

The Mode of Competition between Foreign and Domestic Goods, Pass-Through, and External Adjustment*

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Abstract

We introduce Armington’s (1969) notion of “origin differentiation” into a micro-founded model of pricing to market and examine how this affects the joint dynamics of prices and quantities in an international real business cycle framework. We find that the model, when calibrated using parameters that we structurally estimate from micro data on U.S. domestic and import prices, can match both movements in international relative prices and quantities as observed in the data. The mechanism that drives our results is that a moderate degree of substitutability between origins, combined with a high degree of substitutability between varieties from the same origin implies substantial variability in the markups of importers and limited spillovers into domestic prices, while at the same time it is consistent with a muted quantity response to such pronounced movements in relative prices.

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1 Introduction

In models of the international business cycle, there exists a dichotomy between frameworks that are geared towards matching the dynamics of either prices, or quantities. Frictionless international macro models are calibrated to match quantity fluctuations over the international business cycle,

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and they do not account for variable markups that have been documented by a vast microeconomic literature. On the other hand, micro-founded models that are calibrated to explain precisely such pricing-to-market decisions generally do not match aggregate quantity fluctuations well. This dichotomy, which we call “price-quantity puzzle” has been highlighted in particular by Drozd and Nosal (2013), who examine the performance of several models of pricing-to-market.

In this paper, we construct a micro-founded model that brings in line variable markups that result from firms’ pricing-to-market decisions with the response of aggregate quantities. To do so, we introduce Armington (1969)’s notion of origin-differentiation into the preferences of Dornbusch (1987): within each sector, we allow for a different degree of substitutability amongst varieties from the same origin, and varieties from different origins. We then examine how such origin-differentiation affects the models’ performance of explaining both quantity and price dynamics in stylized examples and a stochastic general equilibrium model of the international real business cycle. We find that our model can match both movements in international relative prices and quantities as observed in the data. We also demonstrate that the model is useful for our understanding of pricing-to-market decisions, in particular regarding the low observed degree of “price complementarities” between foreign and domestic goods (see Loecker et al. (2012)), and rationalizing pricing-to-market decisions in sectors dominated by domestic firms.

The mechanism that drives our results is that a moderate degree of substitutability between origins, combined with a high degree of substitutability between varieties from the same origin, implies substantial variability in the markups of importers and limited spillovers into domestic prices. At the same time, it is consistent with a muted quantity response to such pronounced movements in relative prices. What is crucial for our results is how the introduction of origin differentiation affects the tradeoff the model offers between matching quantity and price moments in the data: while greater origin differentiation directly implies a smaller quantity response to a given relative price movement, it also affects the price setting response of importers to relative cost shocks as well as the price reaction by domestic firms.

Next, when we take the model to the data, we ask two questions: what is the extent of origin

differentiation implied by the data, and given the estimated relevant parameter values, can the model match exchange rate pass-through and quantity responses observed in the data?

To measure the extent of origin differentiation in the data, we embed our model in the Atkeson and Burstein (2008) heterogeneous firm setting of our setup, and then structurally estimate the parameters of interest in our preference framework using the information in the micro dataset underlying the US import and producer price indices. To cleanly identify the importance of price complementarities between foreign and domestic firms, we also take into consideration the effect of price fluctuations of imported intermediate inputs on the production cost of domestic firms. We do this in two steps. In the first step, we identify intermediate goods in the BLS micro import price data and construct sector-and-trade-partner specific intermediate import price indices. In the second step, we then use further information from input-output tables to determine how these changes in the prices of imported inputs affect the production cost of domestic firms and how this varies across US sectors and over time.

We first estimate common parameters for the entire sample, that is, we assume that parameters are identical across sectors. This gives us our first main finding regarding the general degree of separation between domestic and foreign firms. We find that while the elasticity of substitution between varieties from the same origin is around -9 , it is equal to -4 between a domestic and a US firm. Our first main finding is thus that the set of foreign and imported goods is quite differentiated, but far from being perfectly so. That is, we do not find that our results resemble those of Armington (1969).

Next, we calibrate our model using the estimated preference parameters. We find that we can reconcile pricing to market decisions with empirically observed movements in quantities over the business cycle. While we can generate incomplete exchange pass-through, we are also able to generate output movements whose volatility matches the data when we introduce origin differentiation. What drives this results is that there may be substantial pricing-to-market by foreign firms even if these firms are small compared to the domestic industry. Origin differentiation in effect increases their market power. Our exercise also shows that the price response of domestic firms to exchange rate movements is limited in nature which is true in the data given incomplete domestic

price pass-through of exchange rate movements. We then show that these findings have important implications for the nature of external adjustment. First, the fact that the sets of imported and domestic goods are substantially differentiated automatically leads to a small quantity response for any given movement in the relative prices of imported versus domestic goods. Second, since a higher degree of “origin-differentiation” goes along with lower exchange rate pass through, also the movement of relative prices of imported goods is smaller if imported and domestic goods are differentiated.

Relation to the Literature. In this paper, we develop a straightforward extension of the theory of firms’ pricing-to-market decisions that goes back to Dornbusch (1987) and in the particular functional form that we examine to Atkeson and Burstein (2008). This theory is based on the simple notion that when a firm’s market share in the relevant sector is non-negligible, its pricing decision affects the price level in the entire sector. Under the assumption that consumers find it easier to shift expenditure away from a single firm than from the sector in total, large firms that also affect the price level in the entire sector thus enjoy less elastic demand than small firms and the equilibrium markup of each firm depends on its market share in the relevant industry.

We expand upon this intuitive idea that market share matters for pricing by augmenting it with Armington’s (1969) notion of origin differentiation. We show that in the context of pricing-to-market decisions, the degree of “origin differentiation” alters how firms set their markups: what matters for the optimal markup of each firm is not its market share in the industry alone, but both the market share within its industry and origin, as well as the market shares of all goods from the same origin.

Our framework thus connects two strands of literature that explain pricing decisions and external adjustment from two distinct viewpoints. The first strand builds on estimates of exchange rate pass-through in microeconomic datasets.¹ While the results of this literature have uncovered much

¹While some of these studies focus on structural analysis of exchange rate pass-through in single industries (see Knetter (1989) and Knetter (1992) and the analysis of pricing-to-market practices in Verboven (1996), Goldberg and Verboven (2001, 2005) for the car industry, Hellerstein (2008) for the beer industry, and Nakamura and Zerom (2010) for the case of the coffee industry), our approach is more closely related to the reduced-form analysis of pass-through rates in datasets spanning many industries (see Gopinath and Rigobon (2008), Gopinath and Itskhoki (2010), Gopinath et al. (2010), and Nakamura and Steinsson (2008)). It is also related to the work of Fitzgerald and Haller (2010), who use plant-level prices of identical goods sold on different markets to study pricing-to-market

heterogeneity in pass-through rates along multiple dimensions of firm or good characteristics,² a common finding is that pass-through, even when estimated at the dock and over long horizons, is quite incomplete: import prices do not move one-to-one with the exchange rate. Such incomplete long-run pass-through can be explained by markups being adjusted to accommodate the local market environment, a channel first pointed out in Krugman (1986) and Dornbusch (1987) and more recently in Melitz and Ottaviano (2008), Atkeson and Burstein (2008), Chen et al. (2009), Gust et al. (2009, 2010), and Gopinath and Itskhoki (2011), and Auer and Schoenle (2012), and Amiti et al. (2012).

Berman et al. (2012), Gopinath and Neiman (2012), and Gopinath et al. (2011) also document that modeling variable markups across firms is also key to our understanding of the firm-specific rate of external adjustment, even within finely defined industries: because the price response to a given exchange rate movement is small, the quantity response is muted.

The second strand of literature our paper connects to focuses on estimating the correct Armington elasticity using information on the volume of trade and exchange rates. While this literature dates back long in time (see Goldstein and Kahn (1985) for a survey of that literature), most of the new contributions in this literature are based on the seminal methodology of Feenstra (1994).

Our approach is inspired by Feenstra et al. (2010), who estimate “macro” and “micro” elasticities defined as the elasticity of exports to the trade-weighted and to the bilateral exchange rate respectively (also see Gopinath and Neiman (2011)). We note, however, that our framework is conceptually quite different, since we only use the trade weighted-exchange rate to identify price complementarities (that is we only measure the “macro” elasticity with our measure of origin-

decisions. Burstein and Gopinath (2012) present an excellent overview of this literature.

²When evaluating prices at the dock (that is, net of distribution costs), the main dimensions along which the heterogeneity of pass-through rates are identified include the currency choice of invoicing as in Gopinath et al. (2010), Goldberg and Tille (2009), Bacchetta and van Wincoop (2005), inter- versus intra-firm trade as in Neiman (2010), multi-product exporters as in Chatterjee et al. (2011), sectoral import composition as in Campa and Goldberg (2005); Goldberg and Campa (2010), and input use intensity. When evaluating retail prices, the share of the distribution costs may matter for pass-through as found by Bacchetta and van Wincoop (2003) and Burstein et al. (2003) – and, in a general equilibrium analysis in Corsetti and Dedola (2005) –, while the movement of margins seems to play only a minor role as shown in Goldberg and Hellerstein (2012). Generally, also the size and origin of the exchange rate movement matter for pass-through (see Michael et al. (1997) and Burstein et al. (2005, 2007)) as does the general equilibrium interaction between exchange rate volatility, invoicing currency choice, and pass-through rate (see Devereux et al. (2004)). Again, see Burstein and Gopinath (2012) for an overview of this literature.

differentiation).

Rather than untying the “macro” elasticity from the country-specific “micro” elasticity as in Feenstra et al. (2010), we allow the degree of firm-specific variety-differentiation (ρ) to differ from the degree of origin-differentiation (μ). Our estimations thus untie firms’ pricing responses to changes in own costs and the relevant index of competitors’ prices (both responses are guided by ρ) from the degree to which the relevant index of competitors’ prices reacts differently to competitors from the same and from a different origin (guided by μ).³

More generally, our work draws on Imbs et al. (2005) in that we estimate sector-specific parameters to avoid an “aggregation bias” in the uncovered relations between exchange rates, import prices, and domestic prices. When comparing actual and predicted external adjustment rates, we follow Imbs and Mejean (2009) and again evaluate sectoral rates rather than the aggregate one to avoid a similar aggregation bias in quantities.

We contribute to these two strands of literature by showing how the Armington assumption affects the interplay of import prices and domestic prices and thus shapes the relative price response to exchange rate movements. We view this extension of Atkeson and Burstein (2008) as an important one as it can shed further light on our understanding of the real exchange rate. We in particular view the gained understanding on the effect of exchange rate fluctuation on the prices of domestic firms as a potentially important implication.⁴

Second, we also view our findings of interest to the literature on external adjustment. Compared to the existing literature, the main novelty of our approach is to identify the parameters of this model from micro data on import and domestic prices. We then apply the insights gained from this approach to examine whether and to what extent we can shed light on one of the main puzzles in international macroeconomics, the “exchange rate disconnect” (see, for example, Obstfeld and Rogoff (2001)) and show that our theory can accurately match the average and the dispersion of external adjustment rates (EARs) in the data. We find this to be a very strong result since we

³It would be possible to combine our approach with that of Feenstra et al. (2010) by adding a further tier to the preferences developed below so that all varieties from each trade partner form one composite, these trade partner composites form the foreign composite, which then competes with the domestic composite.

⁴For example, from a central bank perspective, such second-order effects are probably more important than understanding the total impact of import prices on the level of the consumer price index, especially given the focus on core inflation rates in many countries.

do not use any information of trade volume to identify the parameters of the model, which makes our exercise akin to an out-of-sample prediction. We also shed some light on the cross-sectoral variation in EARs.

1.1 A Model of Competition between Domestic and Foreign Firms

Our model relies on the preferences of Dornbusch (1987) in which markups are variable since a firm's market share affects the perceived elasticity of substitution and we also draw heavily on the particular analysis of Atkeson and Burstein (2008) specification of the Dornbusch (1987) setup. This preference setup captures two main economic forces: first, pass-through is less than one as markups adjust to a cost shock and second, not only a firm's own costs matter, but also the prices of all other firms.

We augment Dornbusch (1987)'s two-tiered setup by the possibility that foreign and domestic goods are not equally substitutable within a sector, that is, we go to a three tiered setup. The preferences are given by a three-tiered "love of variety" utility/production function setup in which consumers consume the output of different sectors k and the output of each sector is produced by combining varieties n within each sector.

On the production side, within each sectors there exist a number N_k^D of individual domestic firms each holding the monopoly to produce a variety of input. There also there exists a number N_k^F of individual foreign firms each holding the monopoly to produce a variety of input. All input varieties within a sector are then used as inputs by competitive firms combining these inputs into the sector composite y_k using a production function that features a constant elasticity of substitution. On the preference side, similar to Dixit and Stiglitz (1977) consumers feature preferences with constant-elasticity demand for each sector's total output.

Final consumption c is produced by competitive firms aggregating input goods into

$$Y = \left(\int_0^1 Y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)} \quad (1)$$

In each sector k , each input is produced by a set of $n \in N$ monopolists, but the sector itself is again

competitive and produces using only the inputs with a production function given by

$$Y_k = \left(w_k \left(\sum_{n \in N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k} \right)^{((\mu_k-1)\rho_k)/(\mu_k(\rho_k-1))} + (1-w_k) \left(\sum_{n \in N_k^F} (q_{n,k}^F)^{(\rho_k-1)/\rho_k} \right)^{((\mu_k-1)\rho_k)/(\mu_k(\rho_k-1))} \right)^{\mu_k/(\mu_k-1)} \quad (2)$$

Within each sector k , there is the domestic and the foreign market segment (denoted by a D and N superscript, respectively). Within each market segment, varieties from the same origin compete and the elasticity of substitution is equal to ρ_k . Within the sector but across the segments, the elasticity of substitution is equal to μ_k .

Throughout the paper, we make the following assumption

$$\rho_k \leq \mu_k,$$

that is, varieties from the same origin are at least as substitutable as are varieties from different origins. We note that for the case $\rho_k = \mu_k$, Equation (2) reduces to the standard Dornbusch-Atkeson-Burstein setup. If $\rho_k < \mu_k$, foreign and domestic firms are separated and compete more with each other than with firms from another origin. Finally, we also allow for a home bias parameter w_k .

Production. Our production setup takes into account the importance of intermediate goods. Following Auer and Saure (2012), the production function of a home firm is

$$q_n = \tilde{\varphi}_n^{-1} (q_n^{NT})^{\alpha_k} (q_n^R)^{\beta_k} (q_n^I)^{(1-\alpha_k-\beta_k)},$$

where q_n^{NT} is the amount of nontraded goods used by firm n , q_n^R is the amount of resources, and q_n^I is the input composite as used by firm n . For each firm n , the input composite of n is equal to

$$q_n^I = \left(\sum_{j \in N_{US,l}^I} w_{n,j} (q_{n,j}^I)^{(\rho_l^I-1)/\rho_l^I} \right)^{\rho_l^I/(\rho_l^I-1)}$$

Price Setting by Variety Monopolists. Dornbusch's main departure from Dixit and Stiglitz

(1977) is that he assumes that firms are non-negligible in size within a sector, so that each firm has an impact on the aggregate price index of the sector, which it takes into account when setting its price.

Each variety producer faces a constant marginal cost ω_n (we will later allow this to be influenced by domestic input prices), which may include iceberg transportation costs and maximizes profits subject to demand.

2 Optimal Pricing under Cournot Competition

We solve for the firm's pricing decision assuming that firms compete all a Cournot, that is, by setting quantities. The appendix solves the case of Bertrand competition.

We begin by noting that for a given total income I , consumers' demand for the output of sector k - Y_k - satisfies

$$\left(\frac{Y_k}{I}\right)^{-1/\eta} = \left(\frac{P_k}{P}\right) \quad (3)$$

where P_k is the price of the Y_k composite and P the price of final consumption, equal to $\left(\int_0^1 P_k^{(1-\eta)} dk\right)^{1/(1-\eta)}$.

The output in sector k itself is produced by combining varieties from home and foreign. We denote the Domestic and foreign composite by Q_k^D and Q_k^N , respectively, which are given by

$$Q_k^D \equiv \left(\sum_{n \in N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k}\right)^{\rho_k/(\rho_k-1)} \quad \text{and} \quad Q_k^F \equiv \left(\sum_{n \in N_k^F} (q_{n,k}^F)^{(\rho_k-1)/\rho_k}\right)^{\rho_k/(\rho_k-1)}.$$

so that the prize of the output in sector k comes from the cost minimization problem Y_k :

$$\min P_k^D Q_k^D + P_k^N Q_k^N \text{ s.t. } \left(w_k (Q_k^D)^{(\mu_k-1)/\mu_k} + (1-w_k) (Q_k^N)^{(\mu_k-1)/\mu_k}\right)^{\mu_k/(\mu_k-1)} = Y_k$$

yielding

$$\frac{Q_k^D}{Y_k} = \left(\frac{P_k^D}{P_k} \right)^{-\mu_k} (w_k)^{\mu_k} \quad (4)$$

$$\frac{Q_k^F}{Y_k} = \left(\frac{P_k^F}{P_k} \right)^{-\mu_k} (1 - w_k)^{\mu_k} \quad (5)$$

Last, for a given amount of the domestic or foreign composite, the demand for each variety again comes from a cost minimization problem

$$\min \left(\sum_{n \in N_k^D} p_{n,k} q_{n,k} \right) \text{ s.t. } \left(\sum_{n \in N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k} \right)^{\rho_k/(\rho_k-1)} = Q_k^D$$

yielding

$$\left(\frac{q_{n,k}^D}{Q_k^D} \right) = \left(\frac{p_{n,k}^D}{P_k^D} \right)^{-\rho_k}. \quad (6)$$

where

$$P_k^D = \left(\sum_{n \in N_k^D} (p_{n,k}^D)^{(\rho_k-1)} \right)^{1/(\rho_k-1)}$$

Firm's Profit maximization under Cournot. Under Cournot, a firm maximizes profits taking as given the quantities of other firms, that is, all the $q_{i,k}^D$ and $q_{i,k}^F$ for $i \neq n$. That is, a firm's demand is a function of three components: demand for the output of the sector Y_k , the domestic composite in sector k Q_k^D conditional on Y_k , and the demand for a variety n, k ($q_{n,k}^D$) conditional on Q_k^D . Putting these elements (see (3), (4), and (6)) together yields:

$$\begin{aligned} \frac{p_{n,k}^D}{P} &= \left(\frac{q_{n,k}^D}{Q_k^D} \right)^{-1/\rho_k} \left(\frac{Q_k^D}{Y_k} \right)^{-1/\mu_k} \left(\frac{Y_k}{I} \right)^{-1/\eta} w_k \\ &= (q_{n,k}^D)^{-1/\rho_k} (Q_k^D)^{1/\rho_k-1/\mu_k} (Y_k)^{1/\mu_k-1/\eta} (I^{1/\eta} w_k) \end{aligned}$$

For simplicity, we set $(I^{1/\eta} w_k) = 1$. Under Cournot competition, the firm's maximization problem

is

$$\begin{aligned} & \max_{q_{n,k}^D} (p_{n,k}^D - c_{n,k}^D) q_{n,k}^D \\ \text{s.t. } \frac{p_{n,k}^D}{P} &= (q_{n,k}^D)^{-1/\rho_k} (Q_k^D)^{1/\rho_k - 1/\mu_k} (Y_k)^{1/\mu_k - 1/\eta} \end{aligned}$$

Where $c_{n,k}^D$ is the marginal cost of production. Substitution of the constraint and taking the first order implies

$$P \frac{\partial \left(q_{n,k}^D \right)^{1-1/\rho_k} (Q_k^D)^{1/\rho_k - 1/\mu_k} (Y_k)^{1/\mu_k - 1/\eta}}{\partial q_{n,k}^D} = c_{n,k}^D.$$

Since

$$\frac{\partial Q_k^D}{\partial q_{n,k}^D} = \left(\sum_{n \in N_k^D} (q_{n,k}^D)^{(\rho_k - 1)/\rho_k} \right)^{1/(\rho_k - 1)} = \left(\frac{q_{n,k}^D}{Q_k^D} \right)^{-1/\rho_k}$$

and

$$\begin{aligned} \frac{\partial (Y_k)}{\partial q_{n,k}^D} &= \frac{\partial \left(w_k (Q_k^D)^{(\mu_k - 1)/\mu_k} + (1 - w_k) (Q_K^N)^{(\mu_k - 1)/\mu_k} \right)^{\mu_k/(\mu_k - 1)}}{\partial q_{n,k}^D} \\ &= w_k (Q_k^D)^{-1/\mu_k} \left(w_k (Q_k^D)^{(\mu_k - 1)/\mu_k} + (1 - w_k) (Q_K^N)^{(\mu_k - 1)/\mu_k} \right)^{\mu_k/(\mu_k - 1) - 1} \frac{\partial Q_k^D}{\partial q_{n,k}^D} \\ &= w_k \left(\frac{Q_k^D}{Y_k} \right)^{-1/\mu_k} \left(\frac{q_{n,k}^D}{Q_k^D} \right)^{-1/\rho_k} \end{aligned}$$

Where we note that two expressions above are equal to relevant market shares in (dollar volumes): define S_k^D to be the market share of all domestic variety producers in sector k and $s_{n,k}^D$ the domestic market share of a single domestic variety producer.

$$w_k \left(\frac{Q_k^D}{Y_k} \right)^{1-1/\mu_k} = S_k^D \text{ and } \left(\frac{q_{n,k}^D}{Q_k^D} \right)^{1-1/\rho_k} = s_{n,k}^D$$

Then, the price of a single firm is equal to

$$\begin{aligned}
p_{n,k}^D &= c_{n,k}^D / \left((1 - 1/\rho_k) + \left((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta) w_k \left(\frac{Q_k^D}{Y_k} \right)^{1-1/\mu_k} \right) \left(\frac{q_{n,k}^D}{Q_k^D} \right)^{1-1/\rho_k} \right) \\
&= c_{n,k}^D / ((1 - 1/\rho_k) + ((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta) S_k^D) s_{n,k}^D)
\end{aligned} \tag{8}$$

and the demand elasticity is equal to

$$\epsilon_{n,k}^D = - (1/\rho_k + ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_k^D) s_{n,k}^D)^{-1}. \tag{9}$$

if $S_k^D = 1$, we have AB 2008

if $\mu_k = \rho_k$ foreign and domestic are symmetric and only $s_{n,k} = S_k^D s_{n,k}^D$ matters

if $\eta < \mu_k < \rho_k$, foreign and domestic firms are separated.

A similar optimization yields that the price of an importer is given by the overall market share of importers $S_k^F = (1 - S_k^D)$, as well as $s_{n,k}^F$, the market share of the importer in the imported-goods market segment.

$$p_{n,k}^F = c_{n,k}^F / ((1 - 1/\rho_k) + ((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta) (1 - S_k^D)) s_{n,k}^F)$$

3 Price Response to Cost Shocks

3.0.1 Partial Equilibrium Response to Cost Shocks

We next derive the equilibrium of the pricing.

Loglinearization. We start by documenting the cost response of domestic firms. Taking log of both sides of (8) yields

$$\ln p_{n,k}^D = \ln c_{n,k}^D - \ln ((1 - 1/\rho_k) + ((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta) S_k^D) s_{n,k}^D) \tag{10}$$

Totally differentiate with respect to $p_{n,k}^D$, S_k^D and $s_{n,k}^D$

$$\begin{aligned}\widehat{p_{n,k}^D} &= \widehat{c_{n,k}^D} - (((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta)S_k^D)s_{n,k}^D\widehat{s_{n,k}^D} + (1/\mu_k - 1/\eta)s_{n,k}^DS_k^D\widehat{S_k^D}) \\ &\quad / ((1 - 1/\rho_k) + ((1/\rho_k - 1/\mu_k) + (1/\mu_k - 1/\eta)S_k^D)s_{n,k}^D)\end{aligned}$$

This results in the response of domestic firms to changes in its costs or changes in market shares:

$$\widehat{p_{n,k}^D} = \widehat{c_{n,k}^D} + \Gamma_1^D(S_k^D, s_{n,k}^D)\widehat{s_{n,k}^D} + \Gamma_2^D(S_k^D, s_{n,k}^D)\widehat{S_k^D}, \quad (11)$$

where

$$\begin{aligned}\Gamma_1^D(S_k^D, s_{n,k}^D) &= \frac{(1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^D}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^D)s_{n,k}^D} s_{n,k}^D \text{ and} \\ \Gamma_2^D(S_k^D, s_{n,k}^D) &= \frac{(1/\eta - 1/\mu_k)}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^D)s_{n,k}^D} S_k^D s_{n,k}^D.\end{aligned}$$

Similarly, the price response of a foreign firm is equal to

$$\widehat{p_{n,k}^F} = \widehat{c_{n,k}^F} + \Gamma_1^F(S_k^D, s_{n,k}^F)\widehat{s_{n,k}^F} + \Gamma_2^F(S_k^D, s_{n,k}^F)\widehat{S_k^F} \quad (12)$$

where

$$\begin{aligned}\Gamma_1^F(S_k^D, s_{n,k}^F) &= \frac{(1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^F}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^F)s_{n,k}^F} s_{n,k}^F \\ \Gamma_2^F(S_k^D, s_{n,k}^F) &= \frac{(1/\eta - 1/\mu_k)S_k^F}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k)S_k^F)s_{n,k}^F} s_{n,k}^F\end{aligned}$$

Lemma: Parameters and Price Sensitivities. for $\rho_k > \mu_k > \eta$ and $\rho_k > 1$, $\Gamma_1^D(S_k^D, s_{n,k}^D)$, $\Gamma_2^D(S_k^D, s_{n,k}^D)$, $\Gamma_1^F(S_k^D, s_{n,k}^F)$, and $\Gamma_2^F(S_k^D, s_{n,k}^F)$ are all positive but smaller than one. We also note that if $\mu_k < \rho_k$, it is always true that domestic firms react relatively more to the price of the

domestic composite than to the price of the foreign composite, and furthermore, the smaller μ is, the more pronounced is this difference.

$$\Gamma_1^D(S_k^D, s_{n,k}^D) > \Gamma_2^D(S_k^D, s_{n,k}^D) \text{ and } \Gamma_1^F(S_k^D, s_{n,k}^F) > \Gamma_2^F(S_k^D, s_{n,k}^F)$$

Further,

$$\begin{aligned} \frac{\partial \Gamma_1^F(S_k^D, s_{n,k}^F)}{\partial \mu_k} &> 0 > \frac{\partial \Gamma_2^F(S_k^D, s_{n,k}^F)}{\partial \mu_k} \\ \frac{\partial \Gamma_1^D(S_k^D, s_{n,k}^D)}{\partial \mu_k} &> 0 > \frac{\partial \Gamma_2^D(S_k^D, s_{n,k}^D)}{\partial \mu_k} \end{aligned}$$

that is, the rate at which firm's prices react to changes of "within-composite" market share is increasing in μ_k , while the rate at which firms' price react to the combined market shares of their composite is decreasing in μ_k .

3.1 Equilibrium Price Response to Cost Shocks

The above-developed preferences relate a domestic firm's markup to both its market share in the domestic market segment, as well as to the overall market share of domestic firms in the industry as a whole. The latter two market shares, in turn, are affected by how expensive the single variety is compared to other domestic varieties and by how expensive the domestic variety composite is compared to the total output of the sector. It holds that

$$\widehat{S}_k^D = (1 - \mu_k) (\widehat{P}_k^D - \widehat{P}_k) \text{ and } \widehat{s}_{n,k}^D = (1 - \rho_k) (\widehat{p}_{n,k}^D - \widehat{P}_k^D).$$

Taking into account that a firm's market share reacts to changes in the cost of production, it holds that

$$\widehat{p}_{n,k}^D = \frac{\widehat{c}_{n,k}^D}{1 + (\rho_k - 1) \Gamma_1^D(S_k^D, s_{n,k}^D)} + \frac{\Gamma_2^D(S_k^D, s_{n,k}^D) (1 - \mu_k) - \Gamma_1^D(S_k^D, s_{n,k}^D) (1 - \rho_k)}{1 + (\rho_k - 1) \Gamma_1^D(S_k^D, s_{n,k}^D)} \widehat{P}_k^D - \frac{\Gamma_2^D(S_k^D, s_{n,k}^D) (1 - \mu_k)}{1 + (\rho_k - 1) \Gamma_1^D(S_k^D, s_{n,k}^D)} \widehat{P}_k \quad (13)$$

Equation (13) documents that for a given price level of all other firms in the economy, a firm's price moves less than one-to-one with its costs.

This pins down prices as a function of the change in the price index of the domestic composite P_k^D as well as in the overall price index in sector k P_k . Noting that the price index

$$\begin{aligned}\widehat{P}_k &= \frac{\dot{P}_k}{P_k} = \left(\dot{P}_k^D \frac{\partial P_k}{\partial P_k^D} + \dot{P}_k^F \frac{\partial P_k}{\partial P_k^F} \right) P_k^{-1} \\ &= \widehat{P}_k^D w_k^{\mu_k} \left(\frac{P_k}{P_k^D} \right)^{-(1-\mu_k)} + \widehat{P}_k^F (1-w_k)^{\mu_k} \left(\frac{P_k}{P_k^F} \right)^{-(1-\mu_k)} \\ &= S_k^D \widehat{P}_k^D + (1-S_k^D) \widehat{P}_k^F\end{aligned}$$

It thus holds that

$$\widehat{p}_{n,k}^D = \alpha_{n,k}^D \widehat{c}_{n,k}^D + \delta_{n,k}^D \widehat{P}_k^D + \zeta_{n,k}^D \widehat{P}_k^F$$

where $\alpha_{n,k}^D$ denotes the rate (elasticity) at which domestic firm n reacts to changes in its own cost, $\delta_{n,k}^D$ the rate at which domestic firm n reacts to the price level of the domestic composite and $\zeta_{n,k}^D$ the rate at which domestic firm n reacts to the price level of the foreign composite.

$$\begin{aligned}\alpha_{n,k}^D &= \frac{1}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D)(\rho_k - 1)} \\ \delta_{n,k}^D &= \frac{-\Gamma_2^D(S_k^D, s_{n,k}^D)(\mu_k - 1) + \Gamma_1^D(S_k^D, s_{n,k}^D)(\rho_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D)(\rho_k - 1)} + \frac{\Gamma_2^D(S_k^D, s_{n,k}^D)(\mu_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D)(\rho_k - 1)} S_k^D \\ \zeta_{n,k}^D &= \frac{\Gamma_2^D(S_k^D, s_{n,k}^D)(\mu_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D)(\rho_k - 1)} (1 - S_k^D)\end{aligned}$$

The rate at which firms react to changes in their own costs or the prices of domestic and foreign goods is heterogenous. We next aggregate over the firms from the two origins to arrive at the overall price responses.

Reminding the definition of P_k^D , it further holds that

$$\widehat{P}_k^D = \sum_{n \in N_k^D} s_{n,k}^D \widehat{p}_{n,k}^D = \widehat{C}_k^D + \Delta^D \widehat{P}_k^D + Z^D \widehat{P}_k^F, \quad (14)$$

where

$$\begin{aligned} \widehat{C}_k^D &= \sum_{n \in N_k^D} s_{n,k}^D \alpha_{n,k}^D \widehat{c}_{n,k}^D = \sum_{n \in N_k^D} \frac{s_{n,k}^D \widehat{c}_{n,k}^D}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D) (\rho_k - 1)} \\ \Delta^D &= \sum_{n \in N_k^D} s_{n,k}^D \delta_{n,k}^D \\ &= \sum_{n \in N_k^D} s_{n,k}^D \left(\frac{\Gamma_1^D(S_k^D, s_{n,k}^D) (\rho_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D) (\rho_k - 1)} - \frac{\Gamma_2^D(S_k^D, s_{n,k}^D) (\mu_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D) (\rho_k - 1)} (1 - S_k^D) \right) \\ Z^D &= \sum_{n \in N_k^D} s_{n,k}^D \zeta_{n,k}^D = \sum_{n \in N_k^D} s_{n,k}^D \left(\frac{\Gamma_2^D(S_k^D, s_{n,k}^D) (\mu_k - 1)}{1 + \Gamma_1^D(S_k^D, s_{n,k}^D) (\rho_k - 1)} (1 - S_k^D) \right) \end{aligned}$$

$$\begin{aligned} \Gamma_1^F(S_k^D, s_{n,k}^F) &= \frac{(1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_k^F}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_k^F) s_{n,k}^F} s_{n,k}^F \\ \Gamma_2^F(S_k^D, s_{n,k}^F) &= \frac{(1/\eta - 1/\mu_k) S_k^F}{(1 - 1/\rho_k) - ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_k^F) s_{n,k}^F} s_{n,k}^F \end{aligned}$$

$$\begin{aligned} \frac{\partial \Gamma_1^F(S_k^D, s_{n,k}^F)}{\partial \mu_k} &> 0 > \frac{\partial \Gamma_2^F(S_k^D, s_{n,k}^F)}{\partial \mu_k} \\ \frac{\partial \Gamma_1^D(S_k^D, s_{n,k}^D)}{\partial \mu_k} &> 0 > \frac{\partial \Gamma_2^D(S_k^D, s_{n,k}^D)}{\partial \mu_k} \end{aligned}$$

The price response of the domestic composite depends on the weighted total direct impulse response of domestic firms to their costs $\widehat{C}_k^D$ and this cost shock is further multiplied because all domestic firms react to all other domestic prices (Δ^D). Last, also domestic prices react to foreign prices, which is captured by (Z^D).

To solve for equilibrium price changes as a response of cost shocks, we need the same relation for foreign prices. We denote by $\delta_{n,k}^F$ the price response of a foreign firm n to $\widehat{P}_k^D$ and by $\zeta_{n,k}^F$ the price response of a foreign firm to $\widehat{P}_k^F$. This implies

$$\widehat{p}_{n,k}^F = \alpha_{n,k}^F \widehat{c}_{n,k}^F + \delta_{n,k}^F \widehat{P}_k^D + \zeta_{n,k}^F \widehat{P}_k^F$$

where $\alpha_{n,k}^F$ denotes the rate (elasticity) at which foreign firm n reacts to changes in its own cost, $\delta_{n,k}^F$ the rate at which Foreign firm n reacts to the price level of the domestic composite and $\zeta_{n,k}^F$ the rate at which foreign firm n reacts to the price level of the foreign composite.

$$\begin{aligned}\alpha_{n,k}^F &= \frac{1}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} \\ \delta_{n,k}^F &= \frac{\Gamma_2^F(S_k^D, s_{n,k}^F)(\mu_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} S_k^D \\ \zeta_{n,k}^F &= -\frac{\Gamma_2^F(S_k^D, s_{n,k}^F)(\mu_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} + \frac{\Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} + \frac{\Gamma_2^F(S_k^D, s_{n,k}^F)(\mu_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} (1 - S_k^D)\end{aligned}$$

and thus

$$\widehat{P}_k^F = \widehat{C}_k^F + \Delta^F \widehat{P}_k^D + Z^F \widehat{P}_k^F \quad (15)$$

where

$$\begin{aligned}\widehat{C}_k^F &= \sum_{n \in N_k^F} s_{n,k}^F \alpha_{n,k}^F \widehat{c}_{n,k}^F = \sum_{n \in N_k^F} s_{n,k}^F \frac{\widehat{c}_{n,k}^F}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} \\ \Delta^F &= \sum_{n \in N_k^F} s_{n,k}^F \delta_{n,k}^F = \sum_{n \in N_k^F} \frac{\Gamma_2^F(S_k^D, s_{n,k}^F)(\mu_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} s_{n,k}^F S_k^D \\ Z^F &= \sum_{n \in N_k^F} s_{n,k}^F \zeta_{n,k}^F \\ &= \sum_{n \in N_k^F} s_{n,k}^F \left(\frac{\Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} - \frac{\Gamma_2^F(S_k^D, s_{n,k}^F)(\mu_k - 1)}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} S_k^D \right)\end{aligned}$$

We note that Δ^O with $O \in \{D, F\}$ always denotes the response to price of the domestic composite while Z^O (capital Zeta) with $O \in \{D, F\}$ denotes the response to the foreign composite.

Together, these two recursive pricing equations for the domestic (14) and for the foreign composite (15) determine the equilibrium response of foreign and domestic prices as

$$\widehat{P}_k^D = \frac{(1 - Z^F) \widehat{C}_k^D + Z^D \widehat{C}_k^F}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \text{ and } \widehat{P}_k^F = \frac{(1 - \Delta^D) \widehat{C}_k^F + \Delta^F \widehat{C}_k^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \quad (16)$$

To gain a better understanding of these equilibrium response of price indices (16), rewrite $\widehat{P}_k^D$ as

$$\widehat{P}_k^D = \frac{1}{(1 - \Delta^D) - \frac{Z^D}{1 - Z^F} \Delta^F} \widehat{C}_k^D + \frac{\frac{Z^D}{1 - Z^F}}{(1 - \Delta^D) - \frac{Z^D}{1 - Z^F} \Delta^F} \widehat{C}_k^F$$

Intuitively, the domestic price composite depends on the initial domestic cost impulse $\widehat{C}_k^D$, which is then multiplied as domestic firms react to other domestic firms (explaining the term $1 - \Delta^D$ in the denominators of the above equation) and then further as also foreign prices react, which again affects domestic prices (explaining the term $Z^D \Delta^F / 1 - Z^F$ in the denominators). It also depends on the foreign initial cost impulse $\widehat{C}_k^F$, but only indirectly at rate $\frac{Z^D}{1 - Z^F}$, which again gets multiplied via secondround effects.

This gives the price responses of an individual firm implied by our theory as a function of its own cost shock and the relevant average cost impulses in home and abroad

$$\widehat{p}_{n,k}^D = \alpha_{n,k}^D \widehat{c}_{n,k}^D + \frac{\delta_{n,k}^D (1 - Z^F) + \zeta_{n,k}^D \Delta^F}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^D + \frac{\delta_{n,k}^D Z^D + \zeta_{n,k}^D (1 - \Delta^D)}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^F \quad (17)$$

$$\widehat{p}_{n,k}^F = \alpha_{n,k}^F \widehat{c}_{n,k}^F + \frac{\delta_{n,k}^F (1 - Z^F) + \zeta_{n,k}^F \Delta^F}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^D + \frac{\zeta_{n,k}^F (1 - \Delta^D) + \delta_{n,k}^F Z^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^F \quad (18)$$

We note that because firms' reaction to changes in costs and to changes in the general price index are heterogeneous, the equilibrium response to $\widehat{C}_k^D$ and $\widehat{C}_k^F$ is firm-specific.

Proposition. Parameters and ERPT. Define ERPT as the elasticity of P_k^F to the exchange rate denoted by $\sigma_{P_k^F, e_{TW}}$. If there is no input use by other firms. E

$$\sigma_{P_k^F, e_{TW}} = \frac{1}{(1 - Z^F) - \frac{Z^D \Delta^F}{1 - \Delta^D}} \sum_{n \in N_k^F} \frac{s_{n,k}^F}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)}$$

which satisfies the following propoerties. $\sigma_{P_k^F, e_{TW}}$ is increasing in Δ^D , increasing in and Z^F and Z^D and increasing in Δ^F .

3.2 General Equilibrium

We embed the industry equilibrium that we have described above in a dynamic stochastic general equilibrium setting as in Atkeson and Burstein (2008). Since the model is well known, we relegate a detailed description of the model equations to the appendix. Our key simplifications relative to Atkeson and Burstein (2008) are that we assume an exogenously given number of firms in the domestic and export markets, assuming away entry and exit decisions. We assume that there are $N = 4$ firms in each domestic market, of which one firm exports. The exporter is large given a higher productivity level. We log-linearize the model around a non-stochastic steady state.

4 Empirical Estimation

We next describe how we map the developed theory to the micro price datasets of the BLS.

4.1 Constructing Market Shares

We note that our data includes extremely detailed information on prices, but no direct information on good-specific market shares. We thus augment this data in two ways. For importers, we augment it by using finely disaggregated trade flows as in Auer and Schoenle (2012). For domestic firms, we collect information on firm-specific turnover from Compustat, and we then allocate the firm-specific turnover to specific goods. The latter is made possible by the fact that the BLS PPI dataset includes information on the fraction of sales each good accounts for in the total revenue of each firm. Together, these datasets thus enables us to construct measures of the market shares of both importers and domestic firms.

We estimate the structural parameters of our model using the price predictions of our theory and exchange rate changes as exogenous drivers of the prices of imported goods. We note that we could also aim to identify these parameters from using only actual price changes of imported and domestic goods, but that we would not have good estimates of common cost to identify the

parameters of interest. We thus use only the information contained in exchange rate movements as exogenous drivers of price movements.

4.2 Input use in other countries.

In this subsection we document how we adjust for input use by foreign firms. It is not only true that domestic firms use intermediate goods, but also, it holds true that intermediate goods are used in the production of goods in other countries that are then exported to the US. This is of importance as costs of foreign producers are not fully paid in their local currency and thus their costs do not comove one-to-one with the exchange rate. The percentage cost change of foreign firm n from trade partner TP is equal to the exchange rate change times $1 - \theta_{n,TP}^{ImInp}$, the proportion of firm n 's costs that are paid in local currency.

$$\widehat{c_{n,k}^F} = \Delta \text{extr}_{us,TP} \left(1 - \theta_{n,TP}^{ImInp} \right)$$

Assembling a dataset of firm-specific local cost shares is not trivial endeavour as it is both true that imported input intensity varies across industries and trade partners, but it also varies across firms of different size within each industry and trade partner. We thus construct $\theta_{n,TP}^{ImInp}$ from both aggregate information on imported input use from the WIOD and the microeconomic findings of firm heterogeneity in imported input use from Amiti et al. (2013).

The WIOD lists, for each country TP the dollar volume of imports by industry k from all trade partners and all supplying industries. For example, it lists the dollar volume of imports the US car industry imports from the Mexican textile industry. From this data, we construct the industry's average input intensity of industry k in country TP from the WIOD by summing over input imports from all countries other than TP and all supplying industries l and dividing by the industry's total costs.

$$\theta_{TP,k}^{WIOD} = \frac{\sum_{c \in C-TP} \sum_{l \in I} \text{Value Input Imports}_{c,TP,k,l}}{\text{Total Var Cost}_{k,TP}}$$

$\theta_{TP,k}^{WIOD}$ measures the average imported inputs intensity of industry k in TP . Amiti et al. (2013) document a further key pattern in the data that we need to take into account: that firms of

heterogeneous productivity also differ in their imported input intensity. Since the exporting decision, differences in input import intensity and market share (that determines the strength of the PTM response to cost shocks) are jointly determined and hence correlated, we need to take into account the heterogeneity in imported input intensity. For our purpose, we need to make two separate adjustments to account for the heterogeneity of imported input intensity across firms. First, of all the imported input goods, we need to take into account that exporters and non-exporters differ in their imported input intensity. Second, of those imported inputs used by exporters, we need to allocate the total to large and small exporters. We do these two adjustments such that they match the patterns of the Belgian data found in Amiti et al. and in total sum up to the aggregate input usage in the World Input output tables database (WIOD).

The first adjustment reflects the fact that exporters are generally more imported input intensive than non-exporters. In the Belgian data of Amiti et al., actually 99.1% of all imported inputs are being used by exporters. These exporters also account for 85.8% of the total costs of the Belgian manufacturing sector. Thus, exporters are a factor $99.1\%/85.8\% = 1.156$ as imported input intensive as the total manufacturing sector.⁵

The second adjustment is to allocate the imported inputs across the various exporters from each trade partner. We postulate that the share of imported inputs is increasing in a firm's productivity.

$$\theta_{n,TP}^{ImInp} = k_{TP,k} (1 - \exp(-\gamma_{n,k} z))$$

where we choose γ as 3.5 such that with our assumed distribution of productivities (from Atkeson and Burstein (2008)), we match the distribution of input intensities in Amiti et al. (2013, see the distribution reported in and 3 as well as the figure in the appendix). The industry-trade partner specific constant $k_{TP,k}$ is chosen such that we match the industry's average input intensity in the

⁵These numbers are calculated from Table 2 of Amiti et al (2013) that splits up all firms into three groups (nonexporters, exporters with above median imported input intensity, exporters with below median imported input intensity). Taking into account the average wage bill per employee and the number of employees as well as total material costs implies the average costs per firm of each of the three groups. Then, taking into the size of the three groups (76.3% non-exporters and 23.7% exporters split up in to equally sized subgroups of above and below median input intensity) yields that 85.8% of total variable costs are created by exporters. Finally, taking into account the average input intensity of the two groups (36.8%, 17.3% and 1.6%, respectively) and again the average variable costs per firm as well as the size of the three groups implies that 99.1% of all intermediate goods imports are imported by exporters.

WIOD (adjusted by 1.156):

$$\sum_{n \in N_c} \theta_{n,k} s_{n,k} = 1.156 * i_{c,k}^{WIOD}.$$

Summing up, we account for the input useage by heterogenous firms originating from different countries and industries in three steps:

- For each trade partner and industry (that is, cars from Germany), we know the total value of imported inputs as a fraction of that industry’s costs. For example, that ratio could be 24%.
- We apply a correction factor of 1.156 to this figure as exporters are generally more input-intensive than the industry is in general.
- We allocate the inputs imported by exporters over the exporters according to their sampled productivity.

4.3 Accounting for input imports by domestic firms.

Our estimations also take into account the effect of imported intermediate goods on the production cost and thus the prices of domestic producers. To quantify the role of intermediate goods, we need to construct an estimate of how much production costs in each US sector change due to price movements of input goods. We also need to incorporate how the latter varies across heterogenous firms. We do this in three steps.

We first construct trade-partner and sector-specific intermediate import price indices (IIPs) using the BLS import price microdata. For this, we follow Schott (2004), who uses the information contained in 10-digit HS sector descriptions and flags all descriptions that contain words such as “part”, “input”, “intermediate”, and variants thereof as input sectors. Using the comparable product description in the BLS microdata (schedule B), we thus flag all goods in the US import price index. We then construct IPIs at the sectoral level for each trade partner. That is, for each supplying sector l and each exporter TP , we construct

$$\widehat{IIP}_{l,TP,t} = \sum_{n \in N_{l,TP}^I} \theta_{n,l,TP}^I \widehat{p}_t \quad (19)$$

where $N_{l,TP}^I$ denotes the set of firms that are input producers from TP in l . $\theta_{n,l,TP}^I$ denotes the input share of the respective firm in the total set of input producers in sector l and from country TP . If firm n is an intermediate goods producer,

$$\theta_{n,l,TP}^I = \frac{s_{n,l,TP}}{\sum_{n \in N_{l,TP}^I} s_{n,l,TP}}$$

and $s_{n,l,TP}$ are the firm's market shares. In the second step, we combine information from the World Input-Output Table database (WIOD) and the constructed IIP s to construct a sector-specific measure of how the costs of imported inputs evolve over time. If k denotes the using sector, we construct $\widehat{IICI}_{k,t}$, the change in the Imported Input Cost Index in US industry as

$$\widehat{IICI}_{k,t} = \sum_{l \in K} \sum_{TP \in C-US} \theta_{TP,l,k} \widehat{IIP}_{l,TP,t}$$

where $\theta_{TP,l,k}$ is the cost share of input goods from TP and sector l in the production of sector k in the US.

$$\theta_{TP,l,k} = \frac{\sum_{l \in K} Input\ Use_{TP,l,k}}{Total\ Variable\ Costs_k}$$

We note that the weights in $\theta_{TP,l,k}$ do not sum to one as input costs only make up one of the components of variable costs. $\widehat{IICI}_{k,t}$ measures the change in imported goods used by sector k as a fraction of the sector's total variable costs.

We next account for the fact that also US domestic firms are heterogenous in their imported input use. We again postulate that each firm's input use intensity is heterogenous following

$$\theta_{n,TP}^{Imp} = k_{TP,k} (1 - \exp(-\gamma_{n,k} z))$$

where $k_{TP,k}$ is such that firm's individual input shares sum to the total WIOD imports.

$$\sum_{n \in N_c} k_{TP,k} (1 - \exp(-\gamma_{n,k} z)) s_{n,k} = \theta_{US,k} = \sum_{l \in K} \sum_{TP \in C-US} \theta_{TP,l,k}$$

If domestic producers were to fully pass such cost changes through into their prices and import producers were not to react to this change, we could simply net them out and evaluate domestic prices net of the input cost shock. However, as the above theory makes clear, this is not the case and the parameters of interest we want to identify also guide the response of domestic firms to cost shocks stemming from the changing costs of imports. We thus incorporate the identified cost shocks into our GMM optimization unveiling the parameters of interest

$$\widehat{c_{n,k}^D} = \widehat{IICI_{k,t}} \theta_{n,TP}^{ImInp}$$

With this in mind, our sub-procedure for taking into account the impact of imported intermediate goods in the production of domestic goods is:

1. We estimate a reduced-form ERPT regression quantifying the response of the imported input prices to the exchange rate. From this, we generate the exchange rate induced projection of $\widehat{IIP I_{l,TP,t}}$.
2. We calculate $\widehat{IICI_{k,t}}$ from the $\widehat{IIP I_{l,TP,t}}$ and the world output tables.
3. We set $\widehat{c_{n,k}^D} = \widehat{IICI_{k,t}} \theta_{n,k}$ where $\theta_{n,k}$ denotes the firm-specific imported input intensity.

5 Accounting for the Endogeneity of the Exchange Rate

We note that

While this, we note that our analysis is much more prone to this problem as are other studies. For example, Gopinath et al. (2011) focus , and also Berman et al. (2012) and Amitit et al. (2013) focus on within-industry differences of ERPT from firms from .

Instead, our theory relates the trade weighted . Because what matters for identifying, no real (we do have sufficient). We thus must take extra care.

The exchange rate is both subject to supply shocks and demand shocks, but

6 Implications for pass through and exchange rate disconnect

In this section, we apply our insights to explain the low rate of external adjustment following exchange rate movements and we also investigate the heterogeneity of external adjustment rates across sectors.

There are in total four channels leading to a low rate of external adjustment following exchange rate movements. Two channels are causing the response of import volumes to fluctuations in the relative price of foreign compared to domestic goods to be small. Two further channels mitigate the response of relative price movements to exchange rate fluctuations.

6.1 External Adjustment Theory

M_k , the volume of imports in sector k is equal to the market share of foreign firms multiplied by total expenses for the industry's good.

$$M_k = S_k^F \left(\frac{P_k}{P} \right)^{-(\eta-1)} I$$

if the exchange rate moves, the response of import volume is equal to

$$\widehat{M}_k = \widehat{S}_k^F - (\eta - 1) \frac{\widehat{P}_k}{P}$$

In our estimations, η is equal to 1 and we thus focus on $\widehat{S}_k^F$. We thus examine how the market share of foreign firms varies with a movement of the exchange rate. In each sector, the response of the market share of importers is given by

$$\widehat{S}_k^F = (1 - \mu_k) \left(\widehat{P}_k^F - \widehat{P}_k \right).$$

Since $\widehat{P}_k = (1 - S_k^D) \widehat{P}_k^F + S_k^D \widehat{P}_k^D$, it further holds that

$$\widehat{S}_k^F = (1 - \mu_k) S_k^D \left(\widehat{P}_k^F - \widehat{P}_k^D \right) \tag{20}$$

Equation (20) documents that rate of external adjustment as a function of parameters, market shares, and the relative price movements of $\widehat{P}_k^F$ compared to $\widehat{P}_k^D$. It says that movements in P_k^F / P_k , the relative price of foreign goods compared to the sector's price index are associated with an isoelastic reduction of foreign market share with elasticity $(1 - \mu_k)$. Second, it says that because foreign firms make up a share of S_k^F of the sector, any movements in foreign prices affects the total price index by a fraction S_k^F of imported price changes. Third, also that domestic prices might co-react to import price movements.

Since we find in the data that μ_k is on average 4, while S_k^F is 0.85, our findings thus indicate the import volume response to relative price movements to be around 2.55.

Next, we take into account the above-derived pricing response to exchange rate fluctuations. It holds that

$$\widehat{P}_k^D = \frac{(1 - Z^F) \widehat{C}_k^D + Z^D \widehat{C}_k^F}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \text{ and } \widehat{P}_k^F = \frac{(1 - \Delta^D) \widehat{C}_k^F + \Delta^F \widehat{C}_k^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F}$$

and that

$$\widehat{S}_k^F = (1 - \mu_k) S_k^D \left(\frac{(1 - \Delta^D) - Z^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^F + \frac{\Delta^F - (1 - Z^F)}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^D \right)$$

If for the moment, we assume that there are no intermediate goods used by domestic firms, $\widehat{C}_k^D = 0$ and we get

$$\widehat{S}_k^F = (1 - \mu_k) S_k^D \frac{(1 - \Delta^D) - Z^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widehat{C}_k^F \quad (21)$$

The first and most important channel is that the foreign and the domestic composite are quite differentiated, so that although each single importer faces a rather elastic demand, the overall demand for foreign goods is rather inelastic to movements in the relative prices of foreign vs domestic goods. The second channel is that foreigners do make up a substantial part of the market, and they thus have an impact on the sector's price index. This again dampens the import volume response to movements in relative prices.

The third and fourth channels mitigate the response of relative price movements to exchange

rate fluctuations. The third channel is that in our setup, markups are variable, hence resulting in a low price response of importers to exchange rate fluctuations. The fourth channel is that also domestic prices react to exchange rate fluctuations; since domestic prices positively commoves foreign prices, this further dampens the response of relative prices to the exchange rate.

Proposition The Rate External Adjustment. Assume that neither domestic nor foreign varieties use traded intermediate goods. The sector-specific rate of **external adjustment following movements of the trade-weighted exchange rate is equal to**

$$\widehat{S}_k^F = (1 - \mu_k) S_k^D \frac{(1 - \Delta^D) - Z^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F} \widetilde{C}_k^F \Delta_{errTW}$$

where

$$\widetilde{C}_k^F = \sum_{n \in N_k^F} \frac{s_{n,k}^F}{1 + \Gamma_1^F(S_k^D, s_{n,k}^F)(\rho_k - 1)} < 1$$

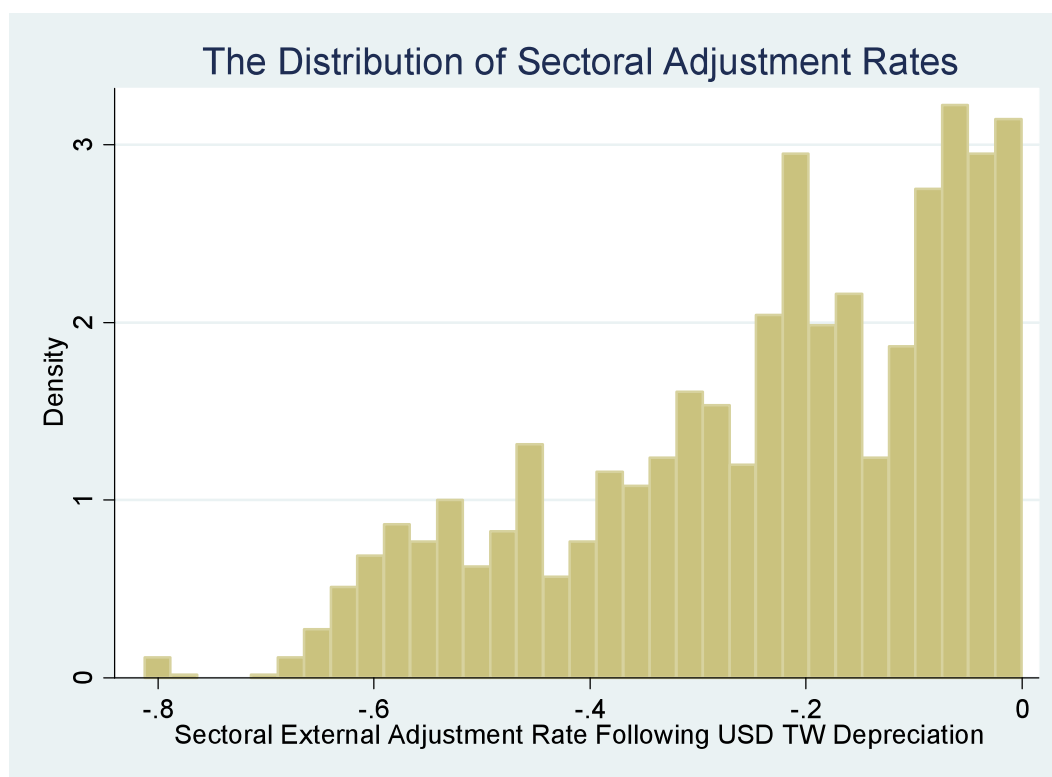
The below Table and Graph highlights the economic importance of our approach: we predict the ERA (external adjustment rate) to be on average very low (median across sectors and time of 0.24), which is well in line with the data. The reason for the low adjustment rate is first that μ_k is estimated low in the data so that for any given rate of relative price movement, the predicted quantity response is small and second, that $\widetilde{C}_k^F$ is low in the data, that is, that the relative pricing response following an exchange rate movement is rather small in the data.

ERA and its Decomposition (all numbers are medians)

$$\underbrace{\widehat{S}_k^F}_{-0.21} = \underbrace{(1 - \mu_k)}_{-3.01} \underbrace{S_k^D}_{0.89} \underbrace{\frac{(1 - \Delta^D) - Z^D}{(1 - Z^F)(1 - \Delta^D) - Z^D \Delta^F}}_{0.99} \underbrace{\widetilde{C}_k^F}_{0.098}$$

Corrolary: Intermediate goods. TBD

Figure 1: Distribution of Sectoral Adjustment Rates



where

$$\widehat{C_k^F} = \begin{cases} \Delta err_{us,TP} & \text{if there are no int abroad} \\ \theta_{k,TP}^{Local\ cost} \Delta err_{us,TP} & \text{otherwise} \end{cases}$$

($\theta_{k,TP}^{Local\ cost}$ is the cost share of non-imported goods abroad).

6.2 Empirical Results

We present the results regarding the fit of our theory aimed at explaining external adjustment rates (EAR) in two steps. First, we ask if we are able to match the magnitude of EARs estimated from the data and if so, what the reasons are why our theory can match the low observed external adjustment rates. Second, we are interested in whether we can also match the cross-sectoral variation in EARs.

We start by showing that our theory can explain why the rate of external adjustment observed in the data is low on average. Given the sizeable aggregation bias uncovered in Imbs and Mejean (2009), we focus on the sector-specific EARs rather than on the aggregate EAR.

First, we estimate the distribution of EARs observed in the data. Figure 1 presents a histogram of our estimated sectoral EARs which we obtain from a panel type regression of the type

$$\Delta M_{k,t} = \alpha_k + \sum_{j=1}^n \beta_{k,j} \Delta e_{k,t-j+1}^{TW} + \sum_{j=1}^n \gamma_{k,j}^{TP} \Delta \pi_{k,t-j+1}^{TP} + \epsilon_{k,t},$$

We choose the 24-months horizon (n=24) and calculate the summed coefficient $\sum_{j=1}^{24} \beta_{k,j}$ for each sector k . Figure 1 presents a histogram of the uncovered elasticities. Our data is not too far of typical estimates of the exchange rate surveyed for example in Goldstein and Kahn (1985). When we estimate the above using sectoral US imports and the US trade-weighted exchange rate in our data, the average EAR is -0.943 and the median is equal to -0.762. That is, an observer assuming a constant markups framework would assume that the median estimated elasticity is equal to -1.762. Figure 1 displays the distribution of the estimated values of (1- μ). Figure 1 is winsorized, so we also display some descriptive statistics of the non-winsorized data below Figure 1.

In Figure 2, we present the similarly winsorized histogram of the predicted sectoral adjustment rates. Again, we report the summary statistic of the un-winsorized data below that Figure. Predictions are considerably less variable, as shown in Figure 2. Still, our theory can thus accurately match the average and the dispersion of EARs in the data. We find this to be a very strong result since we have not used any information of trade volumes to explain EARs, which makes this exercise akin to an out-of-sample prediction.

Our results demonstrate that the degree of origin-differentiation (the structural estimate of the demand elasticity) is nearly by a factor of three different from the “naïve” estimate, that is, from the estimated EAR. Figure 3 plots a Kernel density estimation that compares the distribution of the structural estimate of μ to the estimated EARs. While the mean of the EARs is 0.89, the mean of $(1-\mu)$ is equal to 2.4.

In second set of tests we consider the cross-sectoral variation of estimated and predicted EAR rates. We present the same information as Figure 1 and 2, but jointly in a scatter plot. These results can be seen in Figure 4. The red line corresponds to a simple regression line.

We find that we also match the cross section of EARs well, that is, our sectoral estimates of μ , IPI and PPI rates, as well as market shares of foreign goods contain important information for our understanding of actual EARs in the data. We note that the slope is different from one however (0.38 at significant at the 5% level).

7 Conclusion

In this paper, we augment the two-tiered CES preference structure of Dornbusch (1987) and Atkeson and Burstein (2008) that features variable markups with Armington’s (1969) notion that the set of imported goods is differentiated from domestically produced goods. We examine how the degree of “origin-differentiation” affects pass-through and external adjustment following exchange rate movements using the information in the micro price data underlying the official US import and producer price indices. First, we develop a parsimonious model that allows for both pricing-to-market of imported goods and price complementarities between imported and domestic goods.

Varieties are combined to produce a sector’s output. We extend this setup by allowing for the possibility that foreign and domestic varieties are not equally substitutable within sectors. Second, we structurally estimate the parameters of interest in our preference framework – the elasticity of substitution between varieties from the same origin, between foreign and domestic goods, and across sectors – using the information in the micro price data underlying the US official import and producer price indices.

Our main empirical finding is that the across-origin elasticity of substitution between the imported and domestic varieties is equal to around 4, while the within-origin elasticity amongst domestic or amongst imported varieties is equal to around 9: the set of foreign and imported goods is quite differentiated, but far from being perfectly so. This has two implications regarding pricing decisions. The first is that there can be substantial pricing-to-market by foreign firms even if these firms are small compared to the domestic industry. The second is that the price response of domestic firms to exchange rate movements is small (though non-negligible).

We then highlight the implications of our finding for the nature of external adjustment. First, the fact that the sets of imported and domestic goods are substantially differentiated leads to a small quantity response for any given movement in the relative price of imported versus domestic goods. Second, since a higher degree of “origin-differentiation” goes along with lower exchange rate pass-through, not only the quantity but also the relative price movement of imported goods is smaller the more imported and domestic goods are differentiated. Even a moderate degree of origin-differentiation thus leads to very low external adjustment.

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A APPENDIX: Math in the tripple-nested case assuming Bertrand competition

$$U = \left(\int_0^1 Y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)}$$

where

$$Y_k = \left(w_k \left(\sum_{n=1}^{N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k} \right)^{((\mu_k-1)\rho_k)/(\mu_k(\rho_k-1))} + (1-w_k) \left(\sum_{n=1}^{N_k^F} (q_{n,k}^F)^{(\rho_k-1)/\rho_k} \right)^{((\mu_k-1)\rho_k)/(\mu_k(\rho_k-1))} \right)^{\mu_k/(\mu_k-1)}$$

Note that if $\mu_K = \rho_k$, this reduces to a simple CES (with demand shifters $(1-w_k), w_k$). We proceed by defining

$$Q_k^D \equiv \left(\sum_{n=1}^{N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k} \right)^{\rho_k/(\rho_k-1)} \quad \text{and} \quad Q_k^F \equiv \left(\sum_{n=1}^{N_k^F} (q_{n,k}^F)^{(\rho_k-1)/\rho_k} \right)^{\rho_k/(\rho_k-1)}.$$

For a given Q_k^D , it is thus true that

$$\min \left(\sum_{n=1}^{N_k^D} p_{n,k} q_{n,k} \right) \quad \text{s.t.} \quad \left(\sum_{n=1}^{N_k^D} (q_{n,k}^D)^{(\rho_k-1)/\rho_k} \right)^{\rho_k/(\rho_k-1)} = Q_k^D$$

yields

$$q_{n,k}^D = Q_k^D \left(\frac{p_{n,k}^D}{\lambda_k^D} \right)^{-\rho_k}$$

and solves for the marginal cost of the Q_k^D composite (which also equals its price)

$$\lambda_k^D = P_k^D = \left(\sum_{n=1}^{N_k^D} (p_{n,k}^D)^{(1-\rho_k)} \right)^{1/(1-\rho_k)}$$

so that the prize of the output in sector k comes from the cost minimization problem Y_k

$$\min P_k^D Q_k^D + P_k^N Q_k^N \text{ s.t. } \left(w_k (Q_k^D)^{(\mu_k-1)/\mu_k} + (1-w_k) (Q_k^N)^{(\mu_k-1)/\mu_k} \right)^{\mu_k/(\mu_k-1)} = Y_k$$

yielding

$$Q_k^D = \left(\frac{P_k^D}{\lambda_k} \right)^{-\mu_k} (w_k)^{\mu_k} Y_k \text{ and } Q_k^N = \left(\frac{P_k^N}{\lambda_k} \right)^{-\mu_k} (1-w_k)^{\mu_k} Y_k$$

$$\lambda_k = P_k = \left(w_k^{\mu_k} (P_k^D)^{(1-\mu_k)} + (1-w_k)^{\mu_k} (P_k^N)^{(1-\mu_k)} \right)^{1/(1-\mu_k)}$$

This, in the final maximization

$$\max C = \left(\int_0^1 Y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)} \text{ s.t. } \int_0^1 P_k Y_k dk \leq I$$

the output of in sector k is equal to

$$Y_k = \left(\int_0^1 Y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)} \lambda^\eta P_k^{-\eta}$$

$$\lambda = \left(\int_0^1 P_k^{(1-\eta)} dk \right)^{1/(1-\eta)}$$

$$\begin{aligned} \int_0^1 P_k Y_k dk &= I \\ \left(\int_0^1 Y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)} &= \frac{I}{\lambda^\eta \int_0^1 P_k^{1-\eta} dk} = \frac{I}{\left(\int_0^1 P_k^{(1-\eta)} dk \right)^{1/(1-\eta)}} \end{aligned}$$

$$Y_k = \frac{P_k^{-\eta}}{\int_0^1 P_k^{(1-\eta)} dk} I$$

.Putting together the pieces yields

$$\begin{aligned}
q_{n,k}^D &= \left(\frac{p_{n,k}^D}{P_k^D} \right)^{-\rho_k} Q_k^D \\
&= \left(\frac{P_k^D}{\lambda_k} \right)^{-\mu_k} (w_k)^{\mu_k} Y_k \left(\frac{p_{n,k}^D}{P_k^D} \right)^{-\rho_k} \\
&= (w_k)^{\mu_k} \left(\frac{P_k^D}{P_k} \right)^{-\mu_k} \left(\frac{p_{n,k}^D}{P_k^D} \right)^{-\rho_k} \frac{P_k^{-\eta}}{\int_0^1 P_k^{(1-\eta)} dk} I \\
&= (p_{n,k}^D)^{-\rho_k} (P_k^D)^{(\rho_k - \mu_k)} (P_k)^{(\mu_k - \eta)} \frac{(w_k)^{\mu_k} I}{\int_0^1 P_k^{(1-\eta)} dk}
\end{aligned}$$

So that the elasticity of substitution is equal to:

$$\frac{\partial q_{n,k}^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{q_{n,k}^D} = -\rho_k + (\rho_k - \mu_k) \frac{\partial P_k^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{P_k^D} + (\mu_k - \eta) \frac{\partial P_k}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{P_k}$$

Noting that

$$\begin{aligned}
\frac{\partial P_k}{\partial p_{n,k}^D} &= w_k^{\mu_k} \frac{\partial P_k^D}{\partial p_{n,k}^D} (P_k^D)^{-\mu_k} (P_k)^{\mu_k} \\
&= (P_k)^{(\mu_k - \eta)} \frac{p_{n,k}^D}{P_k} w_k^{\mu_k} (P_k^D)^{-\mu_k} (P_k)^{\mu_k} \frac{\partial P_k^D}{\partial p_{n,k}^D} \\
&= (P_k)^{(\mu_k - \eta)} \frac{p_{n,k}^D}{P_k} w_k^{\mu_k} \left(\frac{P_k^D}{P_k} \right)^{-\mu_k} \frac{\partial P_k^D}{\partial p_{n,k}^D}
\end{aligned}$$

yields

$$\begin{aligned}
\frac{\partial q_{n,k}^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{q_{n,k}^D} &= -\rho_k + \left[(\rho_k - \mu_k) + (\mu_k - \eta) w_k^{\mu_k} \left(\frac{P_k^D}{P_k} \right)^{1-\mu_k} \right] \frac{\partial P_k^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{P_k^D} \\
\frac{\partial P_k^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{P_k^D} &= (p_{n,k}^D)^{-\rho_k} \left(\sum_{n=1}^{N_k^D} (p_{n,k}^D)^{(1-\rho_k)} \right)^{\rho_k/(1-\rho_k)} \frac{p_{n,k}^D}{P_k^D} = \left(\frac{p_{n,k}^D}{P_k^D} \right)^{1-\rho_k}
\end{aligned}$$

Finally, noting that

$$S_k^D = w_k^{\mu_k} \left(\frac{P_k^D}{P_k} \right)^{1-\mu_k}, s_{n,k}^D = \left(\frac{p_{n,k}^D}{P_k^D} \right)^{1-\rho_k} = \frac{(p_{n,k}^D)^{1-\rho_k}}{\sum_{n=1}^{N_k^D} (p_{n,k}^D)^{(1-\rho_k)}}$$

so that

$$\frac{\partial q_{n,k}^D}{\partial p_{n,k}^D} \frac{p_{n,k}^D}{q_{n,k}^D} = -\rho_k + [(\rho_k - \mu_k) + (\mu_k - \eta) S_k^D] s_{n,k}^D$$

B APPENDIX: Non-Linearized System of Equations of the Model in General Equilibrium

The economy is fully characterized by the following set of equations:

$$P_{k,t}^{HD} = \left(\sum_{n \in N^{HD}} (P_{n,k,t}^{HD})^{(1-\rho_k)} \right)^{1/(1-\rho_k)} \quad (22)$$

$$P_{k,t}^{FX} = \left(\sum_{n \in N^{FX}} (P_{n,k,t}^{FX})^{(1-\rho_k)} \right)^{1/(1-\rho_k)} \quad (23)$$

$$P_{k,t}^H = \left((P_{k,t}^{HD})^{(1-\mu_k)} + \theta_{k,t} (P_{k,t}^{FX})^{(1-\mu_k)} \right)^{1/(1-\mu_k)} \quad (24)$$

$$P_t^H = \left(\int_0^1 P_{k,t}^{H(1-\eta)} \right)^{1/(1-\eta)} \quad (25)$$

$$P_{k,t}^{HX} = \left(\sum_{n \in N^{HX}} (P_{n,k,t}^{HX})^{(1-\rho_k)} \right)^{1/(1-\rho_k)} \quad (26)$$

$$P_{k,t}^{FD} = \left(\sum_{n \in N^{FD}} (P_{n,k,t}^{FD})^{(1-\rho_k)} \right)^{1/(1-\rho_k)} \quad (27)$$

$$P_{k,t}^F = \left((P_{k,t}^{HX})^{(1-\mu_k)} + \theta_{k,t} (P_{k,t}^{FD})^{(1-\mu_k)} \right)^{1/(1-\mu_k)} \quad (28)$$

$$P_t^F = \left(\int_0^1 P_{k,t}^{F(1-\eta)} \right)^{1/(1-\eta)} \quad (29)$$

$$\frac{C_{k,t}^H}{C_t^H} = \left(\frac{P_{k,t}^H}{P_t^H} \right)^{-\eta} \quad (30)$$

$$\frac{C_{k,t}^{HD}}{C_{k,t}^H} = \left(\frac{P_{k,t}^{HD}}{P_{k,t}^H} \right)^{-\mu_k} \quad (31)$$

$$\frac{C_{k,t}^{FX}}{C_{k,t}^H} = \left(\frac{P_{k,t}^{FX}}{P_{k,t}^H} \right)^{-\mu_k} \quad (32)$$

$$\frac{C_{n,k,t}^{HD}}{C_{k,t}^{HD}} = \left(\frac{P_{n,k,t}^{HD}}{P_{k,t}^{HD}} \right)^{-\rho_k} \quad (33)$$

$$\frac{C_{n,k,t}^{FX}}{C_{k,t}^{FX}} = \left(\frac{P_{n,k,t}^{FX}}{P_{k,t}^{FX}} \right)^{-\rho_k} \quad (34)$$

$$\frac{C_{k,t}^F}{C_t^F} = \left(\frac{P_{k,t}^F}{P_t^F} \right)^{-\eta} \quad (35)$$

$$\frac{C_{k,t}^{HX}}{C_{k,t}^F} = \left(\frac{P_{k,t}^{HX}}{P_{k,t}^F} \right)^{-\mu_k} \quad (36)$$

$$\frac{C_{k,t}^{FD}}{C_{k,t}^F} = \left(\frac{P_{k,t}^{FD}}{P_{k,t}^F} \right)^{-\mu_k} \quad (37)$$

$$\frac{C_{n,k,t}^{HX}}{C_{k,t}^{HX}} = \left(\frac{P_{n,k,t}^{HX}}{P_{k,t}^{HX}} \right)^{-\rho_k} \quad (38)$$

$$\frac{C_{n,k,t}^{FD}}{C_{k,t}^{FD}} = \left(\frac{P_{n,k,t}^{FD}}{P_{k,t}^{FD}} \right)^{-\rho_k} \quad (39)$$

$$\frac{C_t^{H-\sigma}}{P_t^H} E_t[\rho_{t,t+1}^H] = \beta E_t \left[\frac{C_{t+1}^{H-\sigma}}{P_{t+1}^H} \right] \quad (40)$$

$$\frac{W_t^H}{P_t^H} = \frac{L_t^{H\phi}}{C_t^{H-\sigma}} \quad (41)$$

$$\frac{C_t^{F-\sigma}}{P_t^F S_t} E_t[\rho_{t,t+1}^F] = \beta E_t \left[\frac{C_{t+1}^{F-\sigma}}{P_{t+1}^F S_{t+1}} \right] \quad (42)$$

$$\frac{W_t^F}{P_t^F} = \frac{L_t^{F\phi}}{C_t^{F-\sigma}} \quad (43)$$

$$\rho_{t,t+1}^H = \rho_{t,t+1}^F \quad (44)$$

$$P_{n,k,t}^{HD} = \frac{\epsilon_{n,k,t}^{HD}}{\epsilon_{n,k,t}^{HD} - 1} \frac{1}{A_{n,k,t}^H} W_t^H \quad (45)$$

$$\epsilon_{n,k,t}^{HD} = \left(1/\rho_k + ((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_{k,t}^{HD}) s_{n,k,t}^{HD} \right)^{-1} \quad (46)$$

$$S_{k,t}^{HD} = \frac{P_{k,t}^{HD} C_{k,t}^{HD}}{P_{k,t}^H C_{k,t}^H} \quad (47)$$

$$s_{n,k,t}^{HD} = \frac{P_{n,k,t}^{HD} C_{n,k,t}^{HD}}{P_{k,t}^{HD} C_{k,t}^{HD}} \quad (48)$$

$$P_{n,k,t}^{HX} = \frac{\epsilon_{n,k,t}^{HX}}{\epsilon_{n,k,t}^{HX} - 1} (1 + \tau) \frac{W_t}{S_t A_{n,k,t}^H} \quad (49)$$

$$\epsilon_{n,k,t}^{HX} = - \left(1/\rho_k + \left((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_{k,t}^{HX} \right) s_{n,k,t}^{HX} \right)^{-1} \quad (50)$$

$$S_{k,t}^{HX} = \frac{P_{k,t}^{HX} C_{k,t}^{HX}}{P_{k,t}^F C_{k,t}^F} \quad (51)$$

$$s_{n,k,t}^{HX} = \frac{P_{n,k,t}^{HX} C_{n,k,t}^{HX}}{P_{k,t}^{HX} C_{k,t}^{HX}} \quad (52)$$

$$P_{n,k,t}^{FX} = \frac{\epsilon_{n,k,t}^{FX}}{\epsilon_{n,k,t}^{FX} - 1} \frac{1}{A_{n,k,t}^F} W_t^F \quad (53)$$

$$\epsilon_{n,k,t}^{FX} = \left(1/\rho_k + \left((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_{k,t}^{FX} \right) s_{n,k,t}^{FX} \right)^{-1} \quad (54)$$

$$S_{k,t}^{FX} = \frac{P_{k,t}^{FX} C_{k,t}^{FX}}{P_{k,t}^H C_{k,t}^H} \quad (55)$$

$$s_{n,k,t}^{FX} = \frac{P_{n,k,t}^{FX} C_{n,k,t}^{FX}}{P_{k,t}^{FX} C_{k,t}^{FX}} \quad (56)$$

$$P_{n,k,t}^{FD} = \frac{\epsilon_{n,k,t}^{FD}}{\epsilon_{n,k,t}^{FD} - 1} (1 + \tau) S_t \frac{W_t^F}{A_{n,k,t}^F} \quad (57)$$

$$\epsilon_{n,k,t}^{FD} = - \left(1/\rho_k + \left((1/\mu_k - 1/\rho_k) + (1/\eta - 1/\mu_k) S_{k,t}^{FD} \right) s_{n,k,t}^{FD} \right)^{-1} \quad (58)$$

$$S_{k,t}^{FD} = \frac{P_{k,t}^{FD} C_{k,t}^{FD}}{P_{k,t}^F C_{k,t}^F} \quad (59)$$

$$s_{n,k,t}^{FD} = \frac{P_{n,k,t}^{FD} C_{n,k,t}^{FD}}{P_{k,t}^{FD} C_{k,t}^{FD}} \quad (60)$$

$$y_{n,k,t}^H = C_{n,k,t}^{HD} + (1 + \tau)C_{n,k,t}^{HX}I\{C_{n,k,t}^{HX} > 0\} \quad (61)$$

$$y_{n,k,t}^F = (1 + \tau)C_{n,k,t}^{FX}I\{C_{n,k,t}^{FX} > 0\} + C_{n,k,t}^{FD} \quad (62)$$

$$L_t = \int_0^1 \sum_{n \in N_K^H} \frac{y_{n,k,t}^H}{A_{n,k,t}^H} dk \quad (63)$$

$$L_t^* = \int_0^1 \sum_{n \in N_K^F} \frac{y_{n,k,t}^F}{A_{n,k,t}^F} dk \quad (64)$$

$$S_t \int_0^1 P_{k,t}^{HX} C_{k,t}^{HX} dk = \int_0^1 P_{k,t}^{FX} C_{k,t}^{FX} dk \quad (65)$$

$$\log A_t = \rho_A \log A_{t-1} + \epsilon_{A,t} \quad (66)$$

$$\log A_t^* = \rho_A \log A_{t-1}^* + \epsilon_{A,t}^* \quad (67)$$

C Tables

Table 1: Estimated Long-Run Pass-Through into US Producer Prices

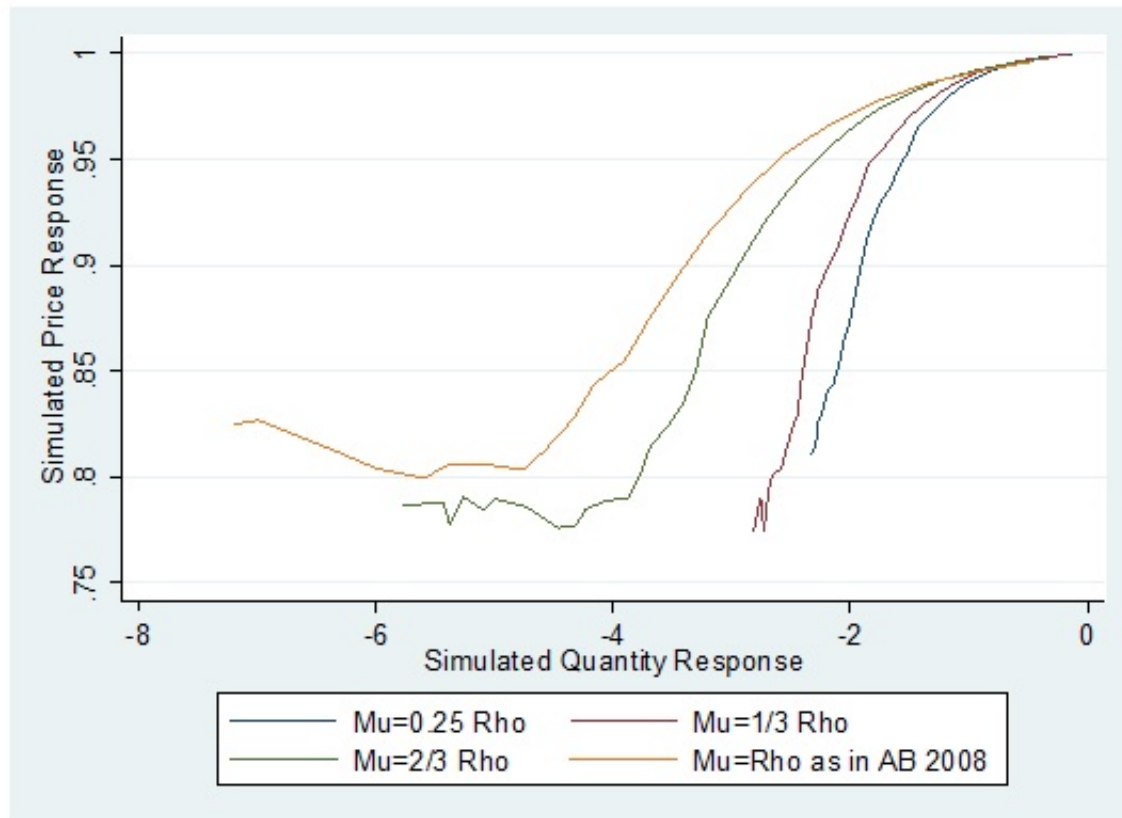
	Fed Broad Exchange Rate	Trade-Weighted Exchange Rate	Sectoral Trade-Weighted Exchange Rate
Estimated Long-Run Pass-Through	10.97% (1.46%)	14.23% (1.73%)	9.69% (1.41%)
R^2	0.30%	0.28%	0.25%
N	2155186	2155186	1183193

Table 2: Sectoral Import Penetration and Pass-Through into US Producer Prices

	Fed Broad Exchange Rate	Trade-Weighted Exchange Rate	Sectoral Trade-Weighted Exchange Rate
Estimated Long-Run Pass-Through	21.14% (2.40%)	26.51% (2.79%)	3.78% (2.14%)
Interaction Term	-13.55% (8.16%)	-15.52% (9.63%)	20.27% (8.59%)
R^2	0.49%	0.46%	0.31%
N	1226237	1226237	1150359

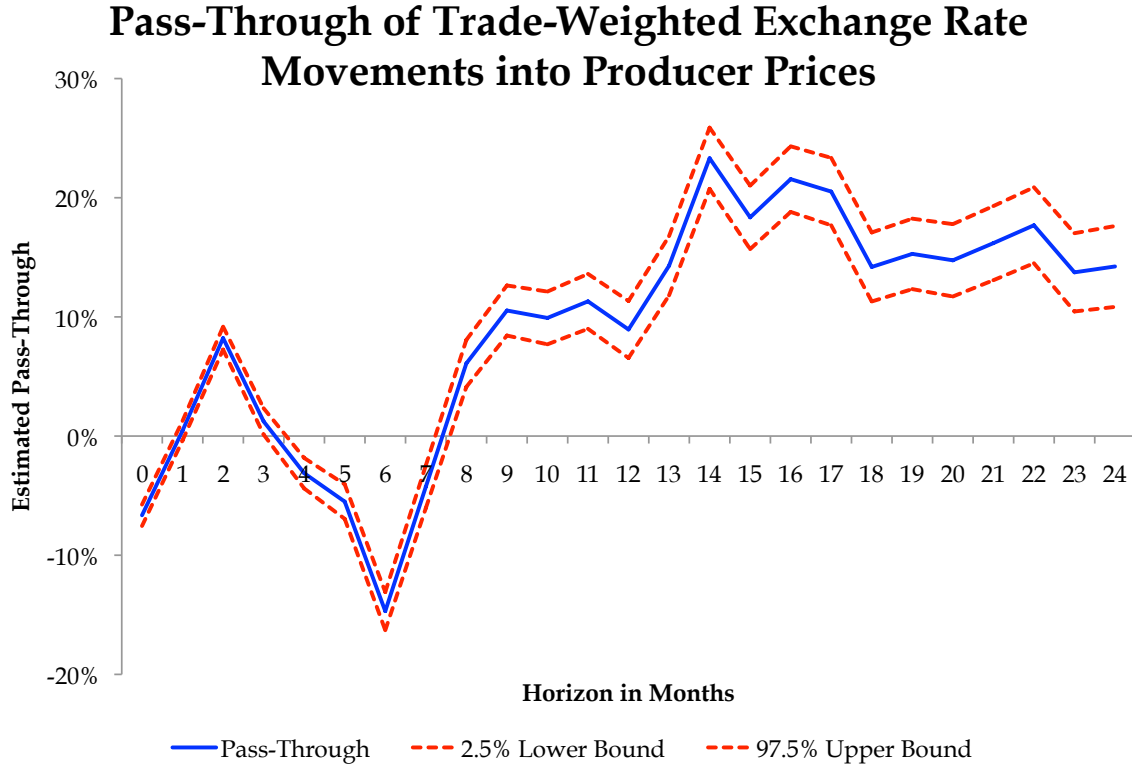
D Figures

D.1 Theoretical Price-Quantity Response



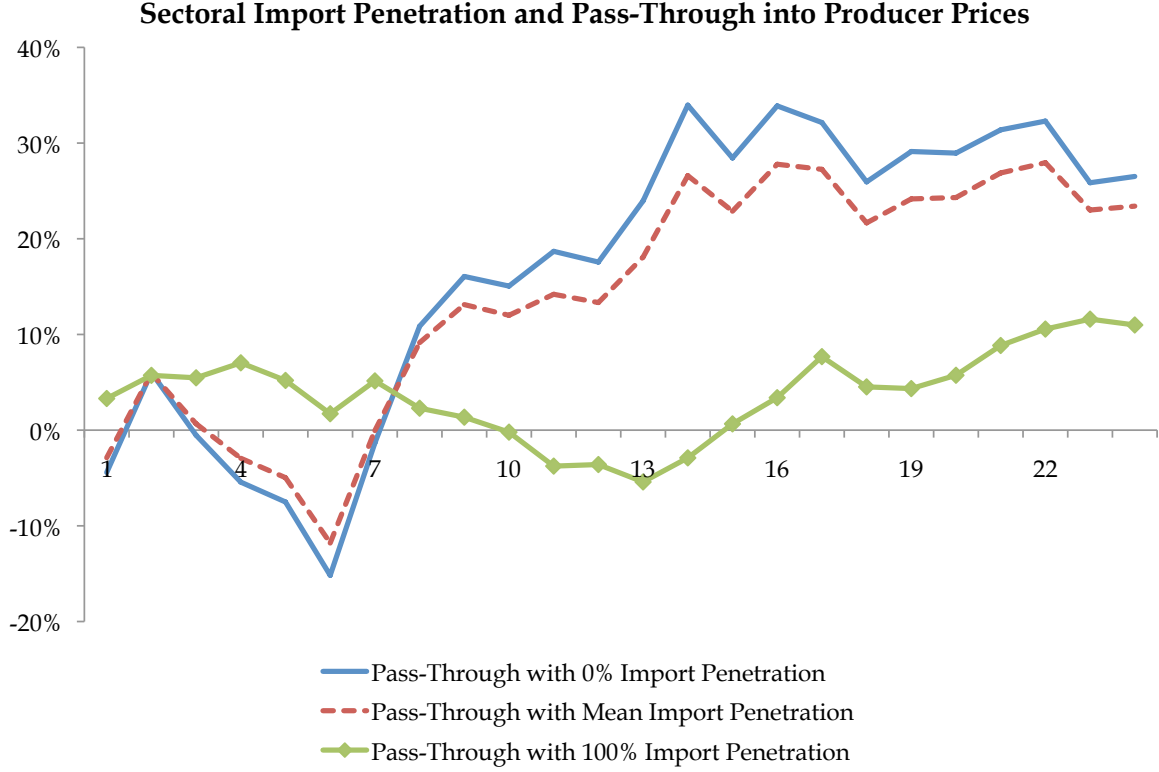
D.2 Pass-Through into Domestic Producer Prices

Figure 2: Pass-Through of Trade-Weighted Exchange Rate into US Producer Prices with 95% Bands



The figure shows estimates from the following specification: $\Delta p_{i,t} = \alpha_i + \sum_{j=1}^n \beta_j \Delta e_{t-j+1} + \epsilon_{i,t}$ where i indexes goods in the US PPI, n measures the length of the pass-through horizon and varies from 1 to 25, and Δe_{t-j+1} is the change in the log of the trade-weighted US exchange rate. Good-specific fixed effects α_i are included. The dependent variable $\Delta p_{i,t}$ is the observed monthly log price change. The figure shows the n -month pass-through rate, summing the coefficients up to the respective horizon.

Figure 3: Sectoral Import Penetration and Pass-Through into US Producer Prices



The figure shows estimates from the following specification: $\Delta p_{i,t} = \alpha_k + \sum_{j=1}^n \beta_j \Delta e_{t-j+1} + \sum_{j=1}^n \gamma_j s_{k,t} \times \Delta e_{t-j+1} + \epsilon_{i,t}$ where i indexes goods in the US PPI, n measures the length of the pass-through horizon and varies from 1 to 25, $s_{k,t}$ the six-digit NAICS import penetration, and Δe_{t-j+1} is the change in the log of the trade-weighted US exchange rate. Good-specific fixed effects α_i are included. The dependent variable $\Delta p_{i,t}$ is the observed monthly log price change. The figure shows the n -month pass-through rate for each level of import penetration, summing the terms β_j and $\gamma_j * \bar{s}_k$ up to the respective horizon.

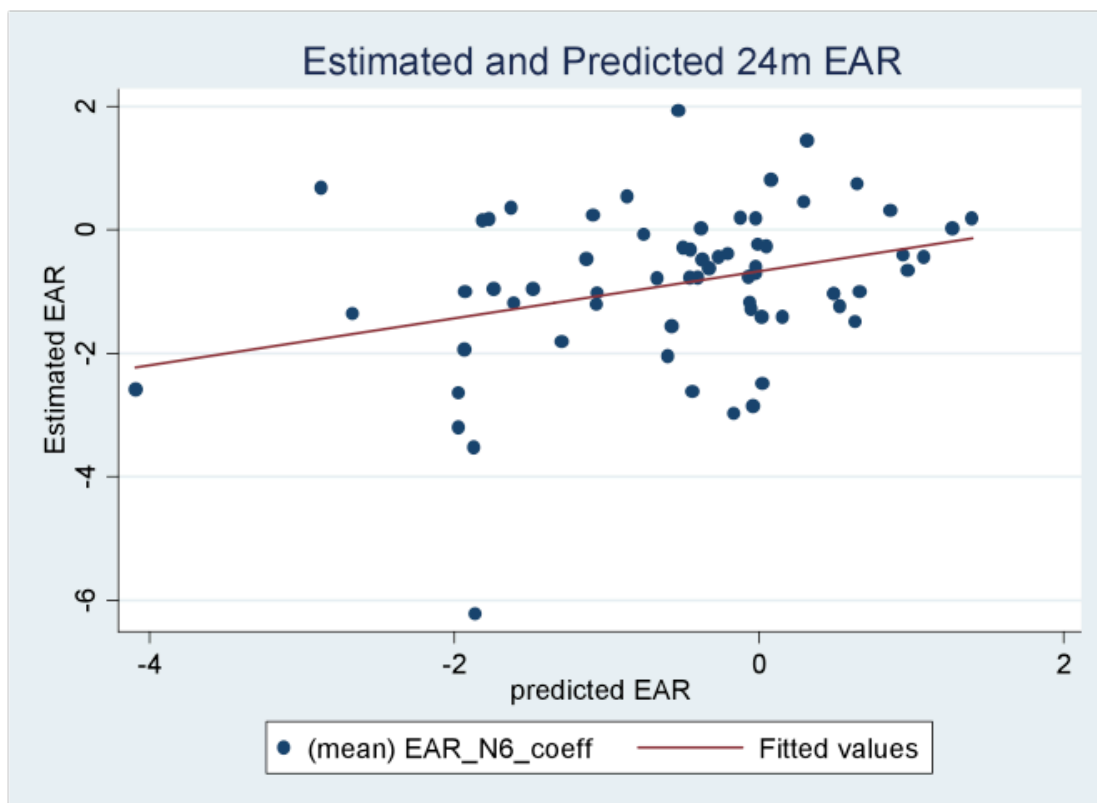
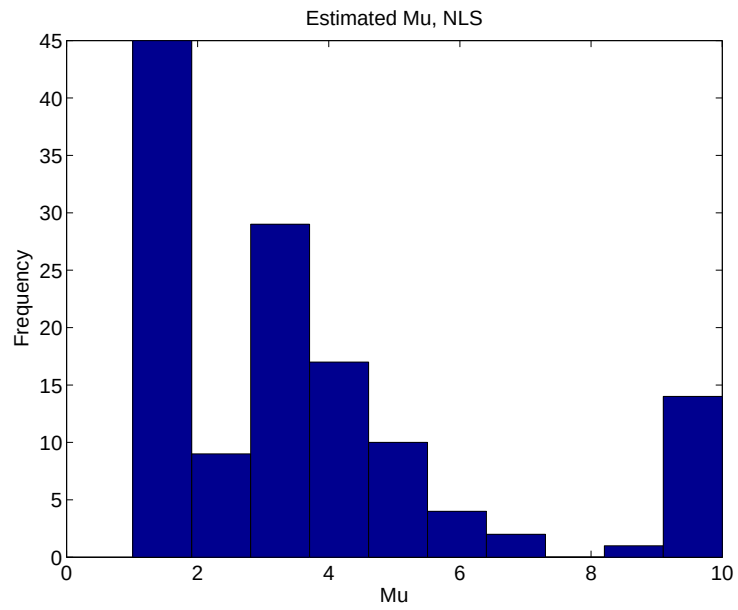
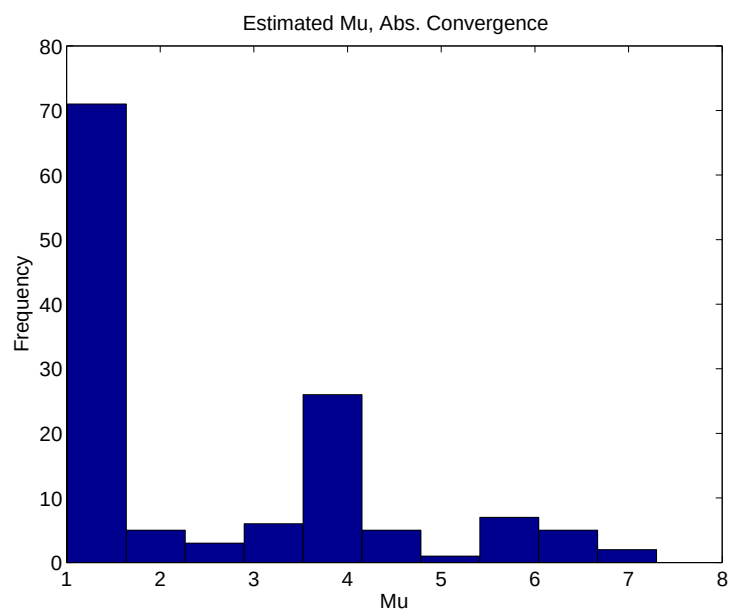


Figure 4: Estimated and Predicted IPI Pass-Through Rates

D.3 Estimation of μ





D.4 Joint Estimation of μ and ρ

