



Market Structure and Exchange Rate Pass-Through

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Working Paper Series

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September 14, 2013

Abstract

In this paper, we first document that two predictions of the heterogeneous firm version of the Dornbusch (1987) pricing model are confirmed in micro data on US import prices: while the rate at which a firm reacts to changes in its own cost is U-shaped in market share, the rate at which it reacts to competitors' prices is hump-shaped in market share. Second, using the theory as a guidance, we present an expression for price changes in industry equilibrium that can be broken down into a component due to the direct cost response at the firm level, and another one due to price complementarities faced by the firm at the industry level. We show empirically that taking into account a sector's market structure and the interplay of heterogeneity in reaction to own cost and reaction to the competition can substantially improve our understanding of the variation in pass-through rates across sectors and trade partners. The direct imperfect cost pass-through channel and the indirect price complementarity channel play approximately equally important roles in determining pass-through but partly offset each other. Including only one of these channels in an empirical analysis results in a failure to explain variation in the aggregate equilibrium rate of pass-through.

JEL Classification: E3, E31, F41

Keywords: Exchange Rate Pass-Through, U.S. Import Prices, Market Structure, Price Complementarities.

*This research was conducted with restricted access to the Bureau of Labor Statistics (BLS) data. The views expressed here are those of the authors and do not necessarily reflect the views of the BLS or the Swiss National Bank. We thank project coordinators Kristen Reed and Rozi Ulics for their substantial help and effort and Rawley Heimer and Miao Ouyang for excellent research assistance. We also thank Gita Gopinath, Oleg Itzhoki, Anthony Landry, and Romain Ranciere, as well as participants at the Milton Friedman Institute Conference on Pricing at the University of Chicago, the University of Geneva, the University of Berne, the University of Munich, the Microeconomic Aspects of the Globalization of Inflation Conference at the Swiss National Bank, the 2011 Midwest Macro Meetings at Vanderbilt University, the 2011 European Economic Association Meetings at the University of Oslo, the 2012 meetings of the Austrian Economic Association at the Technical University of Vienna, the 2012 meetings of the Society for Economic Dynamics in Limmasol, the 2012 CEPR Summer Symposium in International Macroeconomics in Tarragona, the 2012 NBER Summer International Finance and Macroeconomics workshop and in particular an anonymous referee at the SNB Working Paper series for helpful comments and suggestions.

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1 Introduction

Studying firms' pricing-to-market decisions is one of the important research topics in international macroeconomics because it relates to the movement of international relative prices, expenditure switching, and the adjustment of global imbalances. Moreover, this line of research can also inform us about the nature of price-setting, which features prominently in most macro-economic models.

The recent empirical literature estimating exchange rate pass-through (ERPT) at the good level has yielded important insights into firms' pricing behavior following exchange rate shocks.¹ A common finding in the literature is that pass-through is incomplete even in the long run. One leading explanation for this finding is that firms adjust their markups to accommodate the local market environment, a channel first pointed out in Krugman (1986), Helpman and Krugman (1987), and Dornbusch (1987) and more recently for the case of heterogeneous firms in Melitz and Ottaviano (2008), Atkeson and Burstein (2008), Chen et al. (2009), Berman et al. (2012), and Amiti et al. (2012).²

In this paper, we contribute to this literature by investigating how two dimensions of heterogeneity at the firm level are key determinants of pass-through in industry equilibrium. We show that firms are heterogeneous in both the rate at which they respond to changes in their cost of production and in the rate at which they respond to changing competitor prices. Moreover, we find that the firms that react the most to changes in their own cost are also the ones that react the least to changing competitor prices, and that due to this pattern, the presence of our two dimensions of heterogeneity has important implications for how "market structure" – as measured by the size and origin distribution of firms – affects a sector's ERPT.

First, we establish that firms' pricing responses are heterogeneous along two dimensions. Using U.S. firm-level micro data, we document that while the rate at which a firm reacts to changes in its own cost is U-shaped in market share, the rate at which it reacts to competitors' prices is

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 Feenstra et al. (1996), 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 decisions.

²Firm heterogeneity is only one of many dimensions along which pass through rates differ. When evaluating prices at the dock (that is, net of distribution costs), other important dimensions 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), 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), 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 rates (see Devereux et al. (2004)).

hump-shaped in market share. These results are qualitatively consistent with the predictions of the heterogeneous firm model of Atkeson and Burstein (2008) that is based on the preferences of Dornbusch (1987). The results expand on the work of Berman et al. (2012) and Amiti et al. (2012), who uncover a monotonic relationship between market share and cost pass-through.³ Further, we document that market share also affects the rate at which firms react to changing competitor prices, and we show that exactly the firms that react the most to changes in their own cost react the least to changing competitor prices. This finding builds on Gopinath and Itskhoki (2011), who document that firms react to price changes of their competitors.

Second, we show that the interaction of these two dimensions of firm heterogeneity is important for our understanding of how “market structure” affects the industry equilibrium rate of pass-through. Using the model of Atkeson and Burstein (2008) to guide our further empirical analysis, we present an expression for the industry equilibrium rate of exchange rate pass through that can be broken down into a component due to the direct cost response at the firm level, and another one due to price complementarities faced by the firm at the industry level. We then show empirically that these channels play approximately equally important roles in explaining pass-through but partly offset each other. We also show that including only one of these channels in an empirical analysis results in a failure to explain variation in the equilibrium rate of pass-through.

The mechanisms of the model that underlie our empirical results can easily be understood from the point of view of competition: first, the direct cost response of the firm to exchange rate movements depends on its own market share. Therefore, the average direct price response of all firms affected by a given exchange rate shock depends on the distribution of their market shares. Second, price complementarities matter because price changes of firms from a specific trade partner affect the industry’s general price level and the pricing decisions of all firms in the industry. The impact on the general price level is proportional to the combined market share of firms from that trade partner and the correlation structure of exchange rates. However, our expressions show that there is further amplification since all other firms in the industry react to the changing general price level, multiplying the initial impact. In this sense, pass-through is affected by the sector’s entire market structure even if only few firms are affected by a given exchange rate movement.

How do we test these predictions of the model? First, we note that one key ingredient to be able to do so is the availability of market share data at the firm level. One innovation of our paper lies in how we obtain these data, even though the micro data only contain prices. To this purpose, we combine ten-digit market share information from trade data, micro price data and structural equations from our model.

³Amiti et al. (2012), by normalizing each firm’s price change by the sectoral price index, develop a theoretical comparative static that monotonically relates market share and the rate of pass-through. While in our environment such a monotonic comparative static cannot be developed, we note that their result is fully consistent with the U-shaped relation when considering non-normalized price changes as in Dornbusch (1987) and Atkeson and Burstein (2008).

We then use these market share data and data on exchange rate movements in two ways to test the predictions of the heterogeneous firm version of the pricing model of Dornbusch (1987) developed by Atkeson and Burstein (2008). First, we verify the two firm-specific predictions, namely that import prices exhibit a hump-shaped reaction to competitor prices in market share while the response to an exchange rate is U-shaped in market share. We corroborate these two stylized facts further using various ways of estimating pass-through and also accounting for imported input use as in Amiti et al. (2012). Second, we fully utilize the information contained in the distribution of market shares to gauge the importance of the two channels – direct cost responses and price complementarities – and to validate additional model predictions.

To gauge the importance of the two channels, we construct overall predicted price changes as well as their two components that are due to the two channels: We first take exchange rate movements to identify cost shocks in our model-implied expression for firms' equilibrium price responses. Together with the distribution of firms' market shares and origins, this allows us to construct overall predicted price changes for all firms. At the same time, as implied by the model, we can construct one component of these predicted price changes as coming from price complementarities, another from a firm's direct cost response. When we regress observed price changes on these two components, we find that not only are both statistically significantly related to price changes but also have the same economic importance. Next, we also show that the actual and overall predicted price changes are related to each other. Regressions deliver highly significant coefficients.

We find that the heterogeneous firm version of Dornbusch (1987) is also able to deliver high predictive power for ERPT at the aggregate level. To demonstrate this, we estimate sector and trade partner specific pass-through rates, and compare them to our theoretical benchmark and its two components. First, we find that estimated and predicted pass-through rates are significantly related, like for our result on price changes: a regression of estimated on predicted pass-through rates gives us a statistically highly significant coefficient of 0.73 for sector-country pairs, and 0.82 at the country level. Second, we find that both direct cost responses as well as price complementarities are equally important for understanding pass-through. Again, this finding mimics the result on observed and predicted price changes discussed above. Overall, we find that the calibrated model can explain approximately 29% of the variation in pass-through rates across countries.

We emphasize that underlying this overall good fit of the theory, the direct imperfect cost pass-through channel and the indirect price complementarity channel play approximately equally important roles but partly offset each other. We demonstrate that if we include only one of these channels in an empirical analysis, this results in a failure to explain variation in the aggregate equilibrium rate of pass-through. This finding sheds some light on why Gopinath and Itskhoki (2010) find sectoral "market structure", as measured by a Herfindahl index, to have no impact on estimated rates of ERPT. Their empirical exercise is motivated by firm-specific findings relating

firm size to the rate of ERPT, such as in Berman et al. (2012), who predict a correlation between sectoral concentration and the average rate of ERPT. In this paper, we document that the effect of market structure on ERPT is not adequately captured by such measures of sectoral concentration: sectors that are dominated by firms that react strongly to changes in their own cost also tend to be characterized by a low degree of price complementarities. Documenting these two forces separately in microeconomic data and showing how they interact in industry equilibrium constitutes the main contribution of our paper.

The balance of this paper is the following. We first briefly outline a model to guide our analysis in Section 2. Section 3 describes how we construct market shares and establishes our two stylized facts at the firm level. Section 4 examines pass-through in the industry equilibrium. Section 5 concludes.

2 Market Structure and Pass-Through: Theory

To guide our empirical analysis, we review the firm-specific pricing-to-market predictions derived from the variable markup model of Dornbusch (1987). This model is based on Dixit and Stiglitz (1977), but focuses on the case in which firms are large compared to their industry. This differentiation is important because large firms can influence a sector's overall price level and thus face a less elastic demand than small firms. In this preference setup, a firm's market share and its markup depend on its own cost of production and on the prices of competing goods. As a result, it holds that pass-through is generally less than one and also, that prices react to each other.

We focus on the Dornbusch (1987) model instead of alternative theoretical foundations for pricing-to-market decisions since in our data many sectors are dominated by one or a few big firms that coexist with a large number of smaller firms. This feature of heterogeneous firm size makes the class of models based on Dornbusch (1987) – in particular its heterogeneous firm version in Atkeson and Burstein (2008) – the natural modeling strategy to analyze our data. We note that many other previous studies have used this setup to analyze pricing-to-market decisions, for example Feenstra et al. (1996) or Yang (1997).⁴

2.1 The Dornbusch (1987) Model

Preferences are given by a two-tiered “love of variety” utility/production function in which consumers consume the output of sectors k , and the output of each sector is produced by combining varieties i within each sector. As in Dixit and Stiglitz (1977), consumers have constant-elasticity

⁴Many alternative pricing-to-market theories exist that derive variable markups for example by adopting a preference framework that intrinsically allows for variable markups (see Kimball (1995), Melitz and Ottaviano (2008), Bergin and Feenstra (2001), Simonovska (2010), Gust et al. (2010), and Auer et al. (2012)), by modeling costly consumer search and inventories (see Alessandria (2009) and Alessandria and Kaboski (2011)), or by customer accumulation (see Krugman (1986) and Drozd and Nosal (2012)).

demand for each sector's total output. Final consumption c is produced by competitive firms aggregating input goods into $c = \left(\int_0^1 y_k^{(\eta-1)/\eta} dk \right)^{\eta/(\eta-1)}$.

In each sector k , each input is produced by a set of $i \in N_k$ monopolists, while the sector itself is competitive and produces using only inputs with a production function given by $y_k = \left(\sum_{i=1}^{N_k} q_{i,k}^{(\rho-1)/\rho} \right)^{\rho/(\rho-1)}$. Cost minimization implies a price of the sector-composite of $P_{i,k} = \left(\sum_{i=1}^{N_k} p_{i,k}^{(1-\rho)} \right)^{1/(1-\rho)}$ and demand for each individual input i of $q_{i,k} = y_k (P_{i,k} / P_k)^{-\rho}$ where $y_k = (P_k / P)^{-\eta} c$ is equal to the total consumption of the sector's output. P is the unit price of the final output and equal to $\left(\int_0^1 P_k^{(1-\eta)} dk \right)^{1/(1-\eta)}$. A key assumption in this preference framework is that $\rho > \eta > 1$, that is, if we think of two sectors "trousers" and "shoes" and two shoe varieties "Reebok" and "Nike," the assumption is that it is easier to substitute away from Reebok to Nike than it is to substitute from shoes to trousers. The assumption that $\eta > 1$ ensures that markups are finite also for monopolists within a sector.

2.2 Price Setting and Cost Pass-Through

Since firms are non-negligible in size within a sector, each firm has an impact on P_k , the aggregate price index of the sector, which it takes into account when setting its price. Each producer of a variety faces a constant marginal cost w_i , which may include iceberg transportation costs. Given the two-tiered utility/production setup and the fact that the production elasticity ρ differs from the demand elasticity over sector composites η , the first order condition of a firm with a non-negligible market share in sector k implies a pricing rule of that is dependent on the firm's market share $s_{i,k}$:

$$p_{i,k}^* = \frac{\varepsilon(s_{i,k})}{\varepsilon(s_{i,k}) - 1} w_{i,k}, \quad (1)$$

where $\varepsilon(s_{i,k}) = \left(\frac{1}{\rho} (1 - s_{i,k}) + \frac{1}{\eta} s_{i,k} \right)^{-1}$ if firms compete in quantities and $\varepsilon(s_{i,k}) = (\rho (1 - s_{i,k}) + \eta s_{i,k})$ if they compete in prices. Since $\rho > \eta$, a firm's perceived demand elasticity decreases in its market share. Consequently, the equilibrium markup increases in a firm's market share.

Within this framework, Atkeson and Burstein (2008) show that a log-linearization around the steady state results in a straight-forward calibration of how cost changes translate into prices changes depending on a firm's market share. Denoting deviations in logs from the steady state by $\hat{\cdot}$, this log-linearization relates a firm's price change to changes in its marginal cost of production and to changes in its market share:

$$\hat{p}_{i,k} = \Gamma(s_{i,k}) \hat{s}_{i,k} + \hat{w}_{i,k} \quad (2)$$

where $\hat{w}_{i,k}$ is the percentage cost change of firm i and $\Gamma(s_{i,k})$ measures the log-linearized responsiveness of the markup to the market share, a concept closely related to the "super elasticity" of

demand in Klenow and Willis (2007) and Gopinath et al. (2010).

We note that the markup sensitivity is strictly increasing in a firm's market share. If firms compete in quantities, $\Gamma(s_{n,k})$ is equal to $\frac{(1/\eta-1/\rho)s_{n,k}}{1-(1-s_{n,k})/\rho-s_{n,k}/\eta}$. If firms compete in prices it is equal to $\frac{(\rho-\eta)s_{n,k}}{\rho(1-s_{n,k})+\eta s_{n,k}}$. Given this monotonicity, how can the reaction to own costs be non-monotonic? The answer lies in the effect that firm i has on the overall price index \widehat{P}_k . It holds that

$$\widehat{s}_{i,k} = (\rho - 1) \left(\widehat{P}_k - \widehat{p}_{i,k} \right) = (\rho - 1) (1 - s_{i,k}) \left(\widehat{P}_{k,-i} - \widehat{p}_{i,k} \right),$$

where $\widehat{P}_{k,-i}$ is the weighted price change index of all competitors.⁵ A firm's market share can thus change either because its own price changes, or because the prices of competitors change. Any change in relative prices is mitigated by a factor $s_{i,k}$, the fraction of the overall price index that firm i accounts for in sector k .

With these two forces in mind, we next describe how the firm-specific rate of cost pass-through and the rate of reaction to competitor prices depend on a firm's market share. Corresponding to our empirical analysis below, we focus on the conditional rate of cost pass-through and the rate of reaction to the competition.

Proposition 1 *Let CPT_i denote the elasticity of firm i 's price with respect to its own cost for given competitor prices and RCP_i denote the elasticity of firm i 's price to the price index of its competitors for a given own cost. It holds that $\widehat{p}_{i,k} = RCP_i \widehat{P}_{k,-i} + CPT_i \widehat{\omega}_{i,k}$. If $\eta > 1$, CPT_i and RCP_i take values in the interval 0 to 1. It holds that 1) CPT_i is U-shaped in market share, that is, it is monotonically decreasing up to an inflexion point and thereafter monotonically increasing; 2) RCP_i is hump-shaped in market shares, that is, it is monotonically increasing up to an inflexion point and thereafter decreasing in firm market share. The inflexion point is the same for RCP_i and CPT_i . If firms compete in quantities, the inflexion point is $1 - \sqrt{(1 - 1/\eta) / (1 - 1/\rho)}$. If firms compete in prices, the inflexion point is $1 - \sqrt{\eta / \rho}$.*

As the proposition shows, a firm's rate of cost pass-through is hump-shaped in its market share conditional on competitor prices.⁶ This hump-shaped relation derives directly from price changes of large firms affecting the sector's price index. If the market share approaches one, pass-through is nearly complete as the firm dominates the sectoral price index. It holds that

$$\begin{aligned} CPT_i &\equiv \left. \frac{\partial p_{i,k}^*}{\partial \omega_{i,k}} \frac{\omega_{i,k}}{p_{i,k}^*} \right|_{\widehat{P}_{k,-i}=0} = (1 + \Gamma(s_{i,k}) (\rho - 1) (1 - s_{i,k}))^{-1} \text{ and} \\ RCP_i &\equiv \left. \frac{\partial p_{i,k}^*}{\partial P_{k,-i}} \frac{P_{k,-i}}{p_{i,k}^*} \right|_{\widehat{\omega}_{i,k}=0} = \Gamma(s_{i,k}) (\rho - 1) (1 - s_{i,k}) * CPT_i \end{aligned}$$

⁵ $\widehat{P}_k = \sum_{j \in N_k} s_j \widehat{p}_{j,k}$ and $\widehat{P}_{k,-i} = \sum_{j \in N_k, -i} s_j \widehat{p}_{j,k}$

⁶ We note that Proposition 1 is not new to the literature (see, for example, the description in Burstein and Gopinath (2013)).

For the purpose of our empirical analysis, it is relevant that the inflexion point under Cournot competition is always smaller than under Bertrand competition and that the latter is close to one for realistic parameters.

The class of Dornbusch (1987) variable markup models also allows for a different comparative static in which monotonic relations between market share and the rate of cost pass-through emerge:

Corollary 1 *Conditional on the sector's overall price index, the rate of cost pass-through is monotonically decreasing in market share. That is, $\hat{p}_{i,k} = \gamma_{i,k}\hat{P}_k + \alpha_{i,k}\hat{w}_{i,k}$ where $\alpha_{i,k} = (1 + \Gamma(s_{i,k})(\rho - 1))^{-1}$ and $\gamma_{i,k} = \Gamma(s_{i,k})(\rho - 1)\alpha_{i,k} = 1 - \alpha_{i,k}$.*

We do not empirically test Corollary 1 below because the sectoral price index \hat{P}_k is constructed including $\hat{p}_{i,k}$, that is, such a regression could be argued to be spurious.⁷ However, the corollary still proves convenient when solving for the industry-wide equilibrium pass-through rate, which we do next.

2.3 Equilibrium Pass-Through

In industry equilibrium, all prices react to own cost changes and also react to other prices. It follows from the log-linearized recursive pricing equation in Corollary 1 that firm i 's price change is a function of all cost changes in the sector and equal to

$$\hat{p}_{i,k} = \gamma_{i,k} \frac{\sum_{j \in N_k, -TP} s_j \alpha_j \hat{w}_{j,k}}{\sum_{j \in N_k} s_j \alpha_j} + \left(\frac{\gamma_{i,k} s_i}{\sum_{j \in N_k} s_j \alpha_j} + 1 \right) \alpha_{i,k} \hat{w}_{i,k}, \quad (3)$$

where $\gamma_{i,k}$, the rate at which a firm's price is reacting to cost shocks of all other firms is monotonically increasing in its market share. $\left(\frac{\gamma_{i,k} s_i}{\sum_{j \in N_k} s_j \alpha_j} + 1 \right) \alpha_{i,k}$, the rate at which it reacts to its own cost, is equal to 1 if the market share is either 0 or 1. For interior market shares, it is smaller than one.

With our empirical strategy in mind, we are not only interested in such firm-specific predictions of the theory, but also in the implications for the average rate of exchange rate pass-through. To build up to our second main testable expression in Proposition 2, we therefore first examine pass-through in a special case in which the two heterogeneities at the level of the firm cancel out exactly. Then, the rate of pass-through in industry equilibrium is unaffected by market structure: for a given sectoral price index, large firms react only little to changes in own cost but they react strongly to the sectoral price index for given own cost. The interplay of these two forces can be seen most clearly in the example of random cost shock.

⁷Amiti et al. (2012) develop an empirically meaningful monotonic comparative static by normalizing price changes by the changes of the price index of all goods originating from the same trade partner.

Lemma 1 *In industry equilibrium, the weighted average price change \widehat{P}_k is equal to $\sum_{j \in N_k} s_j \alpha_j \widehat{w}_{j,k} / \sum_{j \in N_k} s_j \alpha_j$. A cost shock of mean \widehat{w} that is uncorrelated with market shares ($\widehat{w}_{i,k} = \widehat{w} + \epsilon_{i,k}$; $\epsilon_{i,k} \perp s_{i,k}$) is fully passed through irrespective of the market share of firm i , the number of competitors, and the distribution of their market shares.*

Lemma 1 states a strong result: Market structure – as measured by the distribution of firm market shares – may have no effect on the equilibrium rate of pass-through. This may appear counter-intuitive: based on the empirical findings of Berman et al. (2012) or Amiti et al. (2012) that the firm-specific rate of cost pass-through is strictly decreasing in the firm’s market share, one might expect the industry equilibrium rate of cost pass-through to be a decreasing function of sectoral concentration. However, this specific example demonstrates that the direct cost response and price complementarities can even exactly offset each other. The underlying intuition is that if a cost shock affects all firms in exactly the same proportion, it does not affect the market share of any firm. Consequently, there is no markup response, and the cost shock is passed through fully by all firms. The same holds true if the shock is noisy, but the noise is uncorrelated with firm-specific market shares.

To understand more generally how market structure does affect the average rate of pass-through in industry equilibrium, one needs to take into account the interaction of firm-specific heterogeneity in both cost pass-through and reaction to competition and the fact that exchange rates only affect the cost of production of a certain subset of firms. We properly isolate the cost element of exchange rate changes by following Amiti et al. (2012) and taking into account that exchange rate changes are cost changes at a rate of less than one because not all costs are paid in the local currency of the exporter. Denoting by $\widehat{e}_{i,TP}$ the percentage change of the bilateral exchange rate of country TP that firm i originates from and by θ_i^l the rate at which a bilateral exchange rate change affects the cost of firm i ($\widehat{w}_{i,k} = \theta_i^l \widehat{e}_{i,TP} + \epsilon_{i,t}$), we can define the equilibrium rate of cost pass-through:

Definition 1 *Equilibrium pass-through rate of exchange rate-induced cost shocks.* $ECPT_{i,k}$ denotes the firm i ’s industry equilibrium rate of pass-through of exchange rate induced cost shocks, equal to the unconditional elasticity of firm i ’s price with respect to the exchange rate-induced cost shock: $\theta_i^l \widehat{e}_{i,TP}$, that is, $ECPT_{i,k} \equiv \frac{\partial p_{i,k}}{\partial (\theta_i^l \widehat{e}_{i,TP})} \frac{\theta_i^l \widehat{e}_{i,TP}}{p_{i,k}}$.

We focus on the equilibrium rate of cost pass-through rather than on the rate of equilibrium exchange rate pass-through because we want to highlight the effect of variable markups while abstracting as much as possible from the importance of imported intermediate inputs, a channel that has been analyzed elsewhere. At the same time, the pass-through rates are related: the equilibrium exchange rate pass-through rate ($\frac{\partial p_{i,k}}{\partial e_{i,TP}} \frac{e_{i,TP}}{p_{i,k}}$) is equal to $ECPT_{i,k}$ times θ_i^l , the local cost share.

In the context of our model, the firm-specific equilibrium pass-through rate is equal to

$$ECPT_{i,k} \equiv \frac{\widehat{p}_{i,k}}{\theta_i^l \widehat{e}_{i,TP}} = \gamma_i \frac{\sum_{j \in N_k} s_j \alpha_j \theta_j^l \frac{\widehat{e}_{i,TP}}{\theta_i^l \widehat{e}_{i,TP}}}{\sum_{j \in N_k} s_j \alpha_j} + \theta_i^l \alpha_i + \widetilde{\epsilon}_{i,t} \quad (4)$$

With our empirical section in mind, we are not only interested in the firm-specific rate of exchange rate pass-through, but in the sector- and firm specific average rate of pass-through. Aggregation of (4) across all the firms originating from TP implies the following.⁸

Proposition 2 *Let $ECPT_{TP,k}$ denote the market share-weighted average of $ERPT_{i,k}$ in the set of all firms that originate from TP in sector k ($i \in N_{k,TP}$). It holds that*

$$ECPT_{TP,k} \equiv \frac{\sum_{j \in N_{TP,k}} s_j ECPT_{i,k}}{\sum_{j \in N_{TP,k}} s_j} = \overline{\gamma_{TP}} \left(\sum_{c \in C} m_{c,k} \frac{\widehat{e}_c}{\widehat{e}_{TP}} \right) + \overline{\alpha_{TP}} + \overline{\epsilon_{TP}}, \quad (5)$$

where $\overline{\gamma_{TP}}$, $\overline{\alpha_{TP}}$ and $\overline{\epsilon_{TP}}$ correspond to the market share-weighted averages of $(\theta_i^l)^{-1} \gamma_i$, α_i , and $\widetilde{\epsilon}_{i,t}$ in the set of firms from TP and in industry k and $m_{c,k}$ is the elasticity of the price index in sector k with respect to the exchange rate of country c .

Proposition 2 shows how the industry equilibrium rate of exchange rate pass-through can be broken down into a component due to the direct cost response at the firm level, and another due to price complementarities faced by the firm at industry level. On the one hand, it relates the equilibrium rate of cost pass-through to a direct cost pass through channel reflecting the average rate at which firms from country TP react to changes in their own cost. As $\partial \alpha_{i,k} / \partial s_{i,k} > 0$, this rate is increasing in the average market share of firms from that country. On the other hand, the second channel captures the effect of price complementarities: the firm also reacts to changes in the general price level. As $\partial \gamma_{i,k} / \partial s_{i,k} > 0$, this rate is decreasing in the average market share of firms from TP .⁹

Importantly, $\overline{\gamma_{TP}}$ multiplies $\sum_{c \in C} m_{c,k} \frac{\widehat{e}_c}{\widehat{e}_{TP}}$, which is a function of the entire sector's market structure: the price complementarity response also incorporates how the sectoral price index changes for a given distribution of firm market shares and imported input intensities, origins, and exchange rate movements. The change in the sectoral price index is the sum over all relative exchange rate movements times $m_{c,k}$, the equilibrium elasticity of the sectoral price index with re-

⁸ $\widetilde{\epsilon}_{i,t} = \gamma_i \frac{\sum_{j \in N_k} s_j \alpha_j (\widehat{w}_{j,k} - \theta_{j,TP} \widehat{e}_{i,TP,t})}{1 - \sum_{j \in N_k} s_j \gamma_j} + \alpha_i (\widehat{w}_{j,k} - \theta_{i,TP} \widehat{e}_{i,TP,t})$

⁹ Note that corresponding to our definition of $ECPT_{i,k}$, the average $\overline{\gamma_{TP}}$ normalizes individual γ_i by local cost intensity, that is, $\overline{\gamma_{TP}} = \sum_{i \in N_{k,TP}} s_i^{TP} \gamma_i (\theta_i^l)^{-1}$ where $s_i^{TP} = s_i / \sum_{j \in N_{k,TP}} s_j$. For the other averages, it holds that $\overline{\epsilon_{TP}} = \sum_{i \in N_{k,TP}} s_i^{TP} \widetilde{\epsilon}_{i,t}$ and $\overline{\alpha_{TP}} = \sum_{i \in N_{k,TP}} s_i^{TP} \alpha_i$.

spect to the exchange rate of country c . This term is equal to

$$m_{c,k} \equiv \sum_{j \in N_{k,c}} s_j \alpha_j \theta_j^l \left/ \left(1 - \sum_{j \in N_k} s_j \gamma_j \right) \right. . \quad (6)$$

The term in the numerator of equation (6) captures how the prices of all firms from country c react on impact to a change in their exchange rate for a given overall price level. The term of equation (6) captures how this initial “price impulse” is then multiplied as all prices react to each other. In particular, equation (6) incorporates how firms of heterogeneous size vary in their $\alpha_j \theta_j^l$, how exchange rates are correlated with \hat{e}_{TP} (a channel highlighted in Bergin and Feenstra (2009), Naknoi (2013), and Pennings (2012)), and on the “mass” of firms originating from TP (a channel highlighted in Feenstra et al. (1996)). Unless we are in a special case like Lemma 1, the first, price-complementarity channel, and the second, cost pass-through channel, will not allow for pass-through to be 1 independently of market structure.

In the empirical section below, we take realized exchange rate changes for the construction of the predicted rates of equilibrium cost pass-through $ECPT_{TP,k}$. This way, we do not require any assumptions on the underlying exchange rate process. To highlight the intuition at work, it is however informative to further examine (5) theoretically under the assumption that exchange rate changes are normally distributed.

Corollary 2 *Assume that for any country c , it holds that $\hat{e}_c = \beta_c e_w + \tilde{e}_c$ with $e_w \sim N(\mu_W, \sigma_W)$ and $\tilde{e}_c \sim N(0, \sigma_c)$, where \bar{e}_c , \tilde{e}_c , and e^W are independent from each other and so are all \tilde{e}_i and \tilde{e}_j for $i \neq j$. A second-order Taylor approximation of the expected rate of $ECPT_{TP,k}$ is given by the following expression:*

$$E[ECPT_{TP,k}] \approx \overline{\gamma_{TP,k}} \left(m_{TP,k} + \left(1 + \frac{\sigma_{TP}^2}{\beta_{TP}^2 \mu_W^2} \right) \sum_{c \in C_{-TP}} m_{c,k} \frac{\beta_c}{\beta_{TP}} \right) + \overline{\theta_i^l \alpha_{TP}} . \quad (7)$$

In this corollary, exchange rate changes have a global component with country-specific loadings β_c , as well as orthogonal country-specific shocks. Then, what matters for pass-through are two factors: first $m_{TP,k}$, the direct impact of \hat{e}_{TP} on the sector’s price index and second, the elasticity-weighted relative loading of the global shock $\sum_{c \in C_{-TP}} m_{c,k} \frac{\beta_c}{\beta_{TP}}$. Estimated pass-through rates will be affected most by the presence of price complementarities if β_{TP} is small in absolute magnitude.

Overall, we take away for our empirical analysis that two elements of market structure are important determinants of the trade partner and sector-specific rate of equilibrium pass-through: on the one hand, the market share of each individual firm affects its responsiveness to own costs and to the general price level. On the other hand, the combined market share of all firms from a trade partner, how exchange rates are correlated, and the sector’s entire market structure affect how the general price level evolves. Below, we empirically investigate the importance of these

two channels.

3 Market Share, Pass-Through, and Responsiveness to Competitor Prices.

In this section, we first describe our methodological innovation of constructing firm-specific market shares, describe the construction of indices of competitor prices, and account for the effect of imported inputs. We then use confidential U.S. micro data to establish our two stylized facts that are robust across a variety of pass-through specifications: the rate at which a firm reacts to competitors' prices is hump-shaped in market share while the rate at which it reacts to changes in its own cost is U-shaped in market share.

3.1 Data

We use data from three sources: we take exchange rates and inflation data from the IMF's International Financial Statistics database, trade data at the Harmonized System (HS) ten-digit level from the U.S. Census Bureau, and import prices at the good level from the BLS import price database. These micro price data have been the topic of intense study since the original analysis of this dataset by Gopinath and Rigobon (2008).

We refer the reader to Gopinath and Rigobon (2008) for a detailed description of the U.S. import price micro data. In this paper, we analyze the years from 1994 through 2005. We apply our analysis to the 34 largest trade partners in the data. In manipulating the data, we follow the main steps taken in Gopinath and Rigobon (2008). In particular, we drop net price data which are flagged by the BLS as not usable, not index usable or for which a price has been estimated. There are 771872 usable prices in our sample. In addition, we pull forward a last observed price when a price is missing as in Nakamura and Steinsson (2012). We also disregard an entire price series if more than 10% of prices of a series have been flagged as price records with no trade. All of our prices are market price transactions invoiced in USD.¹⁰

3.2 Constructing Market Shares and Competitor Prices

One of the major limitations of the BLS micro price data is that it does not include information on the sales of individual firms, which we need to predict firm-specific price responses from the model. We overcome this limitation in the following way. First, we merge in country-specific trade flows that are highly disaggregated. This gives us the actual market share of most (but not all) firms at an already narrow level of disaggregation. Second, if necessary, we infer the exact size

¹⁰As Gopinath and Rigobon (2008) have documented, almost all U.S. imports are priced in USD. For example, 93.4% of all import prices are in USD in 2004. Neiman (2010) explicitly studies the behavior of intra-firm prices which account for approximately 40% of the data.

distribution of firms. We do this by using information contained in prices in the BLS dataset to infer market shares.

To construct market share, we note that the model structurally implies that market shares are pinned down by relative prices. We use this relationship to infer the size distribution of firms from prices in conjunction with available disaggregated data on bilateral imports and domestic production by sector: Within each ten-digit HS sector, the market share of a given firm $n \in N_{TP,k}$ from country TP and sector k is equal to

$$s_{n,k} = m_{TP,k} \frac{p_{n,k}^{(1-\rho)}}{\sum_{j \in N_{k,TP}} p_{j,k}^{(1-\rho)}}, \quad (8)$$

where $m_{TP,k}$ is the sectoral import share of country TP .

To compute sectoral import shares, we merge in extremely disaggregated, country-specific US import data at the HS ten-digit level from Feenstra et al. (2002), who update the data of Feenstra (1996). The main advantage of using these highly disaggregated data is that there are only very few firms from a specific trade partner in a specific HS ten-digit code. There are 18320 different HS ten-digit codes in the Feenstra data, which is comparable in the order of magnitude to the BLS sample size. We therefore expect to have very precise information on firm-specific market shares from the trade data alone, when the firm-level market share factor, the fraction in (8), implied by relative prices equals 1.

Indeed, for 61.2% of the observations in our sample, there is only one active firm per trade-partner-HS-year-month combination, and we thus precisely know that firm's market share within its industry. We can use this subsample to gauge whether quality heterogeneity is an issue of importance by running a robustness test of our analysis in which we only consider sectors where there is one firm per trade-partner-year-month. Since we find that it is not, we subsequently use our full sample that includes trade-partner-HS-year-months with more than one firm.

If we consider TP-HS-year-month combinations with more than one firm, we find that there are typically very few firms per combination. For example, for 18% of the observations, there are 2 firms per combination and there are 6 or more firms per combination for fewer than 2% of the observations, with the maximum being 54. The average number of firms per combination is 1.92. For the cases in which there is more than one firm, we use the structurally implied relationship of prices and market shares, incorporated into (8), to compute firm-level market shares.¹¹

We find the estimates of market shares computed by using our main method to be quite plau-

¹¹As an alternative, in the working paper version of this paper, we simulate firm market shares rather than inferring them from prices, following Atkeson and Burstein (2008). To do so, we first generate productivity draws and assume that each firm n draws its idiosyncratic productivity z_n from a log-normal distribution ($\log z_n \sim N(0, \sigma^2)$), where $\sigma^2 = 0.385$ as in Atkeson and Burstein (2008). For the given realizations of z_n within each sector, we then compute numerically the optimal price of each firm and its market shares as implied by (8).

sible and consistent with what we know from the Feenstra et al. data. On average, firms have a 22.7% market share in a given ten-digit sector. We note that our data is also characterized by a large number of small firms. For example, the median market share is 4.3%. In the bottom quintile of firms, market share is approximately zero, while in the top quintile, market share is 80.7%. Table 1 summarizes these results. We also consider the evolution of these market shares over time. We find that the mean market share has remained fairly constant from 1998 to 2005 while the median share has fallen somewhat. Figure 2 summarizes these results.

Finally, we follow Gopinath and Itskhoki (2011) and compute an index of competitors' log price changes in each HS-year-month combination for our subsequent analysis as follows:

$$\Delta \bar{P}_{i,k,t}^{com} = \sum_{j \neq i}^{N_{k,t}} \omega_{j,k,t} \Delta p_{j,k,t}$$

where $\Delta p_{i,k,t}$ denotes firm-specific log price changes for firm i at time t and $\omega_{i,k,t}$ market-share weights. To avoid endogeneity issues, we omit firm i from the $N_{k,t}$ firms in sector k . Therefore, $\Delta \bar{P}_{i,k,t}^{com}$ varies across firms in sector k .

3.3 Baseline Results: The Response of Individual Prices

In this subsection, we establish our two stylized facts relating price setting and a firm's market share. First, we show that the direct response of import prices to an exchange rate shock is U-shaped in market share. This finding underlies the result of Berman et al. (2012) that ERPT is – on average – negatively related to a firm's market share. It relates to the result of Feenstra et al. (1996) that exchange rate pass-through is U-shaped in the country's aggregate market share.¹² Second, we present our key salient fact that is new to the literature to the best of our knowledge: the response of import prices to competitors' prices is hump-shaped in a firm's market share. This finding extends the insights from the regression in Gopinath and Itskhoki (2011) to the dimension of firm heterogeneity.

We build up to the first result in three steps. First, we confirm conventional estimates of ERPT: pass-through of exchange rate shocks is incomplete, with an elasticity of prices to exchange rates of 0.15. We obtain this result from estimating a specification of price changes on 12-month lagged exchange rate movements, as follows:

$$\Delta p_{i,TP,t} = \alpha_{TP} + \sum_{j=0}^{12} \beta_j \Delta e_{i,TP,t-j} + \eta Z_t + \epsilon_{i,TP,t}. \quad (9)$$

where i denotes a good and TP the country the good is exported from (the trade partner). Controls Z_t include inflation in the source country plus 12 lags thereof, and various sets of fixed effects. The

¹²In the working paper version of this paper, we examine the relation between country-specific market share and pass-through.

sum of estimated coefficients, $\sum_{j=0}^{12} \widehat{\beta}_j$, gives us the degree of ERPT, shown in the first row of Table 2.

Second, we show that controlling for market share implies a lower degree of exchange rate pass-through. We obtain this result from estimating a specification that is augmented with an interaction of market share and exchange rate movements:

$$\Delta p_{i,TP,t} = \alpha_{TP} + \sum_{j=0}^{12} \beta_j \Delta e_{i,TP,t-j} + \sum_{j=0}^{12} \gamma_j m_i e_{i,TP,t-j} + \eta Z_t + \epsilon_{i,TP,t}. \quad (10)$$

where m_i denotes the firm specific market shares. Again, we estimate this using 12-month lags. Choosing a 12-month lag structure closely reflects the annual unit value approach in Berman et al. (2012), and also matches the annual specification in Amiti et al. (2012).

Our estimates of the interaction effect, $\sum_{j=0}^{12} \gamma_j$, confirm the finding of Berman et al. (2012) that the degree of exchange rate pass-through is decreasing in market share. The second column of Table 2 summarizes this result. In particular, our estimates imply that the rate of pass-through for a firm with negligible market share is nearly three times as large as that of a monopolist: 19.4% vs. 19.4% – 12.5% = 6.9%. Incidentally, since Berman et al. (2012) obtain their result using finely disaggregated unit value data, this also validates our approach of using the BLS micro price data that is survey-based.¹³

Third, we refine the result of Berman et al. (2012) on the role of market share by documenting that underlying the relation which on average is decreasing is in fact a U-shaped relationship. When we add an interaction of the squared market share with the exchange rate to the above specification, we find that the response of prices is U-shaped in the firm-specific market share. The coefficients of the linear and quadratic terms significantly estimated at –0.56 and 0.39 imply that the degree of exchange rate pass through reaches its minimum of 0.02 around a market share of 72% (=0.564/(2 * 0.39)) and thereafter increases in market share. Column 3 shows the coefficient estimates. The rate of exchange rate pass-through implied by the estimates is 18% for very small firms and 21.5% for near monopolists.

While we do not view uncovering this U-shaped relationship as our main empirical finding, the uncovered shape of the relationship is conceptually important: it underlines that the qualitative predictions of the class of models based on Dornbusch (1987) are supported by the data. In this class of models, incomplete pass-through follows from a firm's markup changing with its market share. This mechanism necessarily entails that the degree of pass-through is decreasing in market share up to a certain size, but it must be increasing in market share as a firm begins to

¹³Our result as well as that in Berman et al. (2012) seem to oppose that in Garetto (2012) that the degree of ERPT is increasing in a firm's market share. However, this discrepancy may simply be due to the particular industry examined in Garetto (2012).

dominate its industry. We also note that in terms of model fit, adding the quadratic interaction term is as important as including the linear interaction term (compare the R^2 in columns 1, 2, and 3).

Our key, new salient fact is that the rate at which firms react to changes in the prices of competitors is hump-shaped in market share. To establish this fact, we draw on Gopinath and Itskhoki (2010) and examine how firms react to changes in their competitors' prices. Following their approach, we estimate a regression of price changes on exchange rates, and the index of competitor's price changes $\Delta \bar{P}_{j,k,t}^{com}$. We then augment this specification with interactions with market share and squared market share. Columns 4 and 5 in Table 2 summarize our results.

We find that the index of competitor prices has strong predictive power when added to the regression. This is shown in column 4. The large estimate of the coefficient is similar in magnitude to Gopinath and Itskhoki (2010).¹⁴ Moreover, we find that there is a hump-shaped relationship between a firm's market share and the extent to which it reacts to competitors' prices. The rate of reaction takes the values of 0.42 for a tiny firm with approximately zero market share, is maximized at around 0.61 for a market share of 36% and is thereafter decreasing in market share to around 0 for near-monopolists (see column 5).¹⁵

Finally, we note that the uncovered U-shaped relationship between the degree of exchange rate pass-through and market share holds both conditionally on conditioning on competitor prices and the heterogeneous response to it (see column 5) and also unconditionally (see column 3). However, this U-shape is more pronounced (in terms of comparing the linear to the two interaction terms) when conditioning on competitor prices and the heterogeneous response to it.

3.4 Accounting for Imported Inputs

Here, we show that both the pattern of U-shaped pass-through and that of hump-shaped responsiveness to competitor prices are robust and even more pronounced when we filter out cost changes of imported intermediate inputs from exchange rate changes.

We construct the cost change due to an exchange rate movement by netting out the effect of imported intermediate inputs. First, we construct a sector and trade partner specific measure of imported input intensity from the World Input Output Tables Database (WIOD). The latter database tells us how imported-input-intensive production abroad is. For example, this database allows us to construct a measure of how imported input intensive the Italian leather industry is. We then allocate it to heterogeneous firms using the microeconomic insights of Amiti et al. (2012).

¹⁴Note that Gopinath and Itskhoki (2010) construct an unweighted index of competitor prices since the BLS micro data do not include firm-specific market shares. Since we have constructed the latter, we construct the weighted index of competitor prices, which corresponds to the theoretically relevant index (see Section 2).

¹⁵We exclude full monopolists from this exercise as it is not possible to construct an index of competitors' prices in such cases.

Proceeding in this way, we construct each firm's imported-input-intensity $\theta_{i,TP,t}^{ImInp}$ as

$$\theta_{i,TP,t}^{ImInp} = \frac{\text{cost of imported inputs}_{i,TP,t}}{\text{total variable costs}_{i,TP,t}}.$$

The appendix describes our procedure of constructing $\theta_{i,TP,t}^{ImInp}$ in detail.

Second, we use the imported input intensity to construct our measure of cost change: When counted in US dollars, the percentage cost change of foreign firm i from trade partner TP to service the US market is equal to the exchange rate change times $1 - \theta_{i,TP,t-1}^{ImInp}$, the lagged proportion of firm i 's costs that are paid in local currency (we use the lagged imported input intensity as the contemporaneous one might react to exchange rate movements). Our estimate of the cost change of firm i that is driven by the exchange rate is equal to

$$\Delta c_{i,TP,t} = \Delta e_{i,TP,t} \left(1 - \theta_{i,TP,t-1}^{ImInp} \right) \quad (11)$$

We estimate cost pass-through exactly as in the previous section, but now using the cost change $\Delta c_{i,TP,t}$ instead of the exchange rate change as independent variable. Correspondingly, also the interactions with market share and market share squared are based on $\Delta c_{i,TP,t}$ instead of the exchange rate change. Table 3 summarizes the results.

We find – consistent with the results of Amiti et al. (2012) – that accounting for input use intensity has a major impact on the estimated rate of pass-through. The rate of cost pass-through is on average much larger than the rate of exchange rate pass-through, and the U-shape of the relation between market share and cost pass-through is more pronounced.¹⁶

Moreover, we also find evidence for our second, main, stylized fact: the hump-shaped response to competitor prices is both economically and statistically highly significant, conditional on the U-shaped cost pass-through. This presents an important empirical finding: the large economic magnitude of this heterogeneity and the simultaneously opposing shapes of the relations suggest that it is important to examine their interactions in industry equilibrium.

Finally, following Amiti et al. (2012), we construct an alternative measure of cost changes that takes into account that imported inputs might be priced to market in the trade partner countries. This may be a concern because pricing-to-market of inputs imported in the trade partners may be correlated with exchange rate movements. Our alternative cost measure $\Delta c_{i,TP,t}^{alt}$ is equal to

$$\Delta c_{i,c,t}^{alt} = \Delta e_{i,c,t} \left(1 - \theta_{i,TP,t-1}^{ImInp} \right) + (\Delta e_{i,c,t} + \Delta IPI_{TP,k,t}) \theta_{i,TP,t-1}^{ImInp}.$$

¹⁶We note that the empirical finding that the *absolute* rate of cost pass-through is U-shaped in market share does not conflict with the theoretical result and empirical finding of Amiti et al. (2012) that the rate of cost pass-through is monotonically decreasing in a firm's market share when evaluating *relative* prices in a particular environment. Amiti et al. evaluate the response of the price of firm i relative to all competitor prices from the same origin in the same destination market and in the same industry (also see the discussion of this issue in Amiti et al.).

where $\Delta IPI_{TP,i,t}$ is the percentage change of the price index for imported inputs in trade partner TP and the sector k that firm i is active in. $\Delta IPI_{TP,i,t}$ is taken from Auer and Saure (2013) who construct it by using industry-specific import price indices and information on the sectoral composition of the inputs used by each industry. Because $\Delta IPI_{TP,i,t}$ is measured in the trade partner's local currency, we add to it the movement of the relative exchange rate to our cost measure.

Again, we find that our stylized facts are robust when taking into account cost fluctuations of imported inputs in the trade partners: the relationship between the rate of cost pass-through and a firm's market share is U-shaped, while the relationship between the rate of responsiveness to the competition a firm's market share is hump shaped. Table 3 column 2 summarizes these results.

3.5 Further Robustness Tests

Two additional refinements show the robustness of our stylized facts. First, we find that our results are invariant to second-order effects of market shares on prices that are assumed away in the loglinearization of Atkeson and Burstein (2008). We control for such effects directly by including market share into the regression: we add the change of the market share as well as 12 lags thereof to the estimation. This modification has no effect on the coefficients of interest, as shown in Table 3 column 3 (coefficients of market share changes are not reported). The result is expected because we know from Figure 2 that average market shares have remained rather constant over time.

Second, we find that including various fixed effects does also not change the qualitative shape of the presented relations. In column 4, we add time fixed effects to the estimation, thus controlling for all aggregate variation. In column 5, we add time fixed effects for each HS two-digit strata in the data. When we thus absorb all average price developments in each strata, the U-shape response to cost shocks and the hump-shaped response to competitor prices are economically pronounced and statistically significant (the linear interaction term is significant only at the 10% level; however, a joint test that the linear and square interactions are insignificant is rejected at the 1% level). We find the latter robustness test especially strong since it filters out all time-varying strata specific patterns that could be caused by sector specific technological developments.

Overall, we conclude from this and the previous estimations that our two stylized facts are quite robust: conditional on accounting for firm-specific heterogeneity in imported input intensity and conditional on absorbing all common variation over time, both the hump-shaped response and the U-shaped response are strongly present in the data.

3.6 Alternative Pass-Through Estimates from Non-Parametric Specifications

Next, we demonstrate that the linear and quadratic interactions adequately capture the non-linearities between market shares and the rate of pass through. Moreover, we show that the uncovered non-linearities also emerge when employing alternative estimation methods of pass-through rates and the reaction to the competition.

To show our first point, we split our sample into quintiles and estimate the average rate of cost pass-through and responsiveness to competitor prices within each quintile, thereby demonstrating that the quadratic specification employed above is not an artifact of some higher order relations. To show our second point, we estimate by quintiles the 12-months dynamic regressions presented in the previous section, but also estimate specifications that condition on price changes (see Gopinath and Rigobon (2008)), as well on lifetime price changes of goods (also see Gopinath and Rigobon (2008)).

In addition to the above-explained 12-months dynamic regressions, we estimate the following medium-run pass-through specification that conditions the estimation on a price changes actually happening:

$$\Delta p_{i,t_i-t_i^{-1}} = \beta_0 + \beta_1 \Delta c_{i,t_i-t_i^{-1}} + \beta_2 \Delta \bar{P}_{i,t_i-t_i^{-1}}^{com} + \beta_3 Z_{t_i} + \epsilon_{i,t_i}$$

and for the long-run:

$$\Delta p_i = \beta_0 + \beta_1 \Delta c_i + \beta_2 \Delta \bar{P}_i^{com} + \beta_3 Z_{t_i} + \epsilon_{i,t_i}$$

where $\Delta p_{i,t_i-t_i^{-1}}$ denotes the good-specific log price changes between the most recent and the penultimate price changes, $\Delta c_{i,t_i-t_i^{-1}}$ the corresponding log cost changes (constructed as in equation (11)), $\Delta \bar{P}_{i,t_i-t_i^{-1}}^{com}$ the corresponding price change of competitors, and Z_{t_i} the set of controls.

The long-run specification has the same form, but here all changes are cumulated over the lifetime of a good: $\Delta p_i = \Delta p_{i,T-t_0}$. Following Gopinath and Rigobon (2008), we require that there is at least one price change during the life of a good.

While resulting in a smaller sample size, employing conditional pass-through methods has the advantage of eliminating periods of price stickiness. This brings our empirical approach closer to the flex-price environment of our model. In particular, conditioning on life-time price changes takes into account several rounds of price adjustments. This is important especially in a modeling context with price complementarities, because not all firms may adjust at the same time. A single price change may therefore not fully take into account the effect of complementarities. Thus, if this were indeed going on, one would expect stronger results from our model for the long-run pass-through specification.

When we estimate these specifications across the five quintiles of market shares, we find that pass-through is robustly U-shaped for the cases of the dynamic regression, the conditional regression, and the lifelong regressions. Figure 1 Panel A shows this result: for all three estimation methods, the minimum pass-through rate is interior, and it is monotonically decreasing up to the minimum and monotonically increasing after the minimum. As found by Gopinath and Rigobon (2008), the long-run rate of cost pass-through is the highest of the three rates across all bins.

Similarly, the upper panel documents that the responsiveness to competitors' prices is hump-shaped for these three cases. Figure 1 Panel B shows this result: for all three estimation methods, the maximum rate of responsiveness is interior, it is monotonically increasing up to the maximum

and monotonically decreasing after the maximum.

4 Pass-Through in Industry Equilibrium

In this section, we use the above-developed version of the Dornbusch (1987) model as guidance to highlight the aggregate implications of the uncovered microeconomic patterns.

To build up to our main result, we first examine the firm-specific predictions of this theory in industry equilibrium, that is, incorporating that all firms react to their cost shock and that prices react to each other. Using the model as a guidance for this empirical exercise allows us to study the industry-equilibrium rate of pass-through directly based exclusively on cost shocks, avoiding the use of any information in competitors' actual price changes. It also allows us to examine whether the Dornbusch (1987) model accurately captured the nonlinearities of the data that we uncover in Section 3 above.

We note that we do not view this first exercise as our main empirical finding: we know from previous work that most price changes in the data arise due to firm or product-level factors beyond exchange rate movements. Given that the developed model is not designed to explain these firm- or product-specific price movements, we have little hope that it can explain a substantial fraction of the variation of price changes in the data.

Instead of focusing on good-specific price changes that are dominated by idiosyncratic noise, in the second and main exercise, we thus focus on aggregated pass-through rates to demonstrate the aggregate implications of the uncovered microeconomic patterns. We aggregate our theoretically predicted price changes up to the sector-trade partner dimension and examine how well theory and data correlate at this level. Our main finding is that the direct imperfect cost pass-through channel and the indirect price complementarity channel play approximately equally important roles in determining pricing but partly offset each other. Including only one of these channels in an empirical analysis results in a failure to explain variation in the aggregate equilibrium rate of pass-through.

4.1 Firm-level Price Changes

We begin by establishing the empirical relevance of the model at the firm level: We show that actual and predicted price changes are significantly related to one another. Predicted price changes in this comparison are only based on market shares, input intensities, and primitive exchange rate shocks. We do not include competitor prices in the construction of predicted price changes. We find that our model is exhaustive in the sense that cost changes and interaction of changes with a firm's market share and market share squared are no longer informative when added to a specification that includes theoretically predicted price changes as regressor.

We construct predictions only taking into account how the exchange rates of all partners evolve and how this should affect a firm's pricing decisions based on the model and each firm's input intensity. That is, our prediction is the one in (4) based on the constructed cost shocks (11), where we are using the parametrization of Atkeson and Burstein (2008). The predicted price change $\Delta p_{i,k}^{pred}$ of firm i is equal to

$$\Delta p_{i,k,t}^{pred} = \gamma_{i,k} \widehat{P_k^{pred}} + \alpha_{i,k} \Delta C_{i,TP,t} + \epsilon_{i,TP,t} \quad (12)$$

where $\widehat{P_k^{pred}}$ is the predicted change in the sector's price index as solved for in Lemma 1. We focus on the case of Cournot competition for these predictions.¹⁷

Using these predicted price changes, we estimate the following comparison specification to examine the fit of the theory:

$$\Delta p_{i,k,t} = \alpha_{TP} + \sum_{j=0}^{12} \delta_j \Delta p_{i,k,t-j}^{pred} + \eta Z_t + \epsilon_{i,k,t}$$

We find that the theoretically predicted price change $\Delta p_{i,k,t}^{pred}$ comes out highly significant. At the same time, conditional on the inclusion of this prediction neither the cost change nor the cost change interacted with market share and market share squared – included into the set of controls Z_t – add information to the model. Table 4 summarizes our results. Column 1 only includes the theoretical prediction (12) as independent variable as well as the set of time fixed effects for each strata. Next, in column 2 we add the change in the cost of production, and column 3 adds the interactions of the cost change with the firm's market share and the square of the market share. For all three specifications, the theoretical prediction is highly significant, while all other variables are not. We note that throughout columns 1 to 3, the sum of estimated the coefficient of the predicted price changes, $\sum_{j=0}^{12} \delta_j$, is rather low, implying that actual price changes are smaller than predicted ones. We explain why this is the case in the next subsection.

Second, we find that movements in direct costs and price complementarity effects are approximately equally important in explaining equilibrium price changes. We show this by regressing observed price changes on the two components that underlie the predicted price changes: the component that is associated with costs at the firm level and the one component that is associated with the mass of competitors changing prices. We estimate the following specification:

¹⁷The reason for this choice is that the assumption of Cournot competition generates a theoretically predicted shape that follows the shape of the data more closely than under the alternative assumption of Bertrand competition. Figure 5 in Appendix C plots the theoretically predicted rate of cost pass-through as a function of market share for a value of 10 for the elasticity of substitution between varieties and 2 for the elasticity of substitution between sectors. Assuming Bertrand competition typically generates a relation between market share and cost pass-through that is monotonically decreasing until very large market shares. We thank Oleg Itskhoki for bringing this to our attention. See also the discussion in the online appendix of Amity et al. (2012).

$$\Delta p_{i,TP,t} = \alpha_{TP} + \sum_{j=0}^{12} \delta_j^{other} \left(\gamma_{i,k} \widehat{P_k^{pred}} \right) + \sum_{j=0}^{12} \delta_j^{own} (\alpha_{i,k} \Delta c_{i,TP,t}) + \eta Z_t + \epsilon_{i,TP,t}$$

We report the significance of both components of the prediction that derive from cost changes of other firms facing cost shocks ($\sum_{j=0}^{12} \delta_j^{other}$) and from the own cost shock ($\sum_{j=0}^{12} \delta_j^{own}$) in column 5 of 4. We find that both are statistically highly significant and that the coefficients are of comparable magnitude.

4.2 Aggregate Pass-Through Rates

Here, we substantiate our main result at the aggregate level: the imperfect cost pass-through channel is quantitatively slightly less important than the price complementarity channel when it comes to explaining variation in pass-through across sectors and trade partners. Moreover, including only one of these channels results in a failure to explain variation in aggregate pass-through. The underlying reason is that the two channels are negatively correlated. This aggregate implication is consistent with the firm-specific finding that firms characterized by high price sensitivity to own costs react only little to changing competitor prices.

To establish these results, we compare empirically estimated and theoretically predicted rates of pass-through at the trade-partner-sector level. Because such estimation requires a minimum number of observations, we estimate pass-through at the three-digit NAICS level rather than at finer levels of disaggregation. This results in pass-through estimates for 205 three-digit NAICS-trade partner combinations. For each such sector-TP combination, we also construct the theoretically predicted pass-through rate. In this step, we use Equation (12), the constructed market shares, and the benchmark parameters from Atkeson and Burstein (2008) while also accounting for imported input use abroad as described above.

We define the average pass-through rate for each sector-TP combination as the following average of firm-specific rates:

$$\overline{PT}_{3d,TP} = N_{3d,TP}^{-1} \sum_{i \in N_{3d,TP}} \frac{\Delta p_{i,3d}^{pred}}{\Delta c_{i,t}} = \underbrace{N_{3d,TP}^{-1} \sum_{i \in N_{3d,TP}} \alpha_{i,3d}^{-1}}_{=\overline{PT}_{3d,TP}^{CPT}} + \underbrace{N_{3d,TP}^{-1} \sum_{i \in N_{3d,TP}} \frac{\gamma_{i,3d} \widehat{P_{i,3d}^{pred}}}{\Delta c_{i,3d,t}}}_{=\overline{PT}_{3d,TP}^{PCOMP}}. \quad (13)$$

The first term in this equation, $\overline{PT}_{3d,TP}^{CPT}$, is the average direct cost pass-through, while the second term, $\overline{PT}_{3d,TP}^{PCOMP}$, summarizes the effect on pass-through due to price complementarities.

We find that predicted pass-through rates can significantly explain the variation in actual pass-through rates across sectors and trade partners. Figure 3 presents a scatter plot relating estimated to predicted pass-through rates. The vertical axis displays the estimated sector-trade-partner-

specific pass-through rate and the horizontal axis displays the according predicted rate. Column 1 of Table 5 presents the regression line corresponding to this scatter plot. The slope of the line is estimated at 0.732 and statistically highly significant, i.e. the theory can explain differences in pass-through rates across sectors and countries quite well. These differences in pass-through rates are not driven by sectoral characteristics. They persist when we add a set of three-digit NAICS fixed effects as shown in column 2.

However, we note that the predicted pass-through rates much higher than estimated ones. This is reflected by the generally negative intercept in Table 5, which also explains why the coefficients in the previous subsection and Table 4 were small: although the presented theory is a good description of differences in pass-through rates across firms, sectors, and trade partners, the predicted level of pass-through is generally higher than observed in the data.

In terms of economic magnitude, the imperfect cost pass-through channel is slightly less important than the price complementarity channel. Column 3 includes the two elements $\overline{PT}_{3d,TP}^{CPT}$ and $\overline{PT}_{3d,TP}^{PCOMP}$ of the predicted pass-through rate separately, documenting that both elements are significant predictors of the estimated rates of pass-through. We find that a one standard deviation difference in $\overline{PT}_{3d,TP}^{PCOMP}$ (equal to 0.089) is associated with a 6.64% difference in the estimated pass-through rate, while a one standard deviation difference in $\overline{PT}_{3d,TP}^{CPT}$ (equal to 0.068) is associated with a 4.54% difference in the estimated pass-through rate.

Importantly, omission of one of these two channels generates a strong bias in the predicted pass-through rate. We document this in column 4 where we include only the direct cost pass-through element $\overline{PT}_{3d,TP}^{CPT}$ as explanatory variable. This results in an insignificant relationship between estimated and predicted pass-through rates. The underlying reason is that the average direct cost pass-through and the average rate of reaction to the competition are negatively correlated. As a result of this negative correlation, an omitted variable bias makes the coefficient on direct cost pass-through in column 4, $\overline{PT}_{3d,TP}^{CPT}$, drop to 0.055. 0.055 equals the true effect of 0.6673 plus the omitted variable bias of $0.7458 * (-0.82)$, where -0.82 is the coefficient from a regression of $\overline{PT}_{3d,TP}^{CPT}$ on $\overline{PT}_{3d,TP}^{PCOMP}$. We thus significantly underestimate the true rate of pass-through by omitting the element of the prediction that captures the importance of price complementarities. Both channels as well as their covariance are important for understanding the variation in pass-through.

The economic intuition for this aggregate result that both channels need to be taken into account in order to correctly predict pass-through again follows from a firm-specific analogue: firms characterized by high price sensitivity to own costs react only little to changing competitor prices. At the aggregate level, those sectors that are dominated by firms with high price sensitivity to own costs exhibit little reaction to changing competitor prices. This relation, however, is not mechanical since the average rate of reaction to the competition for each sector-trade partner combination depends on the market share distribution of firms from the trade partner in question, on the market

share distribution in the remainder of the industry, and on the correlation structure of exchange rates.

The result presented in column 4 may shed light on why Gopinath and Itskhoki (2010) find that sectoral "market structure", as measured by a Herfindahl index, seems to have no impact on estimated rate of exchange rate pass-through: sectors that are dominated by firms that react strongly to changes in their own cost also tend to be characterized by a low degree of price complementarities, and thus the effect of market structure is not adequately captured by a measure of sectoral concentration such as a Herfindahl index.

Finally, we note that predicted pass-through rates can exceed one (also see Figure 3). The reason is that $PT_{3d,TP}^{PCOMP}$ can take any value because it includes the cost change of competing goods from other nations. The total size of the term depends on the correlation structure of the exchange rate of trade partner TP with that of other exchange rates, as well as the importance of each exchange rate for the price index of sector k .

Our results also hold when we aggregate up to the country level. To produce a country level comparison, we collapse our estimates and predictions to the level of the trade partner. The model predicts that the country specific pass-through rate exceeds one for six economies (Mexico, Norway, Czech Republic, India, Pakistan, and Hong Kong). Figure 4 displays the theoretically predicted and empirically estimated rates. We find that the overall fit of the theory to the data is quite convincing: The slope of the fitted line is 0.82 (significant at the 1% level even with only 34 observations) and the R^2 is around 29% (see column 5 of Table 5). Again, we also find that both the direct cost pass-through coefficient and the indirect price complementarity effect are significant and the coefficients are of comparable magnitude (see column 6).

5 Conclusion

There is now ample notion in the literature that variable markups and price complementarities are behind the low average long-run pass-through rates pervasively found in the empirical literature. We contribute to this literature in two ways.

First, we document the role of a firm's own market share on its rate of cost pass-through and the rate at which it reacts to competitor prices. Exactly the firms that react the most to changes in their own cost react the least to changing competitor prices. While the rate at which a firm reacts to changes in its own cost is U-shaped in market share, the rate at which it reacts to competitors' prices is hump-shaped in market share. These results resemble the qualitative predictions of the heterogeneous firm model of Atkeson and Burstein (2008) that is based on the preferences of Dornbusch (1987).

Second, we document that these two patterns are important for our understanding of how firm-specific pass-through rates interact with price complementarities at the sectoral level in or-

der when shaping the industry equilibrium rate of pass-through. The imperfect cost pass-through channel – how firms react to changes in their own cost for given prices of the competition – and the price complementarity channel – how firms react to changes in competitor prices for given own cost – are quantitatively equally important in explaining the industry wide equilibrium pass-through rate. Additionally, including only one of these channels results in a failure to explain variation in aggregate pass-through rates. The underlying reason for this is that average markup sensitivity and average rate of reaction to the competition are negatively correlated. This aggregate implication follows from the firm-specific finding that firms characterized by high price sensitivity to own costs react only little to changing competitor prices.

Documenting these two forces separately in microeconomic data and showing how they interact in industry equilibrium constitutes the main contribution of our paper.

References

- ALESSANDRIA, G. (2009): “Consumer Search, Price Dispersion, And International Relative Price Fluctuations,” *International Economic Review*, 50, 803–829.
- ALESSANDRIA, G. AND J. P. KABOSKI (2011): “Pricing-to-Market and the Failure of Absolute PPP,” *American Economic Journal: Macroeconomics*, 3, 91–127.
- AMITI, M., O. ITSKHOKI, AND J. KONINGS (2012): “Importers, Exporters, and Exchange Rate Disconnect,” NBER Working Papers 18615, National Bureau of Economic Research, Inc.
- ATKESON, A. AND A. BURSTEIN (2008): “Pricing-to-Market, Trade Costs, and International Relative Prices,” *American Economic Review*, 98, 1998–2031.
- AUER, R., T. CHANEY, AND P. SAURE (2012): “Quality Pricing-to-Market,” GMPi Working Paper 125, Federal Reserve Bank of Dallas.
- AUER, R. AND P. SAURE (2013): “International Price Spillovers via the Global Supply Chain,” Mimeo, Swiss National Bank.
- BACCHETTA, P. AND E. VAN WINCOOP (2003): “Why Do Consumer Prices React Less Than Import Prices to Exchange Rates?” *Journal of the European Economic Association*, 1, 662–670.
- (2005): “A Theory of the Currency Denomination of International Trade,” *Journal of International Economics*, 67, 295–319.
- BERGIN, P. R. AND R. C. FEENSTRA (2001): “Pricing-to-Market, Staggered Contracts, and Real Exchange Rate Persistence,” *Journal of International Economics*, 54, 333–359.
- (2009): “Pass-Through of Exchange Rates and Competition between Floaters and Fixers,” *Journal of Money, Credit and Banking*, 41, 35–70.

- BERMAN, N., P. MARTIN, AND T. MAYER (2012): "How do Different Exporters React to Exchange Rate Changes?" *The Quarterly Journal of Economics*, 127, 437–492.
- BURSTEIN, A., M. EICHENBAUM, AND S. REBELO (2005): "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy*, 113, 742–784.
- (2007): "Modeling Exchange Rate Passthrough after Large Devaluations," *Journal of Monetary Economics*, 54, 346–368.
- BURSTEIN, A. AND G. GOPINATH (2013): "International Prices and Exchange Rates," forthcoming, *Handbook of International Economics*.
- BURSTEIN, A. T., J. C. NEVES, AND S. REBELO (2003): "Distribution Costs and Real Exchange Rate Dynamics during Exchange-Rate-Based Stabilizations," *Journal of Monetary Economics*, 50, 1189–1214.
- CAMPA, J. M. AND L. S. GOLDBERG (2005): "Exchange Rate Pass-Through into Import Prices," *The Review of Economics and Statistics*, 87, 679–690.
- CHEN, N., J. IMBS, AND A. SCOTT (2009): "The Dynamics of Trade and Competition," *Journal of International Economics*, 77, 50–62.
- DEVEREUX, M. B., C. ENGEL, AND P. E. STORGAARD (2004): "Endogenous exchange rate pass-through when nominal prices are set in advance," *Journal of International Economics*, 63, 263–291.
- DIXIT, A. K. AND J. E. STIGLITZ (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67, 297–308.
- DORNBUSCH, R. (1987): "Exchange Rates and Prices," *American Economic Review*, 77, 93–106.
- DROZD, L. A. AND J. B. NOSAL (2012): "Understanding International Prices: Customers as Capital," *American Economic Review*, 102, 364–95.
- FEENSTRA, R. C. (1996): "U.S. Imports, 1972-1994: Data and Concordances," NBER Working Papers 5515, National Bureau of Economic Research, Inc.
- FEENSTRA, R. C., J. E. GAGNON, AND M. M. KNETTER (1996): "Market Share and Exchange Rate Pass-Through in World Automobile Trade," *Journal of International Economics*, 40, 187–207.
- FEENSTRA, R. C., J. ROMALIS, AND P. K. SCHOTT (2002): "U.S. Imports, Exports, and Tariff Data, 1989-2001," NBER Working Papers 9387, National Bureau of Economic Research, Inc.
- FITZGERALD, D. AND S. HALLER (2010): "Exchange Rates and Producer Prices: Evidence from Micro-Data," *Working paper, Stanford University*.
- GARETTO, S. (2012): "'Firms' Heterogeneity and Incomplete Pass-Through'," Working paper, Boston University.
- GOLDBERG, L. S. AND J. M. CAMPA (2010): "The Sensitivity of the CPI to Exchange Rates: Distribution Margins, Imported Inputs, and Trade Exposure," *The Review of Economics and Statistics*, 92, 392–407.

- GOLDBERG, L. S. AND C. TILLE (2009): "Micro, Macro, and Strategic Forces in International Trade Invoicing," Staff Reports 405, Federal Reserve Bank of New York.
- GOLDBERG, P. K. AND R. HELLERSTEIN (2012): "A Structural Approach to Identifying the Sources of Local-Currency Price Stability," Forthcoming, *Review of Economic Studies*.
- GOLDBERG, P. K. AND F. VERBOVEN (2001): "The Evolution of Price Dispersion in the European Car Market," *Review of Economic Studies*, 68, 811–48.
- (2005): "Market integration and convergence to the Law of One Price: evidence from the European car market," *Journal of International Economics*, 65, 49–73.
- GOPINATH, G. AND O. ITSKHOKI (2010): "Frequency of Price Adjustment and Pass-Through," *The Quarterly Journal of Economics*, 125, 675–727.
- (2011): "In Search of Real Rigidities," in *NBER Macroeconomics Annual 2010, Volume 25*, National Bureau of Economic Research, Inc, NBER Chapters, 261–309.
- GOPINATH, G., O. ITSKHOKI, AND R. RIGOBON (2010): "Currency Choice and Exchange Rate Pass-Through," *American Economic Review*, 100, 304–36.
- GOPINATH, G. AND R. RIGOBON (2008): "Sticky Borders," *Quarterly Journal of Economics*, 123, 531–575.
- GUST, C., S. LEDUC, AND R. VIGFUSSON (2010): "Trade Integration, Competition, and the Decline in Exchange-Rate Pass-Through," *Journal of Monetary Economics*, 57, 309–324.
- HELLERSTEIN, R. (2008): "Who Bears the Cost of a Change in the Exchange Rate? Pass-Through Accounting for the Case of Beers," *Journal of International Economics*, 76, 14–32.
- HELPMAN, E. AND P. KRUGMAN (1987): *Market Structure and Foreign Trade: Increasing Returns, Imperfect Competition, and the International Economy*, vol. 1 of MIT Press Books, The MIT Press.
- KIMBALL, M. S. (1995): "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, 27, 1241–77.
- KLENOW, P. J. AND J. L. WILLIS (2007): "Real Rigidities and Nominal Price Changes," 2007 Meeting Papers 844, Society for Economic Dynamics.
- KNETTER, M. M. (1989): "Price Discrimination by U.S. and German Exporters," *American Economic Review*, 79, 198–210.
- (1992): "International Comparisons of Pricing-to-Market Behavior," NBER Working Papers 4098, National Bureau of Economic Research, Inc.
- KRUGMAN, P. (1986): "Pricing to Market when the Exchange Rate Changes," NBER Working Papers 1926, National Bureau of Economic Research, Inc.
- MELITZ, M. J. AND G. I. P. OTTAVIANO (2008): "Market Size, Trade, and Productivity," *Review of Economic Studies*, 75, 295–316.

- MICHAEL, P., A. R. NOBAY, AND D. A. PEEL (1997): "Transactions Costs and Nonlinear Adjustment in Real Exchange Rates: An Empirical Investigation," *Journal of Political Economy*, 105, 862–79.
- NAKAMURA, E. AND J. STEINSSON (2008): "Five Facts about Prices: A Reevaluation of Menu Cost Models," *The Quarterly Journal of Economics*, 123, 1415–1464.
- (2012): "Lost in Transit: Product Replacement Bias and Pricing to Market," Forthcoming, American Economic Review, American Economic Review.
- NAKAMURA, E. AND D. ZEROM (2010): "Accounting for Incomplete Pass-Through," *Review of Economic Studies*, 77, 1192–1230.
- NAKNOI, K. (2013): "Exchange Rate Pass-Through and Market Structure in Multi-Country World," Mimeo, University of Connecticut.
- NEIMAN, B. (2010): "Stickiness, Synchronization and Passthrough in Intrafirm Trade Prices," *Journal of Monetary Economics*, 57, 295–308.
- PENNINGS, S. (2012): "Pass-Through of Competitors' Exchange Rates," Working paper, NYU.
- SIMONOVSKA, I. (2010): "Income Differences and Prices of Tradables," NBER Working Papers 16233, National Bureau of Economic Research, Inc.
- VERBOVEN, F. (1996): "International Price Discrimination in the European Car Market," *RAND Journal of Economics*, 27, 240–268.
- YANG, J. (1997): "Exchange Rate Pass-Through In U.S. Manufacturing Industries," *The Review of Economics and Statistics*, 79, 95–104.

6 Tables and Figures

Table 1: Market Shares

	I. Quintile	II. Quintile	III. Quintile	IV. Quintile	V. Quintile	All
Mean	0.0034%	0.5107%	6.5065%	30.4549%	82.5581%	23.9040%
Std. Error	0.0000%	0.0026%	0.0189%	0.0585%	0.0865%	0.0765%
Median	0.0002%	0.3092%	5.7537%	28.5037%	87.2009%	5.7536%
N	36045	36046	36046	36396	35691	180224

NOTE: This table presents summary statistics of the market shares in our data. We compute mean, median and standard errors for the pooled market shares of all good-months and their quintiles. Market shares are defined within each ten-digit sector in the harmonized system/Tariff Schedule B and are calculated by first constructing trade partner-specific US import shares at the ten-digit level using data from Feenstra et al. (2002), and then allocating the resulting market shares using the structural implications of the model in equation (8) and the prices in the BLS micro data. We use data from 1998-2005.

Table 2: Market Share, Exchange Rate Pass-Through, and Reaction to Competitor Prices

	(1)	(2)	(3)	(4)	(5)
Δe	0.1476 [0.007]***	0.1938 [0.0195]***	0.2204 [0.0214]***	0.1123 [0.0165]***	0.1721 [0.0216]***
$\Delta e * m$		-0.1252 [0.0353]***	-0.5641 [0.1466]***		-0.6710 [0.1668]***
$\Delta e * m^2$			0.3901 [0.1442]***		0.6444 [0.2021]***
$\Delta \bar{P}^{com}$				0.5675 [0.0174]***	0.5135 [0.0.0243]***
$\Delta \bar{P}^{com} * m$					1.021 [0.0.2014]***
$\Delta \bar{P}^{com} * m^2$					-1.1827 [0.2226]***
N	328825	110172	110172	85228	85228
N_i	16171	6220	6220	5111	5111
R^2	0.371%	0.404%	0.434%	9.261%	9.516%

NOTE: This table presents estimates of exchange rate pass-through obtained from fixed effects panel estimations. All reported coefficients are constructed by summing over the instantaneous and 12 lagged coefficients. The corresponding standard error is reported in square brackets. The dependent variable is the monthly log price change of the imported good. The exchange rate change Δe is equal to the monthly log change of the bilateral exchange rate against the USD. For the construction of market shares m and the change in competitor prices $\Delta \bar{P}^{com}$ see the main text. N (N_i) denotes the number of observations at the good-month (good) level. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

Table 3: Imported Inputs and Cost Pass-Through

	(1)	(2)	(3)	(4)	(5)
Δc	0.2052 [0.0252]***	0.1712 [0.0217]***	0.2077 [0.02522]***	0.1890 [0.0347]***	0.1597 [0.0304]***
$\Delta c * m$	-0.8005 [0.1940]***	-0.6727 [0.1669]***	-0.7418 [0.1941]***	-0.7477 [0.20772]***	-0.7095 [0.2047]***
$\Delta c * m^2$	0.7652 [0.2352]***	0.6490 [0.2022]***	0.6700 [0.2357]***	0.7483 [0.2151]***	0.7451 [0.2229]***
$\Delta \bar{P}^{com}$	0.5131 [0.02427]***	0.5138 [0.0243]***	0.5097 [0.0243]***	0.5220 [0.0492]***	0.3678 [0.0476]***
$\Delta \bar{P}^{com} * m$	1.0209 [0.2014]***	1.0201 [0.2014]***	0.9695 [0.2016]***	0.7528 [0.3115]***	0.5262 [0.3092]*
$\Delta \bar{P}^{com} * m^2$	-1.1831 [0.2227]***	-1.1822 [0.2226]***	-1.1051 [0.2223]***	-0.9862301 [0.3300]***	-0.6791 [0.3370]**
Δm			yes		
Time FEs				yes	
Time-Strata FEs					yes
N	85228	85228	85228	85228	85228
N_i	5111	5111	5111	5111	5111
R^2	9.527%	9.514%	9.663%	10.37%	21.035%

NOTE: This table presents estimates of cost pass-through from fixed effects panel estimations. All reported coefficients are constructed by summing over contemporaneous and 12 lagged coefficients. The corresponding standard error is reported in square brackets. The dependent variable is the monthly log price change of the imported good. In Columns (1), (3), (4), and (5), the cost change of firm i is equal to the firm-specific local cost share multiplied by the monthly log change of the bilateral exchange rate Δe against the USD. The local cost share is equal to one minus the imported input cost share as constructed in the main text and the appendix. For the construction of market shares m , the change in competitor prices, $\Delta \bar{P}^{com}$, and the alternative cost change used in column (2), see main text. Column (3) includes the change in the firms market share as well as 12 lags thereof (coefficients not reported). (4) includes time fixed effects, and (5) includes separate sets of time fixed effects for each two-digit HS strata in the BLS data. N (N_i) denotes the number of observations at the good-month (good) level. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

Table 4: Fit of the Theory in Industry Equilibrium

	(1)	(2)	(3)	(4)
Δp_{cost}^{pred}	0.1064 [0.0240]***	0.1043 [0.0234]***	0.1175 [0.0249]***	
Δc		0.0323 [0.0543]	-0.2283 [0.4189]	
$\Delta c * m$			0.0915 [1.2825]	
$\Delta c * m^2$			0.2939 [0.9574]	
$\Delta p_{own\ cost}^{pred}$				0.1344 [0.0273]***
$\Delta p_{other\ cost}^{pred}$				0.1062 [0.0240]***
Time-Strata FEs	yes	yes	yes	yes
N	100813	100813	100813	100813
N_i	6019	6019	6019	6019
R^2	15.926%	15.924%	15.963%	15.907%

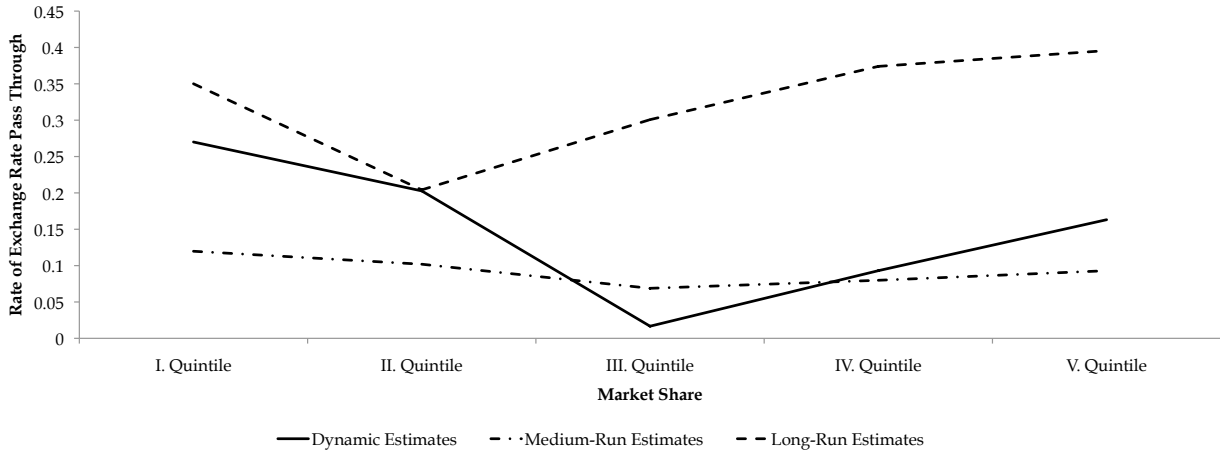
NOTE: This table presents estimates of cost pass-through from fixed effects panel estimations. All coefficients are constructed by summing over contemporaneous and 12 lagged coefficients. The corresponding standard errors are reported in square brackets. The dependent variable is the monthly log price change of the imported good. In Columns (1), (2), (3), the predicted price change Δp_{cost}^{pred} is constructed as in equation (12). The cost change Δc of firm i is equal to the firm-specific local cost share multiplied by the monthly log change of the bilateral exchange rate against the USD, Δe . The local cost share is equal to one minus the imported input cost share as described in the main text and the appendix. For the construction of market shares and the change in competitor prices, see main text. The two sub-elements of the predicted price change in column (4) correspond to the components of the price change in equation (5) that traces back to changes in own costs and to changes in other costs, respectively. These two sub elements add up to the predicted price change that is constructed as in equation (12). N (N_i) denotes the number of observations at the good-month (good) level. *** denotes significance at the 1% level, ** denotes significance at the 5% level, and * denotes significance at the 10% level.

Table 5: Understanding Rates of Exchange Rate Pass-Through

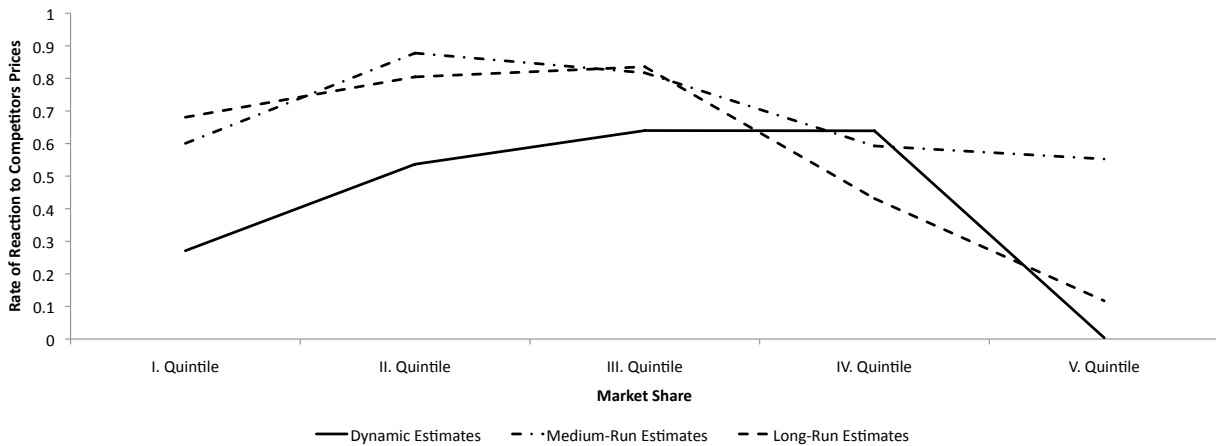
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Estimated PT rate in TP-sector combination				Estimated PT rate of TP	
$\overline{PT}_{3d,TP}$	0.732*** [0.234]	0.574** [0.240]			0.950*** [0.260]	
$\overline{PT}_{3d,TP}^{CPT}$			0.667** [0.310]	0.0550 [0.246]		1.188*** [0.367]
$\overline{PT}_{3d,TP}^{PCOMP}$			0.746*** [0.238]			0.803** [0.306]
Intercept	-0.404* [0.227]	-0.00893 [0.252]	-0.351 [0.282]	0.259 [0.208]	-0.517** [0.249]	-0.691** [0.313]
Industry FEs		yes				
N	205	186	205	205	34	34
R^2	4.6%	21.6%	4.6%	0%	29.4%	31.3%

NOTE: This table presents results from OLS regressions relating theoretically predicted pass-through rates, $\overline{PT}_{3d,TP}$, to estimated rates. Estimated pass-through rates in Columns (1) to (4) correspond to the trade partner-sector average of the estimated cost pass-through rate from a 12-month regression using the BLS micro data. Predicted pass-through rates correspond to the same average over the theoretical prediction constructed following equation (13). Specification (2) includes a dummy for each three-digit NAICS sector. In (4) and (6), the predicted pass-through rate is split into the component associated with cost pass-through, $\overline{PT}_{3d,TP}^{CPT}$, and the one associated with price complementarities, $\overline{PT}_{3d,TP}^{PCOMP}$ (see text). The sample in Columns (5) and (6) is collapsed by the sector dimension, resulting in 34 country-specific data points.

Figure 1: Estimated Pass-Through by Market Share Quintile



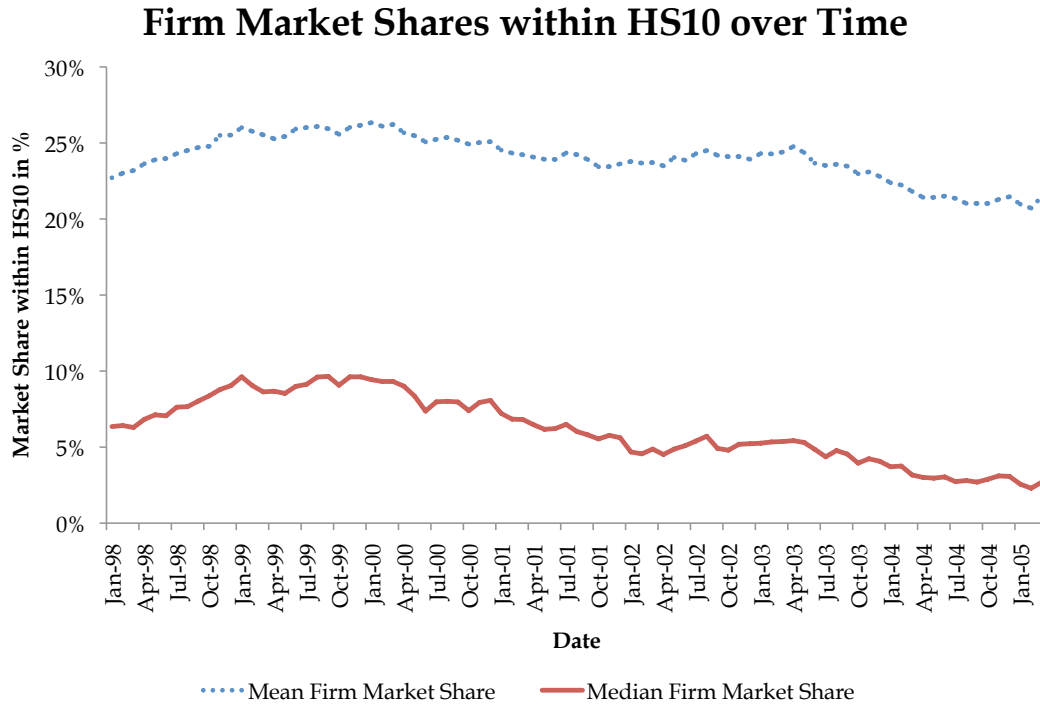
(a) Panel A: Pass-through by quintiles of the market share



(b) Panel B: Responsiveness to competitors' prices, by quintiles of market share

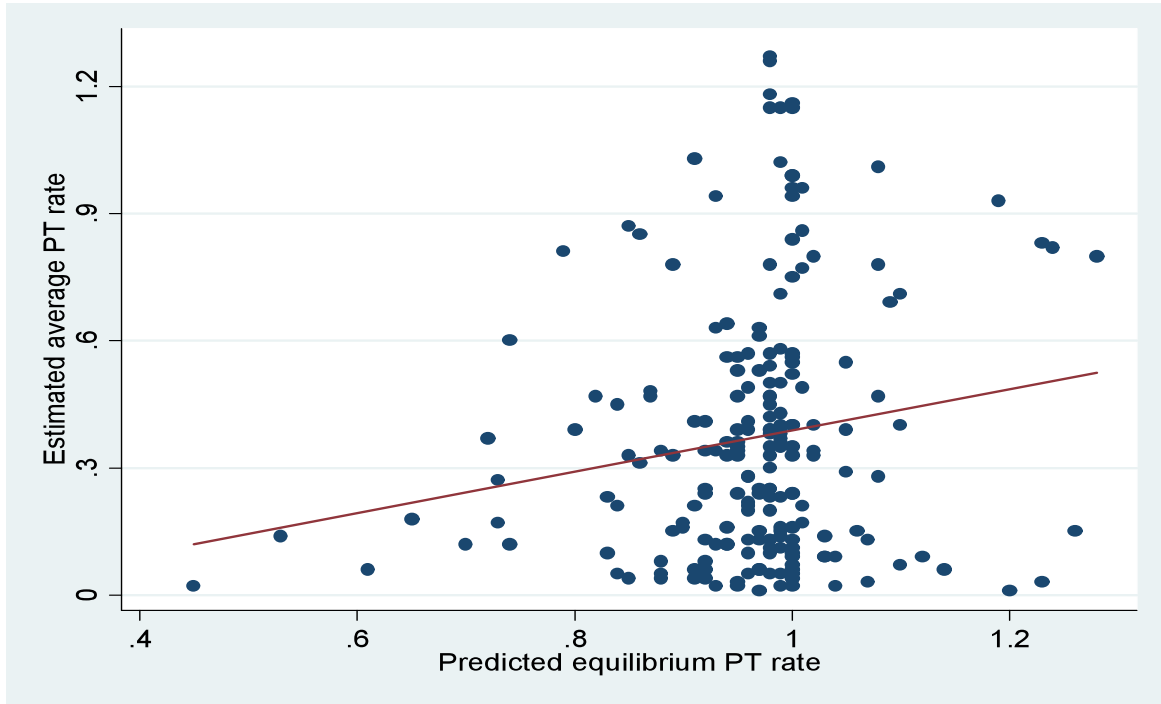
NOTE: We plot the rate of ERPT for each quintile of market shares. The means of the five market share bins are 0.0033%, 0.51%, 6.51%, 30.46%, and 82.56%. The solid lines plots the rate of ERPT and the rate of responsiveness obtained from 12-month dynamic regressions, while the dotted lines present estimates conditional on a price change, so-called medium-run pass-through/responsiveness, and the dash-dotted line presents life-long pass-through estimates, so called long-run pass-through/responsiveness (see Gopinath and Rigobon (2008) and Gopinath and Itskhoki (2010) for detailed discussions and explanations on pass-through). All three specifications are estimated including the exchange rate and local PPI inflation and the change in competitors' prices as dependent variables.

Figure 2: Firm-Level Markets Shares over Time



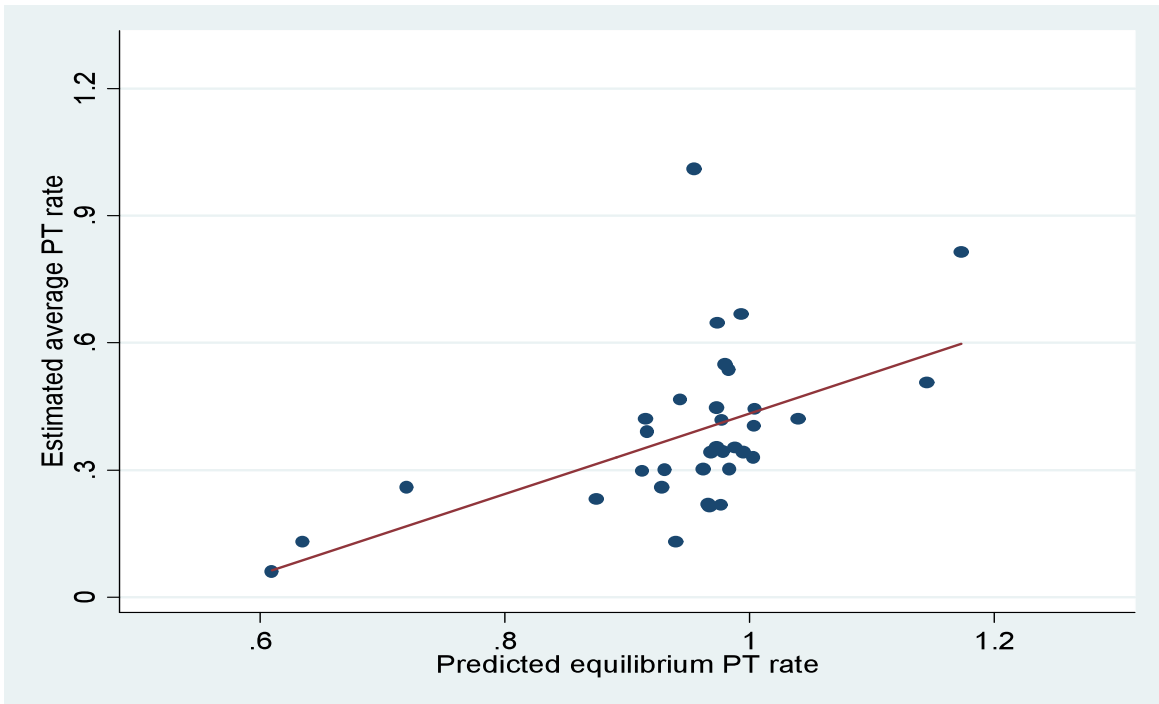
NOTE: This figure displays the evolution of the median (dotted line) and the mean (solid line) of firm-specific market shares in the sample of U.S. importers surveyed by the Bureau of Labor Statistics (BLS) from 01/1998 to 06/2005. Market shares are defined within each ten-digit sector in the harmonized system/Tariff Schedule B and are calculated by first constructing trade partner-specific US import shares at the harmonized system ten-digit level of disaggregation using data from Feenstra et al. (2002), and then allocating the resulting market share using the structural implications of the model in equation (8) and the prices in the BLS micro data.

Figure 3: Estimated and Predicted Pass-Through Rates, by Trade-Partner-Sector



NOTE: This figure presents a scatter plot relating estimated cost pass-through rates (vertical axis) to theoretically predicted equilibrium cost pass-through rates (horizontal axis). The estimated rate is constructed for each three-digit NAICS sector - trade partner combination with more than 100 observations by estimating equation (9) over a horizon of twelve months at the level of the firm, and then generating based on this firm-specific estimate the sector-trade partner specific average pass-through rate, weighted by market shares. The theoretically predicted rate is constructed for the same set of firms, weighted in the same manner, and is constructed following equation (13). The slope of the displayed simple regression line is estimated at 0.732, which is statistically significantly different from 0 at the 1% level.

Figure 4: Estimated and Predicted Pass-Through Rates, by Trade Partner



NOTE: This figure presents a scatter plot relating estimated cost pass through rates (vertical axis) to theoretically predicted equilibrium cost pass-through rates (horizontal axis). The estimated rate is constructed for each three-digit NAICS sector - trade partner combination with more than 100 observations by estimating equation (9) over a horizon of twelve months at the level of the firm and then generating from this firm-specific estimate the trade partner specific average (weighted by market shares within sectors and then unweight across sectors) pass through rate. The theoretically predicted rate is constructed over the same set of firms, weighted in the same manner, and is constructed following Equation (13). The slope of the displayed simple regression line is estimated at 0.82, which is statistically significantly different from 0 at the 1% level.

A APPENDIX: Proofs

Proof of Corollary 2. The expectation of the rate of equilibrium cost pass-through (5) is equal to

$$\begin{aligned} E[ECPT_{TP,k}] &= E \left[\frac{\overline{\gamma}_{TP} \sum_{j \in N_{k,-TP}} s_j \alpha_j \theta_j^l \widehat{e}_{TP,j}}{\theta_i^l \sum_{j \in N_k} s_j \alpha_j} \right] + \frac{\overline{\gamma}_{TP} \sum_{j \in N_{k,TP}} s_j \alpha_j \theta_j^l}{\theta_i^l \sum_{j \in N_k} s_j \alpha_j} + \overline{\alpha}_{TP} \\ &= \frac{\overline{\gamma}_{TP}}{\theta_i^l} E \left[\sum_{j \in N_{k,-TP}} s_j \alpha_j \theta_j^l \widehat{e}_{TP,j} \right] + \frac{\overline{\gamma}_{TP} \sum_{j \in N_{k,TP}} s_j \alpha_j \theta_j^l}{\theta_i^l \sum_{j \in N_k} s_j \alpha_j} + \overline{\alpha}_{TP} \end{aligned}$$

To solve the above, we consider a Taylor approximation of $f(X, Y) = X/Y$ with $X = \widehat{e}_{TP,j}$ and $Y = \widehat{e}_{TP,i}$ both being distributed i.i.d. normally. It holds that

$$f(X, Y) \approx \bar{X}/\bar{Y} + 1/\bar{Y}(X - \bar{X}) - \bar{X}/\bar{Y}^2(Y - \bar{Y}) + \bar{X}/\bar{Y}^3(Y - \bar{Y})^2 - 1/\bar{Y}^2(X - \bar{X})(Y - \bar{Y}) + o(3+)$$

and, taking expectations results in

$$Ef(X, Y) \approx \bar{X}/\bar{Y} + \bar{X}/\bar{Y}^3\sigma_Y^2 - 1/\bar{Y}^2cov(X, Y).$$

Now, with $X = \beta_j e^W + \tilde{e}_j$ and $Y = \beta_i e^W + \tilde{e}_i$ it holds that

$$cov(e(j), e(i)) = E[(\beta_j e^W + \tilde{e}_j - \beta_j \mu_W) * (\beta_i e^W + \tilde{e}_i - \beta_i \mu_W)] = \beta_i \beta_j \sigma_W^2$$

and we thus have, for each country j :

$$\frac{E[\widehat{e}_{TP(j)}]}{E[\widehat{e}_{TP(i)}]} - \frac{cov(\widehat{e}_{TP(i)}, \widehat{e}_{TP(j)})}{(E[\widehat{e}_{TP(i)}])^2} + \frac{var(\widehat{e}_{TP(i)})E[(\widehat{e}_{TP(j)})]}{(E[\widehat{e}_{TP(i)}])^3} = \frac{\beta_j}{\beta_i} \left(1 + \frac{\tilde{\sigma}_i^2}{(\mu_W \beta_i)^2} \right),$$

which proves Corollary 2.

B Appendix: Construction of Good-Specific Input Intensity

The WIOD is an extension of national input-output tables to the international dimension. It 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 that 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 by summing over input-imports from all countries other than TP and all supplying industries l into country TP and industry k . We then divide by the industry's total variable 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. (2012) document a further key pattern in the data that we need to take into account: that firms of het-

erogeneous 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 pricing-to-market 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 micro-patterns of the Belgian data uncovered by Amiti et al. (2012) 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. (2012), 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.¹⁸

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 market share.

$$\theta_{i,TP}^{ImInp} = k_{TP,k} m_i^\gamma \Psi_{TP,k}$$

where we choose γ as 0.3 such that we match the distribution of input intensities in Amiti et al. (2012) (see the distribution reported in Table Table 1 as well as Figure 2). The industry-trade partner specific constant $k_{TP,k}$ is chosen such that we match the industry's average input intensity in the WIOD (adjusted by 1.156):

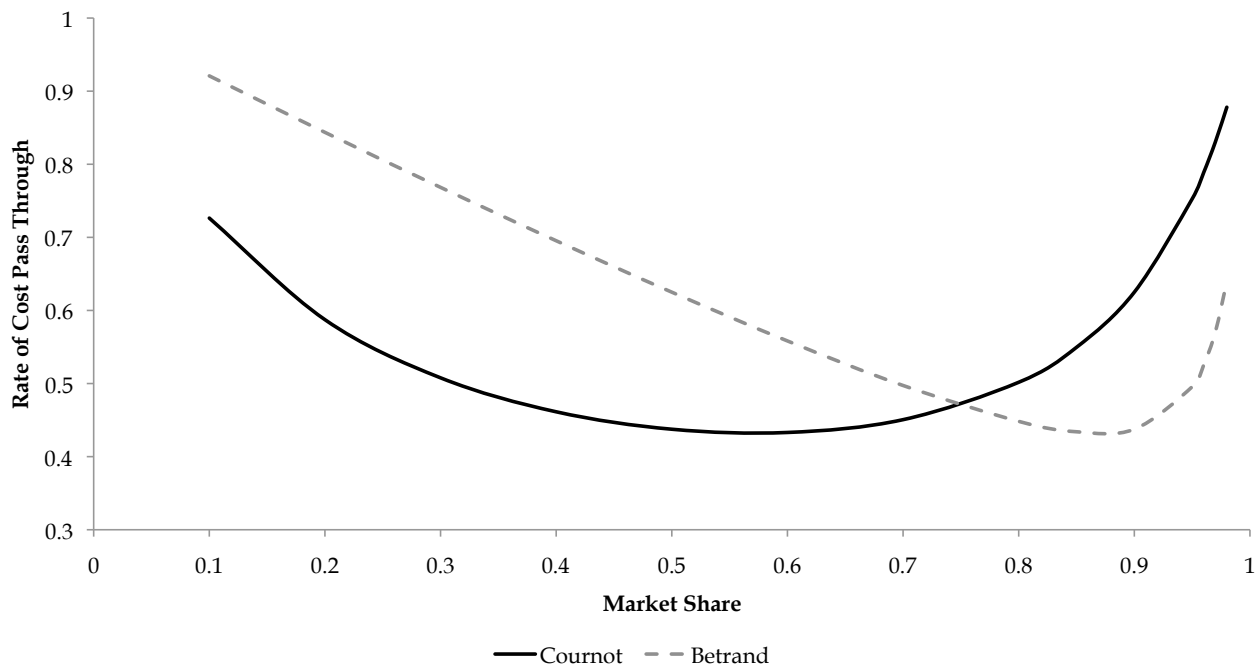
$$\sum_{i \in N_{TP,k}} \theta_{i,TP}^{ImInp} s_{i,k} = 1.156 * \theta_{TP,k}^{WIOD}$$

Summing up, we account for the input usage by heterogeneous firms originating from different countries and industries in two 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 then allocate the inputs imported by exporters over the exporters according to their market shares.

¹⁸These numbers are calculated from Table 2 of Amiti et al. (2012) that splits up all firms into three groups (non-exporters, 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 account 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.

C APPENDIX: Supplementary Figures

Figure 5: Mode of Competition and Relationship between Pass-Through and Market Share



NOTE: This figure displays the theoretically predicted rate of cost pass-through as defined in Proposition (1) for given competitor prices as a function of firm market share. The dashed line assumes that firms compete in prices, while the solid line assumes that firms compete in quantities. Both predictions assume that $\rho = 10$ and that $\eta = 2$.