Journal of International Economics 98 (2016) 60–77

Contents lists available at ScienceDirect

Journal of International Economics

journal homepage: www.elsevier.com/locate/jie

Market structure and exchange rate pass-through☆

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A R T I C L E I N F O

Article history:
Received 5 February 2014
Received in revised form 5 October 2015
Accepted 5 October 2015
Available online 22 October 2015

JEL classification:
D24
E3
E31
F14
F41
L60

Keywords:
Price setting
Exchange rate pass-through
U.S. import prices
Market structure
Price complementarities

A B S T R A C T

We study firm-level pricing behavior through the lens of exchange rate pass-through and provide new evidence on how firm-level market shares and price complementarities affect pass-through decisions. Using U.S. import price micro data, we identify two facts: First, exactly the firms that react the most with their prices to changes in their own costs are also the ones that react the least to changing prices of competing importers. Second, the response of import prices to exchange rate changes is U-shaped in our proxy for market share while it is hump-shaped in response to the prices of competing importers. We show that both facts are consistent with a model based on Dornbusch (1987) that generates variable markups through a nested-CES demand system. Finally, based on the model, we find that direct cost pass-through and price complementarities among importers play approximately equally important roles in determining pass-through but also partly offset each other. This suggests that equilibrium feedback effects in import pricing are large. Omission of either channel in an empirical analysis results in a failure to explain how market structure affects price-setting in industry equilibrium.

1. Introduction

A large empirical literature has studied exchange rate pass-through (ERPT) into import prices because this important topic in international macroeconomics relates to issues such as the movement of international relative prices, the adjustment of global imbalances, or business cycle co-movements. A common finding in the literature which has yielded many insights into firms' pricing behavior is that pass-through of cost shocks into prices is incomplete, even in the long run.[1]

One leading explanation for such incomplete pass-through 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 in Melitz and Ottaviano (2008), Atkeson and Burstein (2008), Chen et al.

☆ 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, Matthew Klepacz and Miao Ouyang for excellent research assistance. We also thank Gita Gopinath, Oleg Itskhoki, 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, an anonymous referee at the SNB Working Paper series and two anonymous referees at the Journal of International Economics for helpful comments and suggestions.

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[1] While 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 the automobile sector in Feenstra et al. (1996), Verboven (1996), Goldberg and Verboven (2001), Goldberg and Verboven (2005), 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 (2013), who use plant-level prices of identical goods sold on different markets to study pricing-to-market decisions.

http://dx.doi.org/10.1016/j.jinteco.2015.10.003

(2009), Berman et al. (2012) and Amiti et al. (2014), Amiti et al. (2015) and Pennings (forthcoming) for the case of heterogeneous firms.[2] Atkeson and Burstein (2008) in particular emphasize that within-sector firm heterogeneity in pricing behavior is essential in order to generate realistic aggregate price dynamics.

We contribute to this literature on exchange rate pass-through and variable markups by providing new empirical evidence on how firm-level market share proxies and price complementarities among importers affect pass-through decisions at the level of the firm, and how heterogeneities in firm-specific responses affect the rate of pass-through in industry equilibrium. We show that in order to explain average price responses, it is not enough to only take into account heterogeneity in the direct response of firms to cost shocks.

In particular, we first show that there is an important type of firm-level heterogeneity in pricing behavior that is undocumented to date and can help discipline our models: exactly the firms that react the most to changes in their own costs are also the ones that react the least to changing prices of competing importers. Second, we also provide new evidence that the rate at which a firm reacts to changing prices of competing importers is hump-shaped in market share. The rate, however, at which a firm reacts to changes in its own cost is U-shaped in market share.

We motivate and rationalize our stylized facts with a model of strategic oligopoly pricing following Dornbusch (1987) and Atkeson and Burstein (2008). Based on the model, we then show that these new heterogeneities are important for our understanding of industry equilibrium pricing. Quantitatively, we find that direct cost pass-through and price complementarities play approximately equally important roles in determining equilibrium pricing behavior, but also partly offset each other. This suggests that equilibrium feedback effects in pricing are large. Indeed, our results show that omission of either channel in an empirical analysis results in a failure to explain how market structure affects price dynamics.

We establish our results in three steps. In a first step, we present a simple theoretical model to guide our intuition about firm heterogeneity and equilibrium pricing. We show how market share affects the firm-level reaction to both own costs and competitor prices. We show this in the framework of strategic oligopoly pricing of Dornbusch (1987) and Atkeson and Burstein (2008). Specifically, we nest preferences following Burstein and Gopinath (2014), who map variation in cost pass-through and price complementarities at the country level into exchange rate pass-through for a wide class of pricing-to-market frameworks. However, we expand upon this framework by allowing for heterogeneity within countries. This leads to our testable expressions: for given own costs, import prices exhibit a hump-shaped reaction to competitor prices in market share while for given prices of competitors, the response to exchange rate changes is U-shaped in market share. The strength of the response to own cost shocks is negatively correlated with the response to competitor prices.

What is the intuition behind these exact shapes? The mechanisms of the model that underlie our predictions can easily be understood from the point of view of competition. A very large firm dominates the price index and can fully pass through its own cost shocks. Similarly, a tiny firm has no market share to lose and will also pass through cost shocks fully. By the same token, the large firm will not care to react to its competitors as will the tiny firm. For intermediate market shares, the responses take a non-zero value. Very intuitively, then, pass-through of own costs and competitor prices must also be negatively correlated.

In a second step, we establish our novel empirical regularities that correspond to these predictions. First, we show that firms' pricing responses are heterogeneous along two important dimensions. To this purpose, we use U.S. firm-level micro data on prices, and construct proxies for firm-specific market share. Using these 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 competitor prices is hump-shaped in the proxy for market share. The first of these two results confirms previous findings from the literature that relate a firm's market share directly to exchange rate pass-through.[3] The second relationship is novel: 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.

In a third step, we show that our intuition from the theoretical framework is important in explaining the cross-section of pass-through responses in the data. Using the micro data, we show that taking into account an industry's market structure and the interplay of heterogeneity in reaction to own cost and to the competition can improve our understanding of the cross-sectional variation in pass-through rates across industries and trade partners. We find that direct cost pass-through and price complementarities play approximately equally important roles in determining pass-through but partly offset each other. Specifically, to gauge the importance of the two channels, we follow the model and construct overall predicted price changes and the two components due to each channel. To do so, we take exchange rate movements to identify cost shocks in our model-implied expression for firms' equilibrium price responses. Then, 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 construct one component of these predicted price changes as coming from price complementarities, and 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. Overall, the actual and total predicted price changes are also related to each other. Regressions deliver highly significant coefficients.

We also document that our results have important aggregate implications. First, we find that the heterogeneous firm model of Atkeson and Burstein (2008) is able to deliver high predictive power for ERPT when we go to the aggregate level. To demonstrate this, we estimate sector and trade partner specific pass-through rates, and compare them to our theoretical benchmark as well as its two components. 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. Moreover, that both direct cost responses as well as price complementarities are equally important for understanding pass-through. Overall, we find that the calibrated model can explain approximately 29% of the variation in pass-through rates across countries.

Second, our results provide important guidance for researchers looking to model how market characteristics affect pass-through rates. For example, our findings shed light on why Gopinath and Itskhoki

[2] Firm 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 (2013). 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)).

[3] A U-shaped relation between market share and pass-through has originally been documented in Feenstra et al. (1996) for the case of country-specific market shares. For the case of firm-specific market shares, Berman et al. (2012) empirically document a monotonic relationship between firm size and pass through, while Garetto (2012), Devereux et al. (2015) and Yoshida (2013) document a U-shaped relation. Amiti et al. (2014) theoretically highlight the close analogy between the monotonic and U-shaped relations conditional on the in- or exclusion of the right set of fixed effects or on normalizing each firm's price change by the sectoral price index.

(2010) find no impact of sectoral "market structure" (as measured by an Herfindahl index) on estimated rates of aggregate 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 strongly react to changes in their own cost also tend to be characterized by a low degree of price complementarities.[4] Documenting these two forces separately in microeconomic data and showing how they interact in industry equilibrium constitutes the main contribution of our paper. We believe that these results provide important guidance for macro modeling choices, as they highlight how heterogeneities at the firm level interact to affect aggregate quantities.

We emphasize that one key ingredient to be able to run our analysis is the availability of proxies for market shares 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 construct market share proxies, we first merge in ten-digit import market share information from bilateral trade data. Then, we use the implications of structural equations for market shares and relative prices from our model to allocate these market shares at the firm level among all importers. A cautious interpretation of our results therefore keeps in mind this nature of the market share proxy.

However, we also show the validity of our market share proxy using three tests. The first test shows that prices really have an allocative function for quantities. This is done by replicating our procedure at a coarser level of aggregation for which we have exact information on market shares at all levels, and documenting that even at this coarser level, our procedure has a lot of predictive power. We base a second check on a comparison of our constructed market shares to market shares based on actual sales data that we obtain from merging in Compustat data on firm-level sales for U.S. importers. For both checks, we find strong evidence that true and constructed shares are highly correlated and similar in magnitudes.

A third test relates to the role of domestic competition: Should domestic prices and sales also not play an important role in shaping the response of import prices? When we include information on domestic firms into our measures of competitor prices and market shares, we find strong evidence that in fact confirms our implicit Armington view of competition in this paper: Foreign firms compete much more intensely with other importers rather than domestic firms. Not only are individual import prices much more strongly correlated with other import prices rather than domestic competitor prices. In fact, we find that our results continue to hold — but mainly because of the information contained in the import competitor prices while domestic prices have no significant relationship to import price and market structure.

Our results are complementary to contemporaneous work by Pennings (forthcoming) and ongoing work by Amiti et al. (2015). Pennings (forthcoming) also uses the BLS micro data to analyze exchange rate pass-through into import prices. While we explicitly examine the role of market structure, his focus lies in documenting that price complementarities among importers and positively correlated exchange rates lead to an upward bias in estimated rates of exchange rate pass-through. Amiti et al. (2015) examine Belgian data on prices and international input use which makes it possible to properly control for marginal cost changes. While it may be a concern that we do not have such detailed imported intermediate input data which could bias our results, this may be less relevant for the U.S. than Belgium. In fact, they confirm one of our key findings that the rate at which a firm reacts to changes in its own cost is negatively related to the rate at which it reacts to changes in competitor prices.

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 takes the firm-level predictions to the data. Section 4 examines pass-through in the industry equilibrium. Section 5 concludes.

2. Pass-through for individual firms and in industry equilibrium

In this section, we derive three sets of testable predictions that guide our analysis. The first set of predictions relates the pricing response of a firm to changes in its own production cost and changes in competitor prices. The second set of predictions solves for the firm's price change in equilibrium. The equilibrium solution takes into account that multiple firms in an industry can face a cost shock and these cost shocks have second round effects due to price complementarities. The third set of predictions demonstrates how the interaction of the reaction to competitor prices and to own costs, along with the correlation structure of the exchange rate, affects estimated pass-through in the aggregate.

We derive these firm-specific pricing-to-market predictions from the variable markup model of Dornbusch (1987). This framework has been used to analyze pricing-to-market decisions in, among others, Feenstra et al. (1996), Yang (1997) and – in the context of heterogenous firms – Atkeson and Burstein (2008). We are fully aware that alternative theoretical frameworks give rise to qualitatively similar microeconomic predictions. For example, in Alessandria (2004), a firm's dynamic optimization of its customer stock implies that pass-through to prices is U-shaped in the market share, while in Garetto (2012) static strategic interactions may give rise to similar nonlinearities. More generally, Burstein and Gopinath (2014) discuss a set of alternative models that yield the same prediction.[5]

For these reasons, we view the contribution of this theoretical section not so much as developing testable predictions that allow us to discern one specific theory of pricing-to-market from others. Rather, we view its contribution as providing a qualitative guide for our analysis: how should microeconomic patterns shape aggregate price dynamics in a preference framework that is qualitatively consistent with the empirical microeconomic regularities that we document?

2.1. Model setup

We summarize the essential elements of our setup in the following. On the preference side, we have a two-tiered "love of variety" utility/production function in which consumers consume the output of sectors k, while the output of each sector is produced by combining varieties i within each sector. As in Dixit and Stiglitz (1977), consumers have constant-elasticity demand for each sector's total output. Final consumption x is produced by competitive firms aggregating sectoral output x_k (which we can think of as goods, for example) into $x = (\int_0^1 x_k^{(\eta-1)/\eta} dk)^{\eta/(\eta-1)}$.

On the production side, in each sector k a set of $i \in N_k$ importers each hold the blueprint to produce a differentiated variety. We denote the output quantity of their variety i by $q_{i,k}$. Each sector k itself is competitive and uses a production function given by $y_k = (\sum_{i=1}^{N_k} q_{i,k}^{(\rho-1)/\rho})^{\rho/(\rho-1)}$. Cost minimization implies that the price of the sector-composite is $P_k =$

[4] In fact, in the context of volatility and pass-through, Berger and Vavra (2013) after going through various potential model explanations reach the conclusion that future research should focus on understanding what underlies heterogeneous responsiveness of firms: they conclude that heterogeneous " responsiveness" of firms – as a result of market structure or complementarities – is crucial for understanding pricing patterns in import prices.

[5] Many 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 (2015), 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).

$\left(\sum_{i=1}^{N_k} P_{i,k}^{(1-\rho)}\right)^{1/(1-\rho)}$. Demand for each individual input i is $q_{i,k} = y_k(P_{i,k}/P_k)^{-\rho}$. Market clearing implies that total consumption of sectoral output is equal to its production: $x_k = y_k = (P_k/P)^{-\eta}x$. P is the unit price of the final output and equal to $(\int_0^1 P_k^{(1-\eta)}dk)^{1/(1-\eta)}$.

Each intermediate good can be produced and delivered to the market at constant marginal cost $mc_{i,k}$, where $mc_{i,k}$ includes transportation costs and is denominated in the importer currency. The latter means that $mc_{i,k}$ generally responds to the exchange rate.

The model is thus identical to Dixit and Stiglitz (1977), except that it focuses on the case in which firms are large compared to their sector. This differentiation is important because large firms can influence a sector's overall price level. A key assumption is that varieties are more substitutable than sectoral output: $\rho > \eta > 1$. For example, if we think of two sectors "trousers" and "shoes" and two shoe varieties "Reebok" and "Nike,"then 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.

A further implicit assumption of our model is that importers only compete with other importers, but not with domestic firms, that is, that foreign and domestic output is differentiated in the Armington sense.

2.2. Cost pass-through for individual firms

In this sub-section, we derive our first two predictions: First, we show how firm-level prices respond to own costs of firms, and competitor prices. Second, we derive an expression for price changes in industry equilibrium.

These predictions build on the assumption that firms are non-negligible in size within a sector. This implies that each firm has an impact on P_k, the sectoral price index. Because the impact of a firm's price $P_{i,k}$ on P_k is increasing in firm market share, the firm-specific elasticity of demand depends on the firm's market share. We denote the former by $S_{i,k}$ and the latter by $\varepsilon_{i,k}$. Then, it holds in our setup that $\varepsilon_{i,k} = \left(\frac{1}{\rho}(1-s_{i,k}) + \frac{1}{\eta}s_{i,k}\right)^{-1}$ if firms compete in quantities and $\varepsilon_{i,k} = (\rho(1-s_{i,k}) + \eta s_{i,k})$ if they compete in prices. A firm's perceived demand elasticity therefore decreases in its market share and consequently, the markup increases with market share.

What does this mean for our first prediction, the reaction of firms to cost shocks, and competitor prices? Since the market share of each firm reacts to changes in its price relative to its competitors, firms clearly react less than one-to-one to marginal cost. We formalize this insight with the following expression:[6]

$$\widehat{P}_{i,k} = \Gamma(s_{i,k})\left(\hat{P}_{i,k} - \hat{P}_k\right) + \widehat{mc}_{i,k}, \tag{1}$$

where $\widehat{mc}_{i,k}$ is the percentage cost change of firm i and $\Gamma(s_{i,k})$ measures the log-linearized responsiveness of firm i's markup to $(\hat{P}_{i,k} - \hat{P}_k)$, the price of firm i relative to the sector. Here, conceptually, the markup sensitivity $\Gamma(s_{i,k})$ is closely related to the "super elasticity"of demand in Klenow and Willis (2007) and Gopinath et al. (2010). The markup sensitivity is strictly increasing in a firm's market share. In particular, if firms compete in quantities, $\Gamma(s_{i,k})$ is equal to $\frac{(1-\rho)(1/\eta-1/\rho)s_{i,k}}{1-(1-s_{i,k})/\rho-s_{i,k}/\eta}$. If firms compete in prices, it is equal to $\frac{(1-\rho)(\rho-\eta)s_{i,k}}{\rho(1-s_{i,k})+\eta s_{i,k}}$.

However, despite this monotonicity in the markup sensitivity, the overall reaction to cost shocks is non-monotonic in market share. The reason for this lies in the effect that firm i has on the overall price index $\hat{P}_k$. We summarize this overall result in the following proposition, leaving detailed derivations to the appendix. The proposition separately relates, with our empirical analysis in mind, the price response to market shares and to own costs, and competitor prices, a variable of interest for example in Gopinath and Itskhoki (2010). As an auxiliary variable, we therefore first define the Weighted Competitor Price Changes, which is the index of weighted price changes of all firms that compete with firm i:

Definition 1. $\hat{P}_{i,k}^{com} \equiv \sum_{j \varepsilon N_k,-i} s_j \hat{P}_{j,k}$ denotes the change in the Weighted Import Competitor Price Changes, the index of all prices in sector k other than firm i.

We note that because N_k includes only the set of importers (that is, it excludes domestic competitors in sector k), $\hat{P}_{i,k}^{com}$ is the import competitor price index. The firm-level price response then is subject to the following relationship between market shares and cost shocks, and competitor prices, ceteris paribus:

Proposition 1. Reaction to changing costs and changing competitor prices

Let $CPT_{i,k} \equiv \frac{\partial P_{i,k}}{\partial mc_{i,k}} \frac{mc_{i,k}}{P_{i,k}}\Big|_{\hat{P}_{i,k}^{com}=0}$ *denote the elasticity of firm i's price with respect to its own cost for given competitor prices and* $RCP_{i,k} \equiv \frac{\partial P_{i,k}}{\partial P_{k,-i}} \frac{P_{k,-i}}{P_{i,k}}\Big|_{\widehat{mc}_{i,k}=0}$ *denote the elasticity of firm i's price to the Weighted Competitor Price Changes for a given own cost. It holds that*

1) $CPT_{i,k} \varepsilon [0, 1]$ and is U-shaped in market share, that is, it is monotonically decreasing up to an inflection point and thereafter monotonically increasing;
2) $RCP_{i,k} \varepsilon [0, 1]$ and is hump-shaped in market shares, that is, it is monotonically increasing up to an inflection point and thereafter decreasing in firm market share.
3) $CPT_{i,k}$ and $RCP_{i,k}$ are negatively related, that is, it holds that $\partial CPT_{i,k}/\partial RCP_{i,k} < 0$.

Proof. In Appendix A. ■

This proposition presents two new results on the exact shape of the monotonicity. First, firm-level prices have a response to competitor prices that is hump-shaped in market shares. At the same time, as is well known, the response to own shocks is U-shaped. The second new result is that these types of responsiveness are negatively correlated, conditional on each other.

The exact functional form of cost pass-through for the case of Cournot competition is as follows:

$$CPT_{i,k} = \left(1 + (\rho-1)\frac{s_{i,k}}{\frac{1-1/\rho}{1/\eta-1/\rho} - s_{i,k}}(1-s_{i,k})\right).$$

For the case of Bertrand Competition, it is as follows:

$$CPT_{i,k} = \left(1 + \frac{(1-\rho)(\rho-\eta)s_{i,k}}{\rho(1-s_{i,k}) + \eta s_{i,k}}(1-s_{i,k})\right)^{-1}.$$

The expressions for the reaction to competitor prices, $RCP_{i,k}$, follow directly from the relationship that $RCP_{i,k} = 1 - CPT_{i,k}$.

What is the intuition behind the exact shapes of the responses? A very large firm dominates the price index and can fully pass through its own cost shocks. Similarly, a tiny firm has no market share to lose and will also pass through cost shocks fully. By the same token, the large firm will not care to react to its competitors as will the tiny firm. For intermediate market shares, the responses take a non-zero value.

[6] We denote percentage changes (in logs) by ^.

Very intuitively, then, it follows that pass-through of own costs and competitor prices must also be negatively correlated.[7]

While Proposition 1 clearly distinguishes the two determinants of price setting that we have in mind in this paper, it can be criticized for one important reason: Conditioning on competitor prices implicitly conditions on a set of unobserved cost shocks that drive the price changes of competitors. But, at the same time, these shocks are also correlated with the cost shock of firm i.

This consideration leads us to our second, more structural, testable proposition on price changes in equilibrium. With it, we circumvent the above problem by solving for all price prices in industry equilibrium: We let all prices react to changes in their own cost and to changes of other prices. That is, we solve for the price changes of all competitors given the entire vector of cost shocks in industry k and the theory-implied price interlinkages.

To do so, we first set down some notation: we define the rate of cost past-through conditional on the sectoral price index as $\delta_{i,k} \equiv \frac{\partial P_{i,k}}{\partial mc_{i,k}} \frac{mc_{i,k}}{P_{i,k}}|_{\hat{P}_k=0} = (1-\Gamma(s_{i,k}))^{-1}$. Similarly, we define $\gamma_{i,k} \equiv \frac{\partial P_{i,k}}{\partial P_k} \frac{\hat{P}_k}{P_{i,k}}|_{\widehat{mc}_{i,k}=0} = \Gamma(s_{i,k})(1-\Gamma(s_{i,k}))^{-1}$ as the rate at which the price of firm i reacts to changes in the sectoral price index conditional on holding fixed its own marginal cost of production. With these definitions at hand, manipulation of Eq. (1) leads to the following proposition:[8]

Proposition 2. Price changes in industry equilibrium

Denote the industry equilibrium price change of firm i by $\hat{P}^{Eq}_{i,k}$. *It is equal to*

$$\hat{P}^{Eq}_{i,k} = \gamma_{i,k} \frac{\sum_{j \epsilon N_k} s_j \delta_{j,k} \widehat{mc}_{j,k}}{1-\sum_{j \epsilon N_k} s_j \gamma_{j,k}} + \delta_{i,k} \widehat{mc}_{i,k}. \tag{2}$$

This proposition extends the analysis of Burstein and Gopinath (2014, in particular their Propositions 1 to 3) to the case of firms that are heterogeneous within origins. It shows how price responses work through several channels: First, the price response of the set of firms affected by a cost shock depends on the market share of each affected firm. The terms $s_j \delta_j \widehat{mc}_{j,k}$ contain this dependence. Further, price complementarities matter because price changes of firms from a specific competitor 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. This is captured by the summation $\sum_{j \epsilon N_k,-i} s_j \delta_j \widehat{mc}_{j,k}$ over all firms. There is further amplification since all other firms in the industry react to the changing general price level, multiplying the initial impact. The term $(1-\sum_{j \epsilon N_k} s_j \gamma_{j,k})^{-1}$ corresponds to this amplification. In this sense, the price response is affected by the sector's entire market structure even if only few firms are affected by a given cost change.

2.3. Estimated exchange rate pass-through in the aggregate

Now we are ready to develop a third set of predictions, which focus on exchange rate pass-through in the aggregate. To get there, we first present an expression for exchange rate pass-through at the firm level. This connects exchange rate pass-through directly to the preceding results on firm-level cost pass-through. Then, we proceed to aggregate these expressions to the sectoral level.

To obtain an expression for exchange rate pass-through at the firm level, we build directly on the previous section. In doing so, we have to move from an unspecified vector of cost changes to pass-through following exchange rate changes. This requires us to specify how the exchange rate affects costs: We assume that the elasticity of marginal cost with respect to the exchange rate at the input source is equal to α_i^l. In the next section, in the empirical implementation, we follow Johnson and Noguera (2012), Amiti et al. (2014) and Bems (2014) and take into account that exchange rate changes translate into cost changes at a rate less than one. The reason is that not all costs are paid in the local currency of the exporter. This implies that α_i^l has the interpretation of the local cost share in production, a terminology which we adopt throughout the remainder of the paper.

To build up to our aggregate pass-through proposition, we also need to define what we mean exactly by firm-specific exchange rate pass-through. To this purpose, we denote by $\hat{e}_i$ the percentage change of the bilateral exchange rate of country c that firm i originates from and by α_i^l the rate at which a bilateral exchange rate change affects the cost of firm i: $\widehat{mc}_{i,k} = \alpha_i^l \hat{e}_i + \varepsilon_i$. Then, we can define the rate of cost pass-through as follows:

Definition 2. Firm-specific pass-through rate

$ECPT_{i,k} \equiv \frac{\partial P_{i,k}}{\partial(\alpha_i^l e_i)} \frac{\alpha_i^l e_i}{P_{i,k}}$ denotes firm i's rate of pass-through following exchange rate-induced cost shocks.

According to this definition, $ECPT_{i,k}$ is the unconditional elasticity of firm i's price with respect to the exchange rate-induced cost shocks and it thus captures all second-round effects. When we apply this definition to Eq. (2), we obtain the following expression:

$$ECPT_{i,k} = \gamma_i \frac{\sum_{j \epsilon N_k} s_j \delta_j (\alpha_j / \alpha_i^l)(\hat{e}_j / \hat{e}_i)}{\sum_{j \epsilon N_k} s_j \delta_j} + \alpha_i^l \delta_{i,k} + \tilde{\varepsilon}_i \tag{3}$$

The firm-specific rate of pass-through then has a similar decomposition as in Proposition 2: It depends on the interaction of firm-specific heterogeneity in cost pass-through and the reaction to competitor prices, and on the fact that exchange rates only affect the cost of production of a subset of firms. Thus, this firm-specific rate of cost pass-through is obviously related to exchange rate pass-through: the equilibrium pass-through rate $(\frac{\partial P_{i,k}}{\partial e_i} \frac{e_i}{P_{i,k}})$ is equal to $ECPT_{i,k}$ times α_i^l, the local cost share.[9]

The numerator of the fraction in Eq. (3) captures how the prices of all firms from country c react to a change in their exchange rate for a given price level. Then, of course, this initial "price impulse" is multiplied as all prices react to each other. In addition, what determines the price complementarity channel is that firms of heterogeneous size vary in their $\delta_j \alpha_j$, how firm i's exchange rate change $\hat{e}_i$ is correlated with all $\hat{e}_j$, the

[7] It is the precise conditionality in Proposition 1 that is new to the literature. For example, Burstein and Gopinath (2014) and Amiti et al. (2014) derive a similar statistic conditional on the sectoral price index being constant. While a U-shaped relation can be derived in other settings under specific assumptions, this pattern of a generically U-shaped relation between market share and pass-through is particular to the class of models deriving from Dornbusch (1987). As documented in Berman et al. (2012), the preference framework of Ottaviano et al. (2002) that are used in Melitz and Ottaviano (2008) generates a monotonic relation between productivity (which determines market share) and cost pass-through under the assumption that firms are small and do not affect a sector's price index. In Appendix A, we document that even when firms do take into account their effect on the price index, these preference setups generate a monotonic relation between productivity and cost pass-through.

[8] Note that $\delta_{i,k}$ and $\gamma_{i,k}$ are monotonically related to market share due to conditioning on the sectoral price index instead of on the price of competitors as in Proposition 1. This difference is implicitly highlighted in Amiti et al. (2014) who demonstrate the close analogy between the monotonic and U-shaped relations conditional on the in- or exclusion of the right set of fixed effects or on normalizing each firm's price change by the sectoral price index. Also see the discussion of direct and indirect pass-through effects in Burstein and Gopinath (2014) (see in particular their Propositions 1 and 2).

[9] It holds that $\tilde{\varepsilon}_{i,t} = \gamma_i \frac{\sum_{j \epsilon N_k} s_j \alpha_j (\widehat{mc}_{j,k} - \theta_{j,c} \hat{e}_{j,c,t})}{1-\sum_{j \epsilon N_k} s_j \gamma_j} + \alpha_i(\widehat{mc}_{j,k} - \theta_{i,c} \hat{e}_{i,c,t})$. We focus on the rate of cost pass-through rather than on the rate of exchange rate pass-through since we want to highlight the effect of variable markups while abstracting from the importance of imported intermediate inputs, a channel that has been analyzed elsewhere.

exchange rate changes of all other firms (a channel highlighted in Bergin and Feenstra (2009), Pennings (forthcoming), and Naknoi (2013)), and the "mass" of firms originating from c (a channel highlighted in Feenstra et al. (1996)). Unless we are in special cases when it comes to these heterogeneities, the price-complementarity channel, and the second, cost pass-through channel, will not generate pass-through of 1 independently of market structure.

Beyond the unit of the firm, what can we say about aggregate exchange rate pass-through at the sector and trade partner (c) levels? Aggregation of (3) across all the firms originating from c implies the following:

Proposition 3. Aggregate pass through rate

Let $m_{c,k} \equiv \frac{\partial P_k^{Eq}}{\partial e_c}\frac{e_c}{P_k^{Eq}}$ *denote the equilibrium elasticity of the sectoral price index with respect to the exchange rate of country c and* $ECPT_{c,k} \equiv \left(\sum_{j\varepsilon N_{c,k}} s_j ECPT_{i,k}\right)\left(\sum_{j\varepsilon N_{c,k}} s_j\right)^{-1}$ *denote the market share-weighted average of* $ECPT_{i,k}$ *in the set of all firms that originate from c in sector k* ($i\varepsilon N_{c,k}$)*. Then,*

$$ECPT_{c,k} = \overline{\gamma}_c\left(\sum_{o\varepsilon C} m_{o,k}\frac{\hat{e}_o}{\hat{e}_c}\right) + \overline{\delta}_c + \overline{\varepsilon}_c, \tag{4}$$

where $\overline{\gamma_c}$, $\overline{\delta_c}$ and $\overline{\varepsilon_c}$ correspond to the market share-weighted averages of $(\alpha_{i,k}^l)^{-1}\gamma_i$, $\delta_{i,k}$, and $\overline{\varepsilon_{i,t}}$ in the set of firms from c and in sector k.

Proof. In Appendix A. ■

This proposition presents an empirically testable prediction of how the industry equilibrium rate of exchange rate pass-through depends on market structure. Its particular feature is that the overall rate of pass through can be broken down into two components: 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 industry level.

What are these two components precisely? On the one hand, Eq. (4) relates the equilibrium rate of cost pass-through to $\overline{\delta_c}$. This is a direct cost pass through channel reflecting the average rate at which firms from country c react to changes in their own cost. As $\partial\delta_{i,k}/\partial s_{i,k} > 0$, this rate is increasing in the average market share of firms from country c. On the other hand, the second channel captured in Eq. (4) is 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 c.[10]

Importantly, the price complementarity response incorporates how the sectoral price index changes for a given distribution of firm market shares and imported input intensities, origins, and exchange rate movements. This is captured by the interaction of $\overline{\gamma_c}$ and $\sum_{o\varepsilon C} m_{o,k}\frac{\hat{e}_o}{\hat{e}_c}$. Naturally, the change in the sectoral price index is the sum over all relative exchange rate movements times $m_{o,k}$, the equilibrium elasticity of the sectoral price index with respect to the exchange rate of country o. This latter term is equal to

$$m_{o,k} = \sum_{j\varepsilon N_{o,k}} s_j\delta_j\alpha_j / \left(1 - \sum_{j\varepsilon N_k} s_j\gamma_j\right). \tag{5}$$

An important element capturing the aggregate implication of price complementarities in the proposition is the term $(\hat{e}_o/\hat{e}_c)$. This term implies that the estimated firm-specific equilibrium pass-through incorporates the correlation structure of exchange rates across the various trade partners.

3. Market share, pass-through, and responsiveness to competitor prices

In this section, we take the firm-level predictions to the data. This requires information on prices, exchange rates, market shares, indices of competitor prices, and information on local cost shares. Detailed market shares are usually not readily available. Therefore, we first describe our methodological innovation to construct firm-specific market share proxies and indices of competitor prices. Then, we use confidential U.S. micro data to establish our two stylized facts: The rate at which a firm reacts to competitor prices is hump-shaped in market share while the rate at which it reacts to changes in its own cost, identified off exchange rate movements, is U-shaped in market share. These correspond directly to our conditional firm-specific predictions, and are robust to several robustness checks. In particular, including information on domestic competitors leaves our results unchanged. Finally, we investigate the other testable predictions, leaving the predictions for industry equilibrium and the aggregate to a separate, subsequent section.

In taking the model to the data, we understand that our model, like the original Atkeson and Burstein (2008) model, is a real model, so that we are taking somewhat of a leap of faith in using it to talk about nominal exchange rate pass-through. Nonetheless, our predictions carry through, especially when it comes to the role of variable markups and prices, the focus of our paper: In the model, prices are set as a function of markup over real marginal cost, and markups are in turn a function of market shares. In our empirical approach, we measure those correctly as real quantities. While we do not directly observe real marginal costs or any measure related to it, such as productivity, our implicit assumption, as throughout the pass-through literature, is that exchange rate shocks are exogenous to the firm and given local-currency pricing, act like a marginal cost shock.

3.1. Import price 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. 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.[11]

3.2. Constructing proxies for market shares

One of the major limitations of the BLS micro price data is that it does not include information on the sales of individual firms. However, we need such information to predict firm-specific price responses from

[10] 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, $\overline{\gamma_{TP}} = \sum_{i\varepsilon N_{k,TP}} s_i^{TP}\gamma_i(\theta_i^l)^{-1}$ where $s_i^{TP} = s_i / \sum_{j\varepsilon N_{k,TP}} s_i$. For the other averages, it holds that $\overline{\varepsilon_{TP}} = \sum_{i\varepsilon N_{k,TP}} s_i^{TP}\overline{\varepsilon_{i,t}}$ and $\overline{\alpha_{TP}} = \sum_{i\varepsilon N_{k,TP}} s_i^{TP}\alpha_i$.

[11] As 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.

the model. We overcome this limitation in the following way. First, we merge in country-specific trade flows that are highly disaggregated. Second, we refine the associated country-specific market shares to obtain the exact size distribution of firms. We accomplish this last step by using the structural relationship between relative prices and market shares implied by the model. We verify the validity of the approach in our dataset with respect to the methodology. We find that our methodology is very robust.

In constructing our market share measure, a key insight is that the model structurally implies how 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 by sector: Within each ten-digit HS sector, the market share of a given firm $i\varepsilon N_{c,k}$ from country c and sector k is equal to

$$s_{i,k} = \frac{IM_{c,k}}{\sum_c IM_{c,k}} \frac{P_{i,k}^{(1-\rho)}}{\sum_{j\varepsilon N_{c,k}} p_{j,k}^{(1-\rho)}} = s_{c,k} \frac{P_{i,k}^{(1-\rho)}}{\sum_{j\varepsilon N_{c,k}} p_{j,k}^{(1-\rho)}}, \tag{6}$$

where $s_{c,k}$ is the sectoral import share of country c, defined by imports $IM_{c,k}$ in sector k. To compute the first term of Eq. (6), the sectoral import shares $s_{c,k}$, 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): "U.S. Imports" 1972–1994). We then compute the second term of Eq. (6), the firm-level factor, using our micro price data.[12]

We find that the estimates of market shares computed from our main method are quite plausible and consistent with what we know from the Feenstra (1996) data. We present simple summary statistics on market shares in Table 1, both for the cross-sectional and the time-series dimension of the data. We present statistics both for the overall sample as well as by quintiles of market share. We find that a representative firm has a 37.79% (37.21%) mean (median) market share over time in its relevant HS-10-digit-trade-partner combination. In the cross section, the representative firm has a 35.47% (16.81%) mean (median) share. The lower medians are due to a large number of small firms in our data. For the bottom quintile of the cross section of firms, we find that market share is approximately zero, while in the top quintile, market share is 98.87%. The time series variation is much smaller: the first quintile has a mean of 32.61% while the top quintile has a mean of 43.88%.

While our estimates only serve as proxies for market shares rather than exact measures, what is important is that the information we provide is qualitatively informative: due to the precise way in which the BLS is sampling – assigning a sampling weight to each firm in each industry that is proportional to its sales – they contain important qualitative information on the market share distribution within each industry. In fact, even though we do not have detailed domestic competitor information, the information contained in our market share proxies justifies our implicit Armington assumption: we provide evidence in Section 3.6 that domestic competition indeed does not play a crucial role in determining pass-through. Of course, two further issues remain: the issue of quality heterogeneity, and the issue of how representative the sampling by the BLS is quantitatively.[13]

Table 1
Market shares.

Source of variation	I. Quintile	II. Quintile	III. Quintile	IV. Quintile	V. Quintile	All
Time series						
Mean	32.6118%	36.3084%	37.3196%	39.0849%	43.8827%	37.7870%
Std. error	0.2071%	0.1006%	0.1003%	0.1120%	1.1045%	0.4398%
Median	32.5373%	36.4355%	37.2206%	39.0239%	40.6300%	37.2109%
N	20	19	19	19	19	96
Cross section						
Mean	0.0444%	2.7511%	17.8088%	57.6076%	98.8663%	35.4111%
Std. error	0.0016%	0.0418%	0.1490%	0.3394%	0.0530%	0.3590%
Median	0.0020%	2.2849%	16.8048%	55.3625%	100.0000%	16.8041%
N	2321	2320	2321	2320	2320	11602

NOTE: This table presents summary statistics of the market shares in our data, both for the full dataset (last column) and by quintiles of market shares (columns I.–V.). Market shares are defined within each ten-digit sector of the harmonized system 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 Eq. (8) and the prices in the BLS micro data. We use data from 1998 to 2005. For the panel "Time Series", we first compute cross-sectional means whose means, medians and standard errors we then report in each column. For the panel "Cross Section", we first compute good-specific time-series means, whose means, medians and standard errors we then report in each column.

Regarding the first issue, our strategy for inferring market shares is invalid if there is systematic variation in quality across firms that originate from the same trade partner within the same HS-10-digit industry (while of course, our proxies capture average quality variation across HS-10-country pairs). Thus, we would like to point out that a more agnostic interpretation of our approach and subsequent results is that we measure a firm-specific characteristic that affects both how firms respond to changes in own costs and in competitor prices. This characteristic is structurally directly related to relative prices as Eq. (6) shows, and our analysis can be read through this lens: prices are a function of that characteristic which we interpret as market share.

We implement two further tests to validate our approach. The first test is to check our methodology per se: do prices really have an allocative function for quantities? Our test for this is done by assuming that we only have trade data at the HS eight-digit country level. Then, we construct market shares analogously to Eq. (6), but only using market shares $s_{c,k}$ at the HS eight-digit level and giving all prices within now each eight-digit category an allocative role. We aggregate up the resulting market shares to the HS ten-digit-country level, and compare these constructed to the actual market shares from the data.

We find strong evidence that our actual and constructed import shares highly correlate. This corroborates our methodological approach of constructing market shares. Fig. 1 summarizes our finding graphically: When we group shares by quintiles, actual market shares (as observed at the HS-10-digit level) and constructed market shares (using only information at the eight-digit level and giving prices an allocative role) line up almost along a 45 degree line. Our constructed market shares slightly underestimate the actual market shares. We quantify this relationship more precisely with a regression of constructed on actual market shares. We estimate a coefficient of 0.8 that is highly statistically significant. We explain 48.57% of all variation. This suggests that our methodology captures a large part of each market's structure even when applied at the eight-digit level of aggregation.

Regarding the second issue, we base a second test on a comparison of our market shares constructed as in Eq. (6) to market shares based on actual sales data. We obtain the latter from merging in Compustat data on firm-level sales for U.S. importers. We merge firms by name, as in Schoenle (2010), obtaining matches for 651 firms. We then compute their import shares by dividing their total sales by the respective total HS ten-digit-trade-partner sales. Since we do not have information about how to allocate firm-level total sales to HS ten-digit sectors if they sell in multiple sectors, we use the same total sales for each allocation.

[12] As 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 ((6)).

[13] In addition to the fact that the BLS only samples a fraction of firms, a further complication when quantifying market shares concerns the difficulty of defining the " market" that a firm is active in. We assume that firms compete within HS ten-digit sectors. However, it could be the case firms actually compete at finer or coarser levels than this. While we present evidence in Section 3.6 that the NAICS six-digit is too coarse, this consideration highlights the qualitative nature of our proxies for market shares.

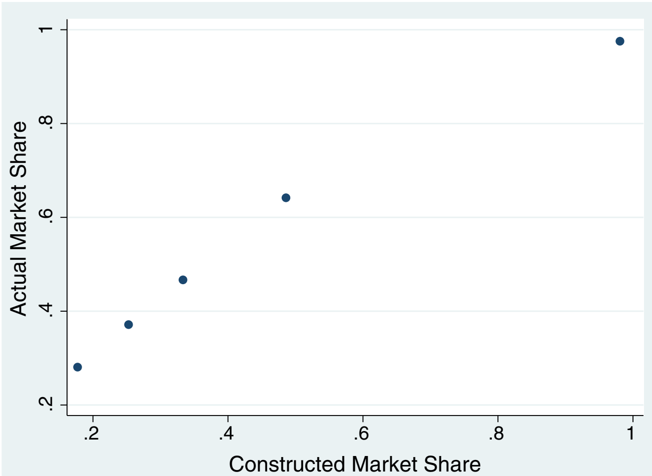

Fig. 1. Actual and constructed HS-10 average market shares, by quintiles. NOTE: The graph summarizes the aggregate relationship between actual and constructed market shares, validating our methodology of constructing import shares. The constructed market shares are computed analogous to Eq. (6), but here, only using market shares $s_{c,k}$ at the HS eight-digit level for country c and letting prices within each eight-digit category allocate. They are then aggregated up to the HS ten-digit-country level. We plot averages by quintiles of the constructed shares.

As before, we group these actual market shares into bins, and relate them to the constructed import shares.

Again, under the caveat that the Compustat data are imperfectly measured for our purpose, we find strong evidence that our constructed shares are highly correlated with the actual shares: The regression coefficient is 1.02 and statistically highly significant. Moreover, consistent with our first test, our constructed market shares again slightly underestimate the actual market shares. This test thus strongly suggests that our market share measures contain important information about market structure.

3.3. Import competitor price indices

For our analysis, we also consider import competitor price indices. To compute them, we follow Gopinath and Itskhoki (2011), but refine their approach by using our market shares constructed above when constructing weighted estimates.

According to Definition 1 in the theory section, the index of import competitor price changes is equal to the weighted average of the log price changes of all competitors in industry k . Using market shares constructed above as in Eq. (6) as weights and information on the price changes of all firms in each sector other than firm i, we thus construct the index, $\Delta P_{i,k}^{com}$, as follows:

$$\Delta P_{i,k}^{com} = \sum_{j \neq i}^{N_{k,t}} s_{j,k} \Delta P_{j,k} \tag{7}$$

Throughout this section and the next, we denote all empirically observed log changes by Δ. $\Delta P_{j,k}$ thus denotes the firm-specific log price changes for firm j (note that time subscripts are ommitted) and $s_{j,k}$ market-share weights. Because $\Delta P_{i,k}^{com}$ omits firm i from the N_k importers in sector k, $\Delta P_{i,k}^{com}$ varies across firms in sector k and in period t.

We note that in calculating (7), we take into account price changes of competing importers, but not the price changes of domestic firms active in the same sector. While we have information on the weighted price changes of domestic firms at the sectoral (six-digit NAICS) level, the reason for not incorporating this information derives from a related study on the same data (see Auer and Schoenle (2014)). In that paper, we estimate the extent to which foreign and domestic goods are competing with each other, that is, whether the origin differentiation in the spirit of Armington (1969) is important in these data. Our findings indicate that the set of imported goods is quite differentiated from the set of domestic goods even in finely disaggregated industries. Based on these findings, we do not incorporate domestic price changes in Eq. (7). Nonetheless, we provide a sensitivity analysis that includes domestic prices in Section 3.6.

3.4. The response of individual prices

In this sub-section, we establish two stylized facts relating price setting and our firm-level market share proxies. 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. What we find also relates to the result of Feenstra et al. (1996) that exchange rate pass-through is U-shaped in the country's aggregate market share.[14] 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 competitor prices is hump-shaped in a firm's market share.

Finally, we establish that these stylized facts are robust when we estimate pass-through in alternative ways. As emphasized, these proxies combine highly disaggregated import shares with relative prices and a cautious interpretation keeps this nature of our market share measure in mind.

We establish the first stylized fact in three steps. First, we confirm conventional estimates of exchange rate pass-through (ERPT). It 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:

$$\Delta P_{i,t} = \alpha_i + \sum_{j=0}^{12} \beta_j \Delta e_{i,t-j} + \eta Z_{i,t} + \varepsilon_{i,t}. \tag{8}$$

where i denotes a good and c the country the good is exported from (the trade partner). Controls Z_t include inflation in the source country plus 12 lags thereof, and fixed effects for for each good i. The sum of estimated coefficients, $\sum_{j=0}^{12} \hat{\beta}_j$, gives us the degree of ERPT. While we identify β_j from the time-series variation in this particular specification, our subsequent analysis derives identification from the cross-section of heterogeneous market shares interacted with time-varying exchange rate movements. We present the estimates in the first row of Table 2.[15]

In a second step, using our main specification, 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:

$$\Delta P_{i,t} = \alpha_i + \sum_{j=0}^{12} \beta_j \Delta e_{i,t-j} + \sum_{j=0}^{12} \gamma_j s_{i,t} \times \Delta e_{i,t-j} + \eta Z_{i,t} + \varepsilon_{i,t}. \tag{9}$$

where $s_{i,k,t}$ denotes the firm-specific market share proxy in sector k at time t. Again, we use 12-month lags in the estimation. Note that we identify γ_j from the cross-section in addition to the time series now

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

[15] We choose a 12-month lag structure for several reasons. First, and this is our main reason, when we condition on price changes, our data become too sparse relative to the noise. This is particularly true for medium-run pass-through specifications. Second, our main specification closely reflects the annual unit value approach in Berman et al. (2012), and also matches the annual specification in Amiti et al. (2014). This allows us direct comparability with these approaches. We nonetheless show that our stylized facts persist when we estimate medium-run or long-run pass-through. We show this result following the presentation of results from our main specification.

Table 2
Market share, exchange rate pass-through, and reaction to competitor prices (baseline).

	(1)	(2)	(3)	(4)	(5)
Δe	0.1476	0.1938	0.2204	0.1123	0.1721
	[0.007]***	[0.0195]***	[0.0214]***	[0.0165]***	[0.0216]***
$\Delta e * s$		−0.1252	−0.5641		−0.6710
		[0.0353]***	[0.1466]***		[0.1668]***
$\Delta e * s^2$			0.3901		0.6444
			[0.1442]***		[0.2021]***
ΔP^{com}				0.5675	0.5135
				[0.0174]***	[0.0243]***
$\Delta P^{com} * s$					1.021
					[0.2014]***
$\Delta P^{com} * s^2$					−1.1827
					[0.2226]***
Firm FEs	Yes	Yes	Yes	Yes	Yes
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 strata-time 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 s and the change in competitor prices ΔP^{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.

since there is cross-sectional variation in $s_{i,k} \times \Delta e_{i,t-j}$. We present a detailed discussion of fixed effects in Section 3.7.

Our estimates of the interaction effect, $\sum_{j=0}^{12}\hat{\gamma}_j$, 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.

Third, we refine the firm-level result of Berman et al. (2012) on the role of market share. We document that in fact a U-shaped relationship underlies the relation which Berman et al. (2012) find to be decreasing on average. When we add an interaction of market share squared 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 remain significant at −0.56 and 0.39. This implies that the degree of exchange rate pass-through reaches its minimum around a market share of 72% (= 0.564/(2 * 0.39)) and thereafter increases in market share. Column 3 shows the estimated coefficients. The rate of exchange rate pass-through implied by the estimates is 22% for very small firms and 5% for near-monopolists.

Such evidence for a non-linear relationship is conceptually important: Our first stylized fact underlines that the qualitative predictions of the class of models based on Dornbusch (1987) (and alternative theoretical frameworks that predict the same relations) are supported by the data. We have explicitly derived them in Proposition 1. Our results in terms of model fit further – though marginally – underline the conceptual importance of this class of models: Including a quadratic interaction term is as important as is including a linear interaction term. To see this, compare the R^2 in Columns 1, 2, and 3 of Table 2.

Our second, new stylized fact is that the reaction of firms to changes in competitor prices 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 competitor prices. Following their approach, we estimate a regression of price changes on exchange rate changes, and the index of competitor price changes $\Delta P_{i,t}^{com}$. We then augment this specification by interactions with market share and market share squared while also including the interactions of market share, market share squared and the exchange rate.

Competitor prices are important: First, we find that the index of competitor prices has strong predictive power when added to the regression. We show this result in Column 4 of Table 2. The large estimate of the coefficient is similar in magnitude to what Gopinath and Itskhoki (2010) find.[16] Second, we find that there is a hump-shaped relationship between a firm's market share and the extent to which it reacts to competitor prices. The rate of reaction takes the values of 0.51 for a tiny firm with approximately zero market share, is maximized at a market share of 43% and is thereafter decreasing in market share to around 0.35 for near-monopolists (see column 5).[17] This relationship is statistically highly significant.

Again, our second stylized fact – the hump-shaped relationship – confirms the qualitative predictions of Proposition 1. This gives further credence to the oligopolistic pricing framework. Even further support comes from the following observation: the U-shaped relationship becomes even more pronounced when we condition on the heterogeneous response of price to competitor prices. This can be seen by comparing the first three rows of Columns 5 and 3. The joint, stronger relationships lend strong support to the qualitative predictions of the oligopolistic model.

Our two stylized facts also emerge when we estimate long-run pass-through and non-parametric specifications. First, we estimate the following specification of long-run pass-through (time subscripts omitted):

$$\Delta P_i = \beta_0 + \beta_1 \Delta e_i + \beta_2 s_{i,k} \times \Delta e_i + \beta_3 s_{i,k}^2 \times \Delta e_i + \beta_4 \Delta P_i^{com} + \beta_5 s_{i,k} \times \Delta P_i^{com} + \beta_6 s_{i,k}^2 \times \Delta P_i^{com} + \beta_7 Z_i + \varepsilon_i$$

where $\Delta P_i = \Delta P_{i,T_i - t_{i,0}}$ denotes the good-specific log price change cumulated over the life-time of a good and $t_{i,0}$ and T_i correspond to the first and last period in which we observe that good in the data. Following Gopinath and Rigobon (2008), we require that there is at least one price change during the life of a good. Δe_i is the corresponding exchange rate change, ΔP_i^{com} the corresponding price change of competitors, $s_{i,k}$ market shares, and Z_i the set of controls. These three variables are constructed in the same manner as ΔP_i by cumulating all changes over a good's lifetime.

While estimation of conditional pass-through results in a smaller sample size, it 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. To the extent that this is indeed going on, one would expect stronger results from our model for the long-run pass-through specification. The obvious downside of conditional specifications is the smaller sample size which may leave too much noise in the data.

This latter concern shows up in the estimated coefficients: On the one hand, the first stylized fact persists under a long-run pass-through specification. When we estimate the long-run specification from above but without any competitor price terms, we find a significant U-shaped relationship between exchange rate pass-through and market shares. Column 1 of Table 3 documents this relationship. On the other hand, our second stylized fact also emerges in the full specification from above. However, now the coefficients are not significant at high

[16] Note 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).

[17] We exclude full monopolists from this exercise as it is not possible to construct an index of competitor prices in such cases.

Table 3
Market share, exchange rate pass-through, and reaction to competitor prices (robustness).

	(1)	(2)	(3)	(4)	(5)
Δe	0.3826	0.2008	0.0775		0.2077
	[0.0158]***	[0.0114]***	[0.0190]***		[0.02522]***
$\Delta e * s$	−0.5201	−0.3861			−0.7418
	[0.1599]***	[0.1380]***			[0.1941]***
$\Delta e * s^2$	0.5341	0.4683			0.67
	[0.1690]***	[0.1458]***			[0.2357]***
ΔP^{com}		0.877	0.6472	0.5131	0.5097
		[0.0122]***	[0.0209]***	[0.02427]***	[0.0243]***
$\Delta P^{com} * s$		0.0385		1.0209	0.9695
		[0.1893]		[0.2014]***	[0.2016]***
$\Delta P^{com} * s^2$		−0.4027		−1.1831	−1.1051
		[0.2088]*		[0.2227]***	[0.2223]***
$\Delta e * log(s)$			−0.0064		
			[0.0021]*		
$\Delta P^{com} * log(s)$			0.0132		
			[0.0028]***		
Δmc				0.2052	
				[0.0252]***	
$\Delta mc * s$				−0.8005	
				[0.1940]***	
$\Delta mc * s^2$				0.7652	
				[0.2352]***	
Δm					Yes
Firm FEs			Yes	Yes	Yes
N			87470	85228	85228
N_i	16037	16037	6220	5111	5111
R^2	5.880%	31.296%	10.162%	9.53%	9.66%

NOTE: This table presents estimates of exchange rate pass-through from several specifications. Columns 1 and 2 show coefficient estimates from long-run pass-through specifications, columns 3, 4 and 5 from a specification with the contemporaneous and 12 monthly lags. Standard errors are reported in square brackets. The dependent variable is the lifetime or respectively monthly log price change of the imported good. The exchange rate change Δe is equal to the lifetime or respectively monthly log change of the bilateral exchange rate against the USD. The cost change Δmc 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. For the construction of market shares s and the change in competitor prices ΔP^{com} see the main text. Column 3 includes firm fixed effects while column 5 has the change in market share as well as 12 of its lags as an additional control. N (N_i) denotes the number of observations at the good-month (good) level.
*** Denotes significance at the 1% level.
* Denotes significance at the 10% level.

levels due to the smaller sample size. Column 2 of Table 3 presents this result.

Second, we show that our stylized facts also emerge in a non-parametric setting. To show this, we estimate the specifications by quintiles of market share: the 12-months dynamic regressions presented in the previous section, lifetime pass-through as in Gopinath and Rigobon (2008), and examine a medium-run pass-through specification as in Gopinath and Rigobon (2008) that conditions on a price change as follows:

$$\Delta P_{i,t_i-t_i^{-1}} = \beta_0 + \beta_1 \Delta mc_{i,t_i-t_i^{-1}} + \beta_2 \Delta P^{com}_{i,t_i-t_i^{-1}} + \beta_3 Z_{t_i} + \varepsilon_{i,t_i}$$

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, $\Delta mc_{i,t_i-t_i^{-1}}$ the corresponding log cost changes, $\Delta P^{com}_{i,t_i-t_i^{-1}}$ the corresponding price change of competitors, and Z_{t_i} the set of controls.

When we estimate these three specifications by quintiles of market shares, we find that pass-through is robustly U-shaped for all three cases. We show the result for our main 12-month specification in Fig. 2 in the top panel, including error bands, and jointly for all three specifications in the top panel of Fig. 2 in Online Appendix C. In all cases, the minimum pass-through rate is interior, and it is monotonically decreasing up to the minimum and monotonically increasing after the minimum. Consistent with Gopinath and Rigobon (2008), the long-run rate of cost pass-through is the highest of the three rates across all bins.

Similarly, our nonparametric estimations also confirm the robustness of our second stylized fact: the responsiveness to competitor prices is hump-shaped for all three specifications. We show this in the bottom panel of Fig. 2, as well as in the bottom panel of Fig. 1 in Online Appendix C 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.

Third, we show that a key prediction of the model – that *CPT*and *RCP* are negatively related (Proposition 1) – is robust to potential scaling errors of the market share, such as omitting domestic competition from the denominator of the market share proxy, or sampling issues.

To account for such scaling errors, we estimate an econometric specification that uses the logarithm of the market share proxy defined by Eq. (7). That is, we estimate our main specification, but instead of interacting with market share $s_{i,t}$, we interact with $\ln(s_{i,t})$. This separates numerator and denominator, and firm fixed effects will absorb any constantly missing factor from the denominator of market shares.

Since we have taken logs, we cannot include quadratic terms. Our specification therefore only includes the interaction of log of market share and the exchange rate change, as well as the interaction of the log of market share and the change in competitor prices:

$$\Delta P_{i,c,t} = \beta_{1,c,i} + \sum_{j=0}^{12} \beta_{2,j} \Delta e_{i,t-j} + \sum_{j=0}^{12} \beta_{3,j} \log s_{i,k,t} \times \Delta e_{i,t-j} + \sum_{j=0}^{12} \beta_{4,j} \Delta P^{com}_{i,k,t-j} + \sum_{j=0}^{12} \beta_{5,j} \log s_{i,k,t} \times \Delta P^{com}_{i,k,t-j} + \eta Z_{i,t} + \varepsilon_{i,c,t}. \tag{10}$$

We find that estimating this specification strongly supports the prediction of Proposition 1 that *CPT*and *RCP* are negatively related: A higher market share interacts negatively with the exchange rate, but positively with competitor prices. We summarize this finding in Column 3 of Table 3. Therefore, scaling errors due to omission of domestic firms or sampling do no affect the information contained in our main market share measure and results. Importantly, this is consistent with the findings from the first part of Section 3.6 that directly includes information on domestic firms and also finds that the key information is contained in our main market share measure.

3.5. Accounting for imported inputs

What remains to show is that our results are robust to several robustness checks. While the next sections present several further robustness checks, we show in this section that both our stylized facts are robust – and even more pronounced – when we filter out cost changes of imported intermediate inputs from exchange rate changes. It is important to control for intermediate input content to properly estimate exchange rate pass-through: If intermediate inputs are dollar imports, they may confound the true local production costs for producers. Therefore, we filter out the imported input content of exchange rate changes. We cannot filter out firm-specific input intensities analyzed in Amiti et al. (2014), Amiti et al. (2015), but we can still account for the heterogeneous reaction of firms to different sectoral imported input intensities.

We construct true local cost changes in the following way: first, we construct a sector and trade partner specific measure of imported input intensity from the World Input Output Tables Database (WIOD).[18] The latter database tells us how intensive production abroad

[18] See Timmer et al. (2014) and Los et al. (2015) for the construction of these international input-output tables and a description of regional and global production networks and Auer and Mehrotra (2014) for an analysis of how exchange rate fluctuations affect domestic production costs.

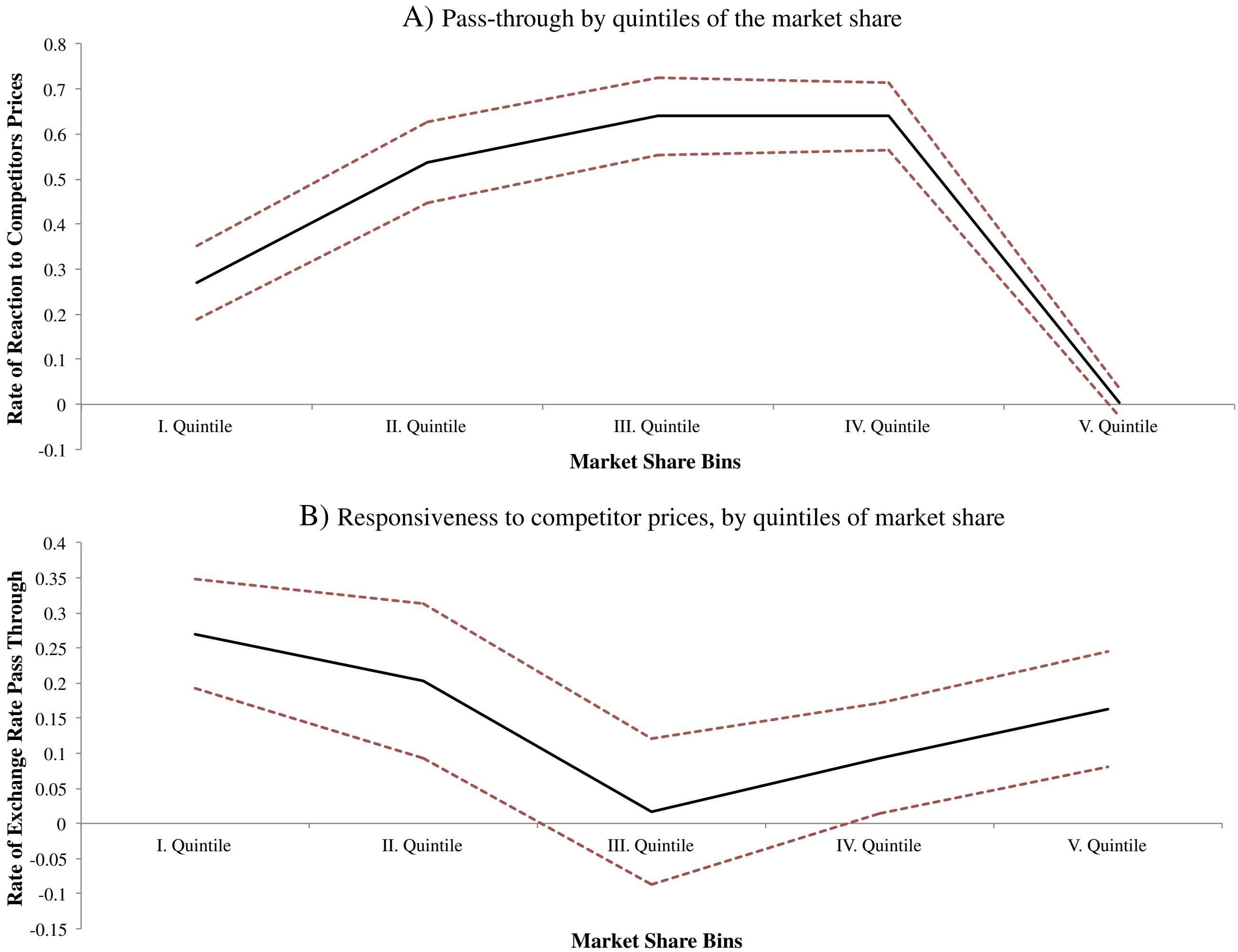

Fig. 2. Estimated pass-through by market share quintile. NOTE: We plot the rate of exchange rate pass-through for each quintile of market shares. The graph shows the rate of pass-through and the rate of responsiveness obtained from 12-month dynamic regressions. The means of the five market share bins are the same as in Table 1. The dependent variable is the item-level log price change. The independent variables include the exchange rate, local PPI inflation and the change in competitor prices.

is in imported inputs. For example, this database allows us to construct a measure of how imported-input intensive the Italian leather industry is. Proceeding in this way, we construct each firm's imported-input-intensity $\alpha_{k,c,t}^{ImInp}$ in sector k as

$$\alpha_{k,c,t}^{ImInp} = \frac{\text{cost of imported inputs}_{k,c,t}}{\text{total variable costs}_{k,c,t}}.$$

The appendix describes our procedure of constructing $\alpha_{k,c,t}^{ImInp}$ in detail.

Second, we use the imported input intensity to construct our measure of cost changes: When counted in US dollars, the percentage cost change of foreign firm i from trade partner c to service the US market is equal to the exchange rate change times $1-\alpha_{k,c,t}^{ImInp}$, the lagged proportion of 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

$$\Delta mc_{i,t} = \Delta e_{c,t}\left(1-\alpha_{k,c,t}^{ImInp}\right) \tag{11}$$

We estimate cost pass-through exactly as in the previous section, but now use the cost change $\Delta mc_{i,t}$ instead of the exchange rate change as independent variable. Correspondingly, we also base the interactions with market share and market share squared on $\Delta mc_{i,t}$ instead of the exchange rate change. We summarize these results in Column 4 of Table 3.

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.

3.6. The role of domestic competition

In this section, we present empirical support for the Armington view of competition that we have implicitly taken in this paper so far. That is, the above analysis assumes that foreign firms compete with other importers but not with domestic firms, so that we can omit domestic prices form our analysis. We now explicitly discuss this assumption using two pieces of evidence.

First, we show that taking an Armington view is approximately correct if we look at the correlation structure of prices in our data. In particular, two correlations support this view. On the one hand, we find that individual import prices and the index of domestic competitor prices[19] are simply not correlated. Their correlation is 0.0445. At the same

[19] We measure domestic competitor prices $\Delta P_{i,k}^{com.dom}$ by six-digit NAICS producer price (PPI) price changes.

time, the correlation between individual import prices and the index of import competitor prices is high. Their correlation is 0.1997[20] This suggests that price complementarities between individual import prices and the domestic competitor price index are not very large, but exist and are much stronger among importers. This also suggests that our approach is justified of relating individual import prices to the index of import competitor prices while omitting domestic prices.

Second, when we include information on domestic firms into market shares and competitor prices at the NAICS six-digit level, we find that our results go through — but mostly because of the information contained in the import competitor prices. We construct these market shares using NAICS six-digit import, export and GDP data provided by Schott (2015) as follows:

$$
\begin{aligned}
s_{dom,i,k} &= \frac{\sum_c IM_{c,k}}{Y_k + \sum_c (IM_{c,k} - EX_{c,k})} \frac{IM_{c,k}}{\sum_c IM_{c,k}} \frac{P_{i,k}^{(1-\rho)}}{\sum_{j \varepsilon N_{c,k}} P_{j,k}^{(1-\rho)}} \\
&= \frac{\sum_c IM_{c,k}}{Y_k + \sum_c (IM_{c,k} - EX_{c,k})} s_{i,k} = sS_k^{IM} s_{i,k}
\end{aligned}
\tag{12}
$$

where $IM_{c,k}$ denotes total imports in sector k from country c, $EX_{c,k}$ total exports in sector k to country c, and Y_k total GDP in sector k. Thus, the market share inclusive of domestic data, $S_{dom,i,k}$, is the product of import penetration at the sectoral level, S_k^{IM}, and our previous market share proxy $s_{i,k}$ which is however now defined at a higher level of aggregation (and hence denoted by $S_{i,k}$ to differentiate it from $s_{i,k}$). We redefine competitor prices analogously to include domestic producer price changes. That is,

$$
\Delta P_{dom,i,k}^{com} = \omega_{dom,i,k} \Delta P_k^{com,dom} + (1 - \omega_{dom,i,k}) \Delta P_{i,k}^{com,IM} \tag{13}
$$

where $\Delta P_k^{com,dom}$ denotes NAICS six-digit PPI price changes, $\Delta P^{com,IM}$ price changes of import competitors exclusive of the firm under consideration and $\omega_{dom,i,k}$ denote weights which are defined as the share of domestic firms in the industry k (exclusive of firm i). As before, we define import competitor prices following Eq. (7) (but now at the NAICS six-digit level), but the set of firms (denoted by $\widetilde{N_{k,t}}$) also includes domestic firms:

$$
\Delta P_{i,k}^{com,IM} = \sum_{j \neq i}^{\widetilde{N_{k,t}}} s_{dom,j,k} \Delta P_{j,k} \tag{14}
$$

Using these measures that include domestic competitor information, we again find support for the Armington view:

To start with, we re-estimate our full baseline specification (5) from Table 2, with our market share proxy $s_{dom,i,k}$ and import competitor price changes $\Delta P_{i,k}^{com}$ now defined at the NAICS six-digit level. We confirm that market share qualitatively has both a U-shaped relationship with the exchange rate and a hump-shaped relationship with competitor prices. We show the estimates in the first column of Table 4.[21] Quantitatively, however, the fit is worse than in the baseline. This may be because we do not capture competition at the right level of aggregation.

Next, we show in column (2) that our main specification still implies a strong and highly significant hump-shaped interaction with competitor prices even if we include information on domestic firms into prices and market shares. At the same time, the U-shape becomes insignificant.

[20] We compute this second correlation using NAICS six-digit import competitor prices (as defined in the next paragraph). The correlation if we compute it at an HS ten-digit level is even higher.

[21] Note that the interaction components have very large coefficient estimates. This is the case since within NAICS six-digit sectors, market shares of single firms are very small relative to our previous HS ten-digit level of aggregation.

Table 4
The role of domestic competitors.

	(1)	(2)	(3)	(4)	(5)
Δe	0.1407				
	[−0.0084]***				
$\Delta e * S$	−0.2644				
	[0.2095]				
$\Delta e * S^2$	1.1771				
	[0.4801]***				
Δe		0.1307	0.1197	0.3275	0.312
		[0.0096]***	[0.0132]***	[0.0124]***	[0.0122]***
$\Delta e * S_{dom}$		0.9601	0.2584	−0.3305	−0.6253
		[0.6106]	[0.9093]	[1.1602]	[1.1483]
$\Delta e * S_{dom}^2$		−2.0241	0.5722	8.1667	9.2158
		[2.5073]	[4.0713]	[6.4973]	[6.4726]
ΔP^{com}	0.3821				
	[0.0259]***				
$\Delta P^{com} * S$	4.5281				
	[0.6485]***				
$\Delta P^{com} * S^2$	−6.7359				
	[1.7553]***				
ΔP_{dom}^{com}		0.447		0.6991	
		[0.0259]***		[0.0362]***	
$\Delta P_{dom}^{com} * S_{dom}$		5.7901		4.2252	
		[0.9828]***		[1.8555]***	
$\Delta P_{dom}^{com} * S_{dom}^2$		−9.1918		−19.5432	
		[3.422]***		[6.6453]***	
$\Delta P^{com,dom}$			0.2272		0.2921
			[0.0427]***		[0.0163]***
$\Delta P^{com,dom} *$			−0.2726		−0.1358
S_{dom}			[2.5465]		[1.4800]
$\Delta P^{com,dom} *$			6.9888		−5.7459
S_{dom}^2			[7.830]		[5.3302]
$\Delta P^{com,IM}$			0.4573		0.7116
			[0.0782]***		[0.0416]***
$\Delta P^{com,IM} *$			11.1688		3.5655
S_{dom}			[2.2680]***		[2.0681]
$\Delta P^{com,IM} *$			−23.2472		−23.5466
S_{dom}^2			[7.0965]***		[8.2507]***
N	132179	109458	109458	15979	15979
N_i	7291	6384	6384		
R2	1.78%	1.43%	1.49%	8.76%	10.94%

NOTE: This table replicates specification (5) from Table 2 using alternative market share and competitor price measures to account for the role of domestic firms. Column (1) replicates that specification exactly but at the NAICS six-digit level. Column (2) uses market shares S_{dom} and competitor prices ΔP_{dom}^{com} that explicitly take into account prices and sales of domestic firms. Column (3) separates the overall competitor prices into a domestic $\Delta P^{com,dom}$ and an importer component $\Delta P^{com,IM}$. While columns (1)–(3) use 12 monthly lags of exchange rate and competitor price movements, columns (4)–(5) estimate long-run pass-through. N (N_i) denotes the number of observations at the good-month (good) level.

*** Denotes significance at the 1% level.

We present key support for the Armington view in Column (3): only information contained in import competitor prices drives the reaction to competitor prices. When we interact linear and quadratic terms of market share with domestic competitor price changes $\Delta P_k^{com,dom}$ separately from importer competitor price changes $\Delta P^{com,IM}$, then only the interaction with import competitor price changes predicts a hump-shaped relationship. The relationship with domestic competitor price changes is insignificant and has the wrong sign. This clearly implies that domestic competitor price changes are not essential in explaining the reaction of import prices to competitor prices.

Also, when we reproduce these specifications for the case of long-run estimates, we find that only information contained in import competitor prices drives the reaction to competitor prices. In Columns (4) and (5), we repeat the estimations presented in Eqs. (2) and (3), but for the long run specifications that follow Gopinath and Rigobon (2008). Again, we find that the response to competitor prices is strongly hump-shaped in market share (see (4)). This is entirely due to the price changes of competing importers rather than domestic price changes in the same sector.

The results in Table 4 thus show that what matters for firm-specific price reactions is market share among importers and not in the industry as a whole. We further note that we have already addressed whether scaling errors in market share matter in Section 3.4, in which we estimate an econometric specification that uses the logarithm of our importer market share proxy defined by Eq. (7). In specification (3) of Table 3, we estimate our main specification but instead of interacting with importer market share $s_{i,k,t}$, we interact with $ln(s_{i,k,t})$. We find that a higher importer market share interacts negatively with the exchange rate, but positively with competitor prices. This confirms the prediction of Proposition 1 that CPT and RCP are negatively related. Importantly, it shows that scaling errors due to omission of domestic firms or sampling do not affect the information contained in our main market share proxy and results. Moreover, this is consistent with the finding from our argument for the Armington assumption, since it finds that the key information for firm pricing is contained already in our main importer market share proxies.

3.7. Further robustness of firm-level stylized facts

Next, we show that our results are robust to several further concerns: first, we show that our stylized facts remain robust when we allow for second-order effects of market shares on price changes. Second, inclusion of various fixed effects also does not influence our results. Finally, we find that the fit of the theory is quite robust to alternative parameter assumptions about the elasticity of substitution both across and within sectors.

First, we find that our stylized facts are invariant to second-order effects of market shares on prices, which are assumed away in our log-linearization of Atkeson and Burstein (2008). We control for such effects directly by including changes of market share into our specification: we add the change of 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 5 (coefficients of market share changes are not reported).

Second, we find that our stylized facts are robust to including various fixed effects. None of the fixed effects we include affect the U-shaped and hump-shaded relationships. In particular, we present specifications with 4 different fixed effects in Table 5. Whether we control for time effects, strata fixed effects, strata-time fixed effects, HS four-digit fixed effects, or HS six-digit-year fixed effects, the U-shaped response to cost shocks and the hump-shaped response to competitor prices are economically pronounced and statistically significant. The last two robustness checks are especially strong: They filter out all time-varying strata-specific or HS six-digit-specific patterns that for example sector-specific technological developments could cause. Note that these robustness results also confirm our previous conclusions from Section 3.4 that our identification of the effect of market structure comes from the interaction of cross-sectional market shares and the exchange rate and is not driven by any of these alternative fixed effects.

As a final robustness check, we examine how the theory fits the data under alternative parameter assumptions for the elasticity of substitution across and within sectors. As before when we study the fit of the theory, we regress predicted on actual price changes. However, now the predicted price changes are based on alternative parameter assumptions.[22] We present results in Table 7 both for dynamic 12-month and long-run specifications. We find that in either type of specification alternative parameter assumptions only have modest effects on the model fit. The dynamic estimates range from 0.127 to 0.133, while in the long-run regressions, the coefficient estimates vary from 0.28 to 0.284 under the various parameter assumptions ($\eta = 1.01$ and $\rho = 5$; $\eta = 1.01$ and $\rho = 15$, $\eta = 1.2$ and $\rho = 10$, and $\eta = 2$ and $\rho = 10$).

Table 5
Market share, exchange rate pass-through, and reaction to competitor prices, various fixed effects.

	(1)	(2)	(3)	(4)	(5)
Δe	0.1554	0.1626	0.1644	0.1291	0.1364
	[0.0290]***	[0.0272]***	[0.0307]***	[0.0256]***	[0.0493]***
$\Delta e * s$	−0.6068	−0.5865	−0.5569	−0.5825	−0.5095
	[0.1764]***	[0.1669]***	[0.2055]***	[0.1731]***	[0.2211]***
$\Delta e * s^2$	0.6039	0.5879	0.5549	0.6049	0.5277
	[0.1831]***	[0.1754]***	[0.2118]***	[0.1886]***	[0.2410]***
ΔP^{com}	0.5232	0.5188	0.5020	0.3684	0.2498
	[0.0493]***	[0.0623]***	[0.0712]***	[0.0476]***	[0.0705]***
$\Delta P^{com} * s$	0.7483	0.7882	0.7392	0.5221	1.0358
	[0.3117]***	[0.2673]***	[0.3340]***	[0.3093]***	[0.4069]***
$\Delta P^{com} * s^2$	−0.9819	−1.0179	−0.9883	−0.6738	−1.2280
	[0.3400]***	[0.2824]***	[0.3432]***	[0.3371]***	[0.4331]***
Time FEs	Yes				
Strata FEs		Yes			
HS4 FEs			Yes		
Strata-Time FEs				Yes	
HS6-Year FEs					Yes
N	85228	85228	85228	85228	85228
R^2	10.355%	10.280%	10.599%	21.018%	15.40%

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, multiplied with the imported input intensity. For the construction of market shares s and the change in competitor prices ΔP^{com} see the main text. N denotes the number of observations at the good-month level. The fixed effects in column 1 are monthly time fixed effects, in column 2 they are strata fixed effects, in Column 3 they are four-digit HS product fixed effects, and in column 4 they are strata-time fixed effects.

*** Denotes significance at the 1% level.

Overall, we conclude from these robustness test as well as the previous section that our two stylized facts are quite robust: conditional on accounting for firm-specific heterogeneity in imported input intensity, conditional on absorbing various fixed effects, and controlling for second-order effects of market share, both the hump-shaped response and the U-shaped response remain strongly present in the data. In addition, the fit of the theory is also quite robust to alternative parameter assumptions about the elasticity of substitution both across and within sectors.

4. Pricing in industry equilibrium and aggregate implications

We next document that our insights about firm-level real rigidities are extremely insightful for understanding the response of aggregate quantities to macroeconomic shocks.

First, to build up to the aggregate, we start at the firm-level. We show that actual and model-predicted price changes are significantly related to one another. Using the model-predicted price changes allows us to study industry-equilibrium pricing based exclusively on primitive cost shocks, which we identify off exchange rate movements (rather than other, unobservable product-specific idiosyncratic cost shocks). This avoids the use of any information in competitors' actual price changes. It also allows us to examine whether the Dornbusch (1987) model accurately captures the nonlinearities of the data documented in Section 3 above.

While we find that true and predicted price changes are highly significantly related, the result of this first step, however, is not our main empirical finding. The reason is that explanatory power is relatively low. Indeed, given that the developed model is not designed to explain

[22] We note that in these counterfactuals, we continue to use the market shares that we have calculated in the above analysis and that use the benchmark values from Atkeson and Burstein (2008). The reason for proceeding in this way is a clearer counterfactual: we keep the distribution of market shares unchanged, but alter the firm-specific responses to cost shocks according to the changing parameters.

Table 6
Fit of the theory in industry equilibrium.

	Dynamic pass-through			Long-run pass-through		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔP_{cost}^{pred}	0.1322	0.1361		0.2828	0.2664	
	[0.0288]***	[0.0295]***		[0.0419]***	[0.0439]***	
Δmc		−0.0202			0.0776	
		[0.0423]			[0.0566]	
$\Delta P_{own\quad cost}^{pred}$			0.1273			0.3007
			[0.0313]***			[0.0488]***
$\Delta P_{other\quad cost}^{pred}$			0.1560			0.2484
			[0.0326]***			[0.0560]***
Strata-time FEs	yes	yes	yes			
Strata FEs				yes	yes	yes
N	100813	100813	100813	17112	17112	17112
R^2	15.930%	15.933%	15.962%	6.44%	6.45%	6.44%

NOTE: This table presents estimates of cost pass-through from fixed effects panel estimations. Coefficients in Columns (1)–(3) are constructed by summing over contemporaneous and 12 lagged coefficients. Coefficients in Columns (4)–(6) are from long-run differences. The corresponding standard errors are reported in square brackets. The dependent variable is the monthly or respectively, long-run log price change of the imported good. In Columns (1), (2), and (3), the predicted price change $\Delta P_{cost}{}^{pred}$ is constructed as in Eq. (15). The cost change Δmc of firm i is equal to the firm-specific local cost share multiplied by the monthly or respectively, long-run 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. The two sub-elements of the predicted price change in columns (3) and (6) correspond to the components of the price change in Eq. (4) that trace 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 Eq. (15). N (N_i) denotes the number of observations at the good-month (good) level.

*** Denotes significance at the 1% level.

these firm- or product-specific price movements, we have little expectation a priori that it can explain a substantial fraction of the variation of individual price changes in the data.

Second, we focus on the predictability of aggregate pass-through rates instead. To do so, we aggregate our theoretically predicted price changes up to the sector-trade partner and trade-partner dimensions, and examine how well theory and data correlate. Our main finding is that direct cost pass-through (identified off exchange rate movements) and indirect price complementarities are approximately equally important in determining pricing but also partly offset each other. Including only one of these channels in an empirical analysis results in a clear failure to explain variation in the aggregate equilibrium rate of pass-through. Overall, we find that we can explain approximately 29% of the country-level variation in 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 both in a set of dynamic and long-run regressions. 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 are no longer informative when added to a specification that includes our model-predicted price changes as regressors.

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 Eq. (3) based on the constructed cost shocks (11), where we are using the parametrization of Atkeson and Burstein (2008). The predicted price change $\Delta P_{i,t}^{pred}$ of firm i is equal to

$$\Delta P_{i,t}^{pred} = \gamma_{i,t}\Delta P_{k,t}^{pred} + \delta_{i,t}\Delta mc_{i,t} + \varepsilon_{i,t} \tag{15}$$

where $\Delta P_{k,t}^{pred} = \frac{\sum_{j\varepsilon N_{k,-c,t}} s_{j,t}\delta_{j,t}\Delta mc}{\sum_{j\varepsilon N_{k,t}} s_{j,t}\delta_{j,t}}$ is the predicted change in the sector's price index from Eq. (2), and $mc_{j,k}$ denotes the relevant exchange rate shocks adjusted for imported inputs. We focus on the case of Cournot competition for these predictions.[23]

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

$$\Delta P_{i,t} = \alpha_i + \sum_{j=0}^{12}\delta_j \Delta P_{i,t-j}^{pred} + \eta Z_{i,t} + \varepsilon_{i,t}$$

as well as a variant with long-run actual and predicted price changes.

We find that the theoretically predicted price change $\Delta P_{i,t}^{pred}$ comes out highly significant. At the same time, adding the cost change does not contribute any information to the model. Table 6 summarizes the result both for the dynamic specification in Columns 1 - 3, and the long-run specifications in Columns 4 - 6. In terms of the dynamic specification, Column 1 only includes the theoretical prediction (15) as independent variable as well as the set of time fixed effects for each

Table 7
Fit of the theory for alternative parameter choices.

ρ	η	Dynamic estimate	Long-run estimate
1.01	5	0.1300	0.2800
		[0.0285]***	[0.0413]***
1.01	15	0.1328	0.2838
		[0.0288]***	[0.0421]***
1.2	10	0.1304	0.2810
		[0.0287]***	[0.0408]***
2	10	0.1269	0.2831
		[0.0282]***	[0.0406]***
Strata-Time FEs		Yes	
Strata FEs			Yes

NOTE: Results presents the coefficient estimates and the corresponding standard errors from a regression of the predicted price change on the actual price change. The predicted price change is as calculated in Eq. (11), using various parameter assumptions: $\eta = 1.01$ and $\rho = 5$ in the first row, $\eta = 1.01$ and $\rho = 15$ in the second row, $\eta = 1.2$ and $\rho = 10$ in the third row, and $\eta = 2$ and $\rho = 10$ in the fourth row. Column 1 presents the results of a 12-month dynamic panel estimation that includes the contemporaneous monthly predicted price change, 12 lags thereof, and strata-time fixed effects as independent variables. Column 2 presents the results of long-run regressions in which the actual price change and the predicted price change are cumulated over the life of the good in the BLS data. Column 2 also includes fixed effects by strata as independent variables.

[23] The 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. Fig. 1 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. Also see the discussion in the online appendix of Amiti et al. (2014).

stratum. In Column 2 we add the change in the cost of production. In both cases, the theoretical prediction is highly significant, while all other variables are not. At the same time, the sum of the estimated coefficients 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. In terms of the long-run specification, we find that it reproduces exactly the same patterns as the dynamic specification. Columns 4 and 5 show the corresponding estimates.

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 component that is associated with the mass of competitors changing prices. We estimate the following dynamic specification, as well as its long-run equivalent:

$$\Delta P_{i,t} = \alpha_i + \sum_{j=0}^{12}\delta_j^{other}\left(\gamma_{i,t}\Delta P_{k,t}^{pred}\right) + \sum_{j=0}^{12}\delta_j^{own}\left(\delta_{i,t}\Delta mc_{i,t}\right) + \eta Z_{i,t} + \varepsilon_{i,t}$$

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 3 of Table 6 for the dynamic specification. Column 6 of Table 6 exhibits the corresponding estimates for the long-run specification. We find that in both cases, the two components are statistically highly significant and that the coefficients are of comparable magnitude.

4.2. Aggregate pass-through rates

Next, we substantiate our main result at the aggregate level: market structure is important for explaining variation in pass-through across sectors and trade partners. We find that underlying this main result, the direct cost pass-through channel is about as important as is the price complementarity channel, but including only one of these channels results in a clear failure to explain variation in aggregate pass-through rates. The 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 the estimation part 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-trade partner combination, we also construct the theoretically predicted pass-through rate. In this step, we use Eq. (15), 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:

$$\overline{PT_{3d,c}} = N_{3d,c}^{-1}\sum_{i\epsilon N_{3d,c}}\frac{\Delta p_{i,3d}^{pred}}{\Delta mc_{i,t}} = \underbrace{N_{3d,c}^{-1}\sum_{i\epsilon N_{3d,c}}\delta_{i,3d}^{-1}}_{=\overline{PT_{3d,c}^{CPT}}} + \underbrace{N_{3d,c}^{-1}\sum_{i\epsilon N_{3d,c}}\frac{\gamma_{i,3d}\Delta P_{i,3d}^{pred}}{\Delta mc_{i,3d,t}}}_{=\overline{PT_{3d,c}^{PCOMP}}} \quad (16)$$

We emphasize that while we need to go to the three-digit NAICS level of aggregation in order to ensure a sufficiently large sample size allowing us to estimate the coefficients of interest, the underlying market shares and predicted price changes are still computed assuming that firm compete within HS ten-digit industries. Thus, $\overline{PT_{3d,c}}$ is a measure of pass-through within ten-digit HS industries, yet only averaged over three-digit NAICS industries.

We find that predicted pass-through rates can significantly explain the variation in actual pass-through rates across sectors and trade partners. Fig. 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 8 presents the regression line corresponding to this scatter plot. The slope of the line is estimated at 0.732 and statistically highly significant. That is, 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.[24]

However, we note that the predicted pass-through rates are much higher than estimated ones. This is reflected by the negative intercept in Table 8, which also explains why the coefficients in the previous subsection and Table 6 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.[25]

In terms of economic magnitude, the direct cost pass-through channel is slightly less important than the price complementarity channel. The first term in Eq. (16), $\overline{PT_{3d,c}^{CPT}}$, is the average direct cost pass-through, while the second term, $\overline{PT_{3d,c}^{PCOMP}}$, summarizes the effect on pass-through due to price complementarities. Column 3 includes the two elements $\overline{PT_{3d,c}^{CPT}}$ and $\overline{PT_{3d,c}^{PCOMP}}$ 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 $\overline{PT_{3d,c}^{PCOMP}}$ (equal to 0.089) is associated with a 6.64% difference in the estimated pass-through rate, while a one standard deviation difference in $PT_{3d,c}^{CPT}$ (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 $\overline{PT_{3d,c}^{CPT}}$ 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, $\overline{PT_{3d,c}^{CPT}}$, 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 $\overline{PT_{3d,c}^{CPT}}$ on $PT_{3d,c}^{PCOMP}$. We thus significantly underestimate the true rate of pass-through by omitting the element of the prediction that captures the importance of price complementarities. Clearly, 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 follows again from the firm-specific analog: firms characterized by a high price sensitivity to own costs react only little to changing

[24] The correlation presented in Fig. 3 is not driven by the four left-most observations that could be outliers. Removing these four left-most observations actually results in a steeper slope of 0.81 that is significant at the one percent level.

[25] We believe that this finding highlights the need for more research on the preference structure that gives rise to firms' desired markups being variable. A potential extension of the model examined in this paper would be to combine of the "large-firm" assumption of Dornbusch (1987) with a framework that yields variable markups also for small firms, for example such as the one used in Melitz and Ottaviano (2008).

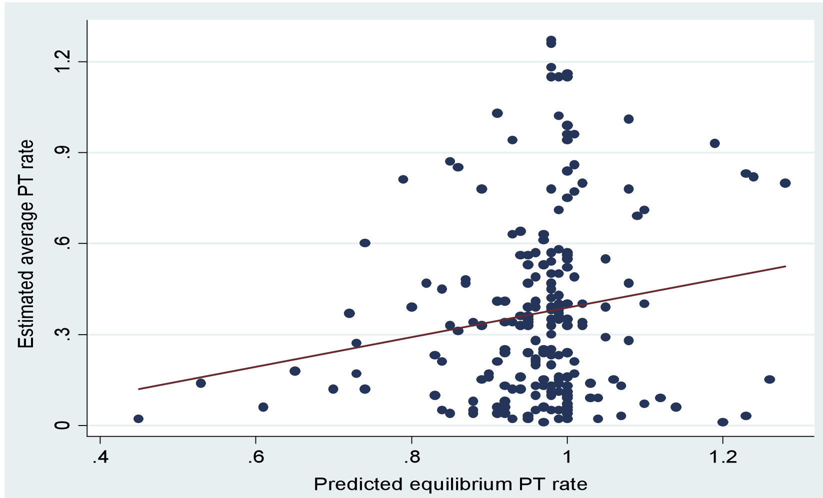

Fig. 3. Estimated and predicted pass-through rates, by trade-partner-sector. NOTE: This figure presents a scatter plot relating estimated cost pass-through rates (vertical axis) to theoretically predicted equilibrium cost pass-through rates (horizontal axis). The estimated rate is constructed for each three-digit NAICS sector–trade partner combination with more than 100 observations by estimating Eq. (8) 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 Eq. (16). The slope of the displayed simple regression line is estimated at 0.732, which is statistically significantly different from 0 at the 1% level. The R^2 associated with the simple regression line is 4.6%.

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.

This result may also 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 strongly react to changes in their own cost also tend to be characterized by a low degree of price complementarities. 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 Fig. 3). The reason is that $PT_{3d,c}^{PCOMP}$ 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 c 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). Fig. 4 displays the theoretically predicted and empirically estimated rates.

We find that the overall fit of the theory to the data at the country level 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 8). 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).

Table 8
Understanding rates of aggregate exchange rate pass-through.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Estimated PT rate in TP-sector combination				Estimated PT rate of TP	
$\overline{PT_{3d,c}}$	0.732*** [0.234]	0.574** [0.240]			0.950*** [0.260]	
$\overline{PT_{3d,c}^{CPT}}$			0.667** [0.310]	0.0550 [0.246]		1.188*** [0.367]
$\overline{PT_{3d,c}^{PCOMP}}$			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%	<0.0001%	29.4%	31.3%

NOTE: This table presents results from OLS regressions relating theoretically predicted pass-through rates, $\overline{PT_{3d,c}}$, 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 Eq. (16). 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, $\overline{PT_{3d,c}^{CPT}}$, and the one associated with price complementarities, $\overline{PT_{3d,c}^{PCOMP}}$ (see text). The sample in Columns (5) and (6) is collapsed by the sector dimension, resulting in 34 country-specific data points.

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 price changes of competing importers. 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 competitor prices is hump-shaped in market share.

Second, we document that these two patterns are important for our understanding of how firm-specific pass-through rates interact with

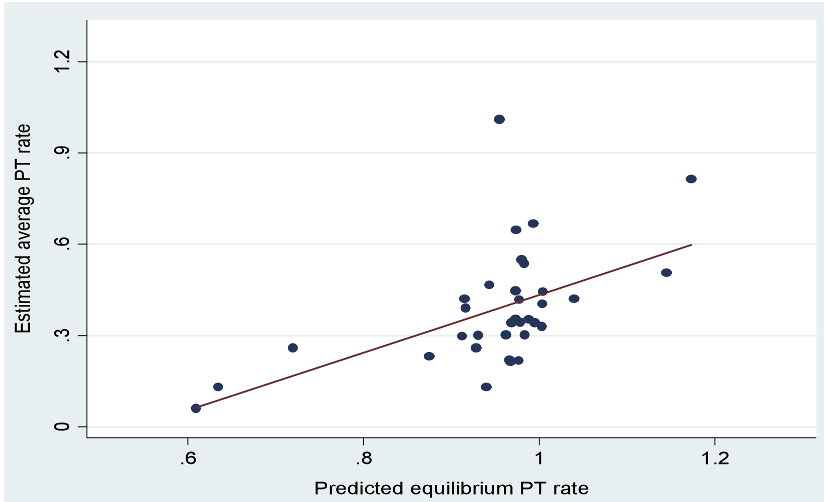

Fig. 4. Estimated and predicted pass-through rates, by trade partner. Note: This figure presents a scatter plot relating estimated cost pass-through rates (vertical axis) to theoretically predicted equilibrium cost pass-through rates (horizontal axis). The estimated rate is constructed for each three-digit NAICS sector–trade partner combination with more than 100 observations by estimating Eq. (8) 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 Eq. (16). The slope of the displayed simple regression line is estimated at 0.82, which is statistically significantly different from 0 at the 1% level. The R^2 associated with the simple regression line is 29.4%.

price complementarities at the sectoral level when shaping the industry equilibrium rate of pass-through. The direct 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. Our findings provide not only guidance for macro modeling choices that have to consistently fit the micro data, but the insight that complementarities in pricing with competitor prices matter may also have implications for our understanding of other aggregate variables, such as external adjustment of trade and exchange rates.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jinteco.2015.10.003.

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