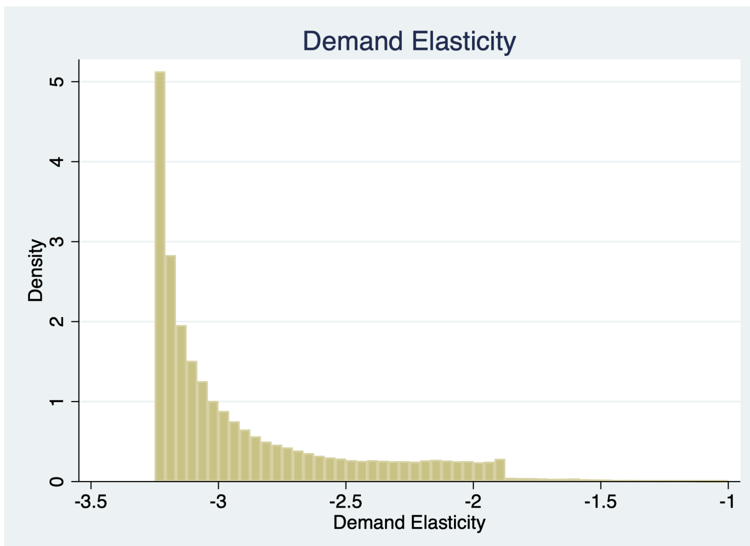
E Demand Elasticity Distribution

From Atkeson and Burstein (2008) I define the demand elasticity as

$$\sigma_{ipjt} = \left[\frac{1}{\eta}S_{ipjt} + \frac{1}{\rho}(1 - S_{ipjt})\right]^{-1}. \tag{47}$$

I calibrate $\eta = 1$ (Cobb-Douglas, following Amiti, Itskhoki, and Konings (2019)), then match the implied markup to De Loecker data, in which the average markup is 1.6 to estimate a $\rho = 3.3$. This calibration, in addition to the estimated market shares from Section 6.1, generates the following distrubtion of demand elasticities σ_{ipjt}:

Figure 8: Distribution of Demand Elasticities



I note that the average elasticity is -2.8.

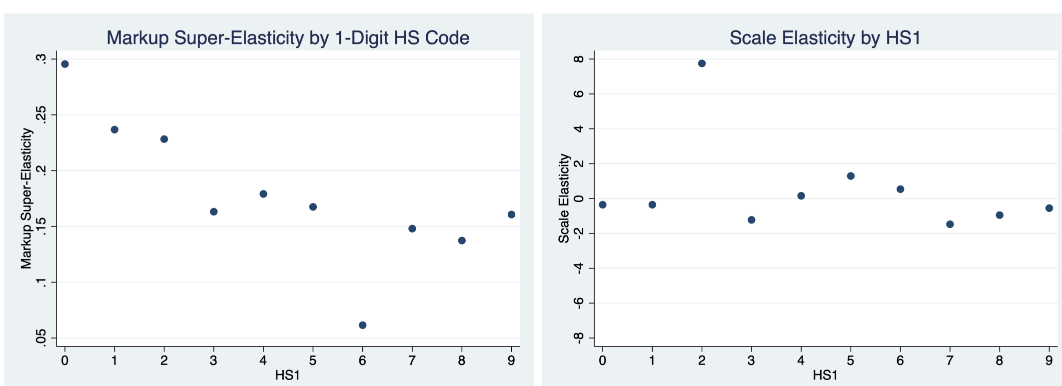
F Industry Heterogeneity

In this section, I estimate heterogeneous markup and scale elasticities by 1-digit HS codes. I define the following HS codes:

- 0 - raw food products
- 1 - processed food products
- 2 - raw minerals
- 3 - processed minerals
- 4 - manufactured materials (rubber, leather, wood, cork etc)
- 5 - fabrics
- 6 - apparel
- 7 - metals
- 8 - machinery
- 9 - optics; arms; furniture; instruments; toys; art; miscellaneous manufacturing

Then I estimate the following distribution of markup and scale elasticities:

Figure 9: Markup Elasticity and Scale Elasticity by HS1



G Full Sales Weighting

In this section, I estimate ν_{ip} using the full NBER-CES manufacturing weights to convert exports to sales. Recall in the main text I estimate $\nu_{ip} = -.65$ by using the median conversion weight of 1.43. In this analysis, I obtain $\nu_{ip} = -.7$.

Table 3: Direct Estimation Method - 2 year horizon - Full Sales Weight

	(1)
	dl_P
dlq1fw2	-0.703*
	(0.362)
R^2	0.01
N	130347

Standard errors in parentheses

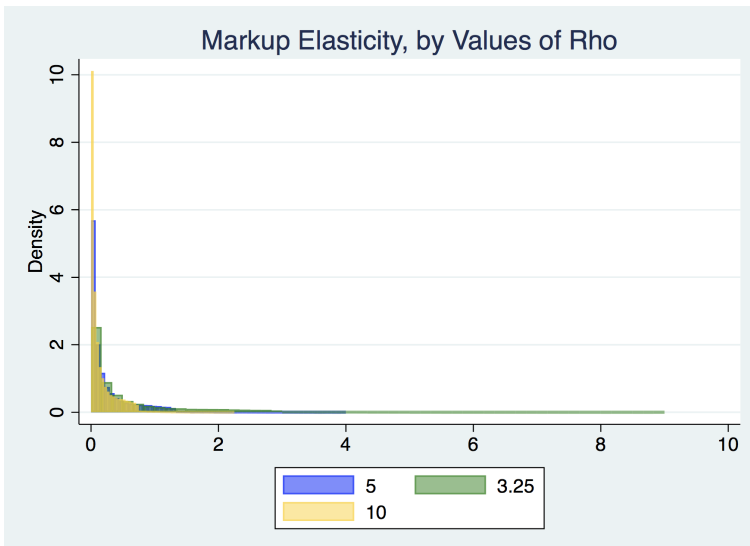
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

H ρ Robustness

In this section, I test a range of parameter values for ρ. In the main text, I estimate a $\rho = 3.25$ to match a Cobb-Douglas framework with measured markups from work by De Loecker. Here I alternatively test parameter values employed by Atkeson and Burstein (2008) and Amiti, Itskhoki, and Konings (2019).

The average markup elasticity for $\rho = 3.25$ is 0.16. The average for $\rho = 5$ is 0.28 and for $\rho = 10$ is 0.64. The original value as in the main text implies pass-through of 86%; the alternatives imply pass-through of 78% and 61% respectively.

Figure 10: Estimated markup elasticities for $\rho = 3.25$ (yellow), $\rho = 5$ (blue), and $\rho = 10$ (green).



Next, I estimate the scale elasticity for the alternative parameterizations of ρ. Column 1 of Table 3 contains the estimate from the main text. Column 2 parameterizes $\rho = 5$ and Column 3 $\rho = 10$. I find that larger values of ρ imply larger values of ν_{ip} due to larger markup elasticities.

Table 4: Direct Estimation Method - 2 year horizon - ρ Variation

	(1)	(2)	(3)
dlq1fw	-0.646**	-0.802**	-1.249***
	(0.298)	(0.325)	(0.412)
ρ	3.25	5	10
R^2	0	0	0
N	130347	130347	130347

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The tariff scale effects from $\rho = 5$ are on average 12% and from $\rho = 10$ are on average 15%, versus 11% from $\rho = 3.25$. The exchange rate scale effects from $\rho = 5$ are on average 32% and from $\rho = 10$ are 39%, versus 29% from $\rho = 3.25$.

Thus increasing ρ generates more markup flexibility and greater degrees of increasing returns-to-scale.