# Market Structure and Exchange Rate Pass-Through*

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**Abstract**

In this paper, we examine the extent to which market structure and the way in which it affects pricing decisions of profit-maximizing firms can explain incomplete exchange rate pass-through. To this purpose, we evaluate how pass-through rates vary across trade partners and sectors depending on the mass of firms affected by a particular exchange rate shock and the distribution of firms' market shares in the sector. In the first step of our analysis, we decompose bilateral exchange rate movements into broad US Dollar (USD) movements and trade-partner currency (TPC) movements. Using micro data on US import prices, we show that the pass-through rate following USD movements is up to four times as large as the pass-through rate following TPC movements. Second, we show that the rate of pass-through following TPC movements is increasing in the trade partner's sector-specific market share, while the USD pass-through rate is decreasing in the market share of domestic producers. In the third step, we draw on the parsimonious model of oligopoly pricing featuring variable markups of Dornbusch (1987) and Atkeson and Burstein (2008) to show how the distribution of firms' market shares within a sector affects the trade-partner specific TPC pass-through rate. We calibrate this model using our exchange rate decomposition and information on the origin of firms and their market shares. We find that the calibrated model can explain a substantial part of the variation in import price adjustments and pass-through rates across sectors, trade partners, and sector-trade partner pairs.

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# 1 Introduction

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

The recent empirical literature estimating exchange rate pass-through at the good level has yielded important insights into firms' pricing behavior following exchange rate shocks.[1] While the results have uncovered much heterogeneity along multiple dimensions of firm or good characteristics,[2] a common finding is that pass-through, even when estimated at the dock and over long horizons, is quite incomplete.

Incomplete long-run pass-through can be explained by markups being adjusted to accommodate the local market environment, a channel pointed out in Krugman (1986) and Dornbusch (1987) and more recently in Melitz and Ottaviano (2008), Atkeson and Burstein (2008), Chen et al. (2009), Gust et al. (2009, 2010), and Gopinath and Itskhoki (2011).

In this paper, we contribute to this literature by identifying how exchange rate shocks affect the market environment differently in different sectors depending on the mass and size distribution of firms that is affected by a particular exchange rate shock. By focusing on the variation in pass-through rates across both sectors and trade partners, we are able to discern the role of market structure from alternative explanations, that is, from the view that costs simply do not move 1 to

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

[2] When evaluating prices at the dock (that is, net of distribution costs), the main dimensions along which the heterogeneity of pass-through rates are identified include the currency choice of invoicing as in Gopinath et al. (2010) and Goldberg and Tille (2009), inter- versus intra-firm trade as in Neiman (2010), multi-product exporters as in Chatterjee et al. (2011), sectoral import composition (Campa and Goldberg (2005); Goldberg and Campa (2010)), and input use intensity. When evaluating retail prices, also the share of the distribution costs matters for pass-through (see Bacchetta and van Wincoop (2003) and Burstein et al. (2003)). 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)).

1 with the exchange rate.

Our analysis proceeds in three steps. First, we show that exchange rate movements are passed through into US import prices significantly differently when the bilateral exchange rate change is driven specifically by the trade partner currency as opposed to when it is reflecting a broad movement of the USD against all trade partners. To this purpose, we decompose bilateral exchange rate movements into broad USD movements common to all importers and into trade-partner currency (TPC) specific movements. We then estimate pass-through following these two different shocks using micro data on US import prices. We find that pass-through at horizons up to two years is equal to up to 31% following a USD movement, but only up to 8% following a TPC movement.

This sizeable difference in pass-through rates following these two different exchange rate movements can potentially be explained by the fact that a general USD appreciation moves the relative costs of all importers and thus affects market "toughness" for all imported goods, whereas an idiosyncratic TPC movement only affects the cost of the few importers originating from the trade partner in question.

To discern this possibility from the alternative view that USD and TPC movements have different general equilibrium effects on the US macro economy and thus also on import prices, we next utilize the information contained in the cross section of US sectors. In the second step of the analysis, we thus analyze whether pass-through rates vary with the mass of firms that is affected by the exchange rate shock considered, either a TPC or a USD shock. For TPC movements, we find that the rate of pass-through is increasing in the trade partner's sector-specific import share. This finding also holds when we control for the general size of the trade partner economy. Thus, what matters for pass-through is not the partner's overall economic importance (through which a country could affect the world economy). Rather, it is the sector-specific importance: Icelandic fish producers have a higher rate of pass-through than Icelandic Banana producers because Iceland is an important fish producer and not because the Icelandic macro economy influences world markets in general.

We find the importance of market share to be economically very large. Over longer horizons, the rate of pass-through of a hypothetical US trade partner with an import share near zero equals around 10%, while the pass-through rate is nearly four times as large for a hypothetical trade partner with a market share of 100%. Nearly one third of the aggregate two-year pass-through rate in our sample, equal to 16%, is explained by the fact that trade partner market shares are non-negligible. For USD movements, we find that sectors with 0% import penetration exhibit pass-through rates of up to 45% whereas sectors with 100% import penetration exhibit up to 85% pass-through.

We view these patterns in the data as a strong indicator that the rate of pass-through is highly dependent on the way in which an exchange rate shock and a sector's market structure interact to shape firms' equilibrium price responses to exchange rate movements. However, these reduced-form estimations are limited in nature because they only capture a very coarse element of market structure, namely the total market share of firms affected by a specific exchange rate shock. Heterogeneous firms of different size potentially react differently to the same exchange rate shock, so that the entire size distribution of firms should matter for pass-through. Indeed, Berman et al. (2012) find that pass-through differs according to firm size.[3] Thus, differences in the distribution of firm size across sectors, trade partners, and trade partner-sector pairs are potentially also important in explaining pass-through.

In the third and final step of our analysis, we thus use the additional structure from a parsimonious model of oligopoly pricing, following Dornbusch (1987) and Atkeson and Burstein (2008), to include information on the entire size distribution of firms into our estimation. We find strong evidence for the predictions of the model relating market structure and pass-through when it is calibrated using the TPC movements and information on a sector's market structure.[4] The model is able to explain both qualitatively and quantitatively the size of price changes as well as a substantial part of the variation in pass-through across sectors and trade partners.

[3] Relatedly, Manova and Zhang (2012) show that export pricing patterns are related to firm characteristics.

[4] This exercise is related to Pennings (2011), who undertakes a similar calibration to evaluate the cross-currency rate of pass-through, that is, the effect of the USD/Euro exchange rate on the prices that Japanese firms charge in the US. Gopinath and Itskhoki (2011) directly estimate the importance of such complementarities using the average change of competitor's prices (see also Bergin and Feenstra (2009) for an estimation of such cross-currency price effects).

We first document how oligopoly-pricing in the preference setup of Dornbusch (1987) and Atkeson and Burstein (2008) determines pass-through rates, identifying two elements how a sector's market structure affects the pass through rate. The first element is that the rate at which a firm reacts to changes in the exchange rate depends on its market share. The average direct price response of firms affected by a given exchange rate shock thus depends on the distribution of their market shares. The second element is that the price changes of firms from a trade partner affect the industry's general price level. The effect on the general price level is proportional to the average direct price response and the overall market share of firms from the trade partner. Moreover, there is also further amplification since all other firms in the industry react to the changing general price level, multiplying the initial impact. In this sense, the pass-through rate is affected by the entire market structure of the sector also if only the exchange rate of one trade partner moves.

We then test whether this preference setup can match actual price changes and explain the heterogeneity of pass-through rates across trade partners when it is calibrated using the TPC movements on the one side and information on a sector's market structure one the other side.

We undertake two distinct sets of calibration exercises. In the first set, we show that the model can explain actual price changes in the BLS micro data when we relate model-predicted to actually observed price changes at the firm level. For this set of tests, we construct firm-specific price change predictions using the theoretical pass-through rate predictions and our exchange rate decomposition. We then relate the predicted to the actually observed price changes. The advantage of this testing strategy is that the large sample size allows us to condition on the exchange rate, on time and trade partner-specific effects, and even on the interaction of TPC movements and aggregate market shares, so that we can precisely pinpoint the variation in the data that is driving our results.

These empirical exercises provide strong evidence for the predictive power of the Dornbusch-Atkeson-Burstein preferences setup in explaining firm's pricing responses to exchange rate movements. First, not only do predicted price changes correlate significantly with actual price changes, but this is also true conditional on the inclusion of the exchange rate, that is, the prediction improves the predictive power of a regression. In fact, it is even true that the exchange rate does not add information conditional on inclusion of the price constructs. Second, the predicted price changes are also highly informative for understanding price changes when eliminating all trade partner-specific time variation in the data by the inclusion of trade partner & time dummies. Third, and importantly, we find that the predicted price changes explain actual price changes also when conditioning on the interaction of exchange rate and trade partner market share (that is, on the information contained in the reduced form regressions). This shows that not only the mass of firms matters, but also the sector's exact market structure.

In the second set of the calibration exercises, we aggregate pass-through and price changes up to the industry-country level and show that our theory is economically highly significant in explaining pricing behavior at these important aggregate levels.[5] Our predicted price changes correlate with actual ones at very high levels of significance and they often do so at a rate that is statistically not different from 1, that is we do not only qualitatively explain pass-through rates, but also quantitatively. When evaluating differences in pass-through rates, we document that a substantial part of the variation in pass-through across sectors and trade partners (approximately a third) can be explained by differences in the mass and size distribution of firms across the trade partners.

Overall, we draw three conclusions from our theoretical and empirical analysis: First, we conclude that the effect of the exchange rate on the competitive environment and, in turn, on equilibrium markups is substantial. This highlights the importance of including price complementarities in macroeconomic models, may these complementarities arise from strategic motives as in Kimball (1995) and Dotsey and King (2005) or from the shape of the utility function as in Gust et al. (2010) based on the model of Melitz and Ottaviano (2008)). This conclusion has also important modeling implications for firms' pricing decisions in the domestic economy: if the optimal price of a firm does react strongly to a cost shock, already small menu costs can substantially reduce the frequency of price changes (see, for example, Bils and Klenow (2004) and Nakamura and Steinsson (2008b) for evidence on how frequently domestic firms change prices).

[5]In this set of exercises, the sample is much smaller than in the first set, as we need a large number of observations to estimate one pass-through rate. However, the second set focuses on the economic significance: we can analyze how much of the empirically observed variation in pass-through rates across sectors, trade partners and sector-trade partners can be explained with differences in market structure.

Second, we conclude that the Dornbusch-Atkeson-Burstein style departure from the case of constantly elastic demand greatly improves our understanding of pass-through rates in the data. As Atkeson and Burstein (2008), we do not view the proposed model as a general model of pricing to market, but rather as the simplest possible departure from the case of constant elasticity demand. However, the fact that already this simplified model is not too far from the data teaches us that it is unlikely that more complex theories of pricing to market are necessary to reconcile theory and data. From an empiricist's point of view, our calibration results suggest that knowing the distribution of firm's market shares is sufficient to calculate aggregate pass-through rates.

Third, from a policy maker's perspective, our findings are relevant given the economic magnitude of the uncovered relations. The finding that pass-through following broad USD movements is very large gives rise to a much bigger role for the exchange rate on inflation dynamics – especially in times of large, permanent exchange rate evaluations – than is commonly assumed: the pass-through response by individual firms is exactly then the largest when all exchange rates move in the same direction vis-a-vis the dollar.[6] Additionally, our findings reveal that the aggregate rate of pass-through is large when the trade partner is either large or concentrated in specific sectors. Potentially, this may explain the observed decline in US exchange rate pass through (Marazzi et al. (2005), Marazzi and Sheets (2007), Campa et al. (2005)), which could be attributed to exports currently being more diversified than in the 1970s.

The structure of this paper is the following. We describe our data in Section 2, the exchange rate decomposition and the resulting pass-through reduced-form estimations in Section 3. Section 4 examines whether pass-through depends on trade partner market shares and the trade openness of U.S. sectors. Section 5 presents the model, highlighting the role of firm- and trade partner-market shares for pass-through, and Section 6 examines whether a calibrated version of the model can explain import price adjustments and pass-through rates. Section 7 concludes.

[6] Such large import price movements, in turn, might also affect the prices domestic firms charge (a channel analyzed in Auer (2011)).

## 2 Data description

We use exchange rates and inflation data from the IMF's International Financial Statistics database, and, most importantly, import prices at the good level from the BLS. The latter 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 US import price micro data. In this paper, we analyze the years from 1994 through 2005. We apply our analysis to the following countries: Austria, Canada, China, Denmark, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, United Kingdom.

In manipulating the data, we follow the main steps taken in Gopinath and Rigobon (2008). In particular, we drop net price data which are flagged by the BLS as not usable, not index usable or for which a price has been estimated. There are 771872 usable prices in our sample. In addition, we pull forward a last observed price when a price is missing as in Nakamura and Steinsson (2012). We also disregard an entire price series if more than 10% of prices of a series have been flagged as price records with no trade. All of our prices are market price transactions invoiced in USD.[7]

To construct trade partner market shares, we use bilateral US import data from the US Census, disaggregated at either the six-digit Harmonized System (HS) or the six-digit North American Industry Classification System (NAICS). To construct measures of the openness of a sector, we require data on domestic sales in addition to imports. We use data on the shipments of domestic firms recorded in the Annual Survey of Manufacturers, which is available from the US census at the six-digit NAICS level.

[7]As Gopinath and Rigobon (2008) have documented, almost all US 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.

# 3 How are General and Trade-Partner Specific Exchange Rate Movements Passed Through Into US Import Prices?

In this section, we discuss how we decompose changes in the nominal bilateral exchange rate into broad USD movements on the one hand and trade-partner specific movements on the other hand. Then, we show that pass-through is systematically different when the USD moves against all of its trade partners rather than when the change in the bilateral nominal exchange rate is caused by a trade partner movement against the rest of the world.

This exercise is motivated by theoretical considerations relating pass-through to how the market environment changes with the exchange rate. For example, if we think along the lines of Atkeson and Burstein (2008), where market power determines pass-through, pass-through should be very different if all foreign firms face the same cost shock as opposed to when only a small set of firms from a country such as Switzerland faces a cost shock. Theoretical models that highlight non-strategic price complementarities such as Chen et al. (2009) or Gust et al. (2009) also predict that pass-through should be higher when the USD appreciates against all countries since all exporters experience the same cost shock in that case.

## 3.1 USD and Trade-Partner Currency Movements

In this section, we decompose the bilateral exchange rate into idiosyncratic TPC movements and broad USD movements, following an approach similar to Gopinath and Itskhoki (2011). First, we define the USD/ROW exchange rate change for a specific trade partner as the import-weighted average change of the log bilateral USD exchange rate against all countries except for the trade partner under consideration. That is, if $TP$ indexes the trade partner, the change of the USD exchange rate against the rest of the world (ROW) except $TP$ equals

$$\Delta USD_{ROW-TP,t} \equiv \sum_{c\epsilon(C\supset\{TP,USA\})} \omega_{c,t}\Delta USD_{c,t}, \tag{1}$$

where country c's weight equals its shares of US imports excluding country TP. To make sure that the weights are not contemporaneously related to current exchange rate movements, we take last year's import share as current weights:

$$\omega_{c,t} \equiv \frac{IM^{US}_{c,t-1}}{\sum_{c \neq TP,USA} IM^{US}_{c,t-1}}.$$

It is important to note that the USD/ROW exchange rate change differs for each trade partner due to the inclusion of a different set of countries. Therefore, it differs from a standard trade-weighted exchange rate. We discuss this difference further below.

Second, we define the "TPC exchange rate movement against the ROW" (TPC) as the difference between the bilateral exchange rate change and the broad USD exchange rate change

$$\Delta TPC_{TP,t} \equiv \Delta USD_{TP,t} - \Delta USD_{ROW-TP,t}. \tag{2}$$

We note that $\Delta TPC_{TP,t}$ is equal to the negative of the average change (using US weights) of the trade partner currency against all countries other than the USA.[8] This exchange rate decomposition is similar in spirit to constructing an import-weighted exchange rate index and then interpreting the residual difference of the bilateral nominal exchange rate and the import-weighted exchange rate index as an idiosyncratic trade partner currency movement.

However, our approach is different in that takes into account the effect of large trade partners on the import-weighted exchange rate index. For example, if the currency of a trade partner providing 15% of US imports appreciates by 10% against the USD, while all other exchange rates remain flat

[8] This can be verified by noting that for any three currencies USD, TPC, and $c$, the absence of arbitrage possibilities implies that

$$\Delta USD_{TP,t} = \Delta USD_{c,t} - \Delta TPC_{c,t}$$

for any country $c$. Since the weights $\omega_{c,t}$ sum to one, it is thus true that

$$\Delta USD_{TP,t} = \sum_{c\epsilon(C \supset \{TP,USA\})} \omega_{c,t} \left(\Delta USD_{c,t} - \Delta TPC_{c,t}\right).$$

Noting the definition of $\Delta USD_{ROW-TP,t}$ and $\Delta TPC_{TP,t}$ then implies

$$\Delta TPC_{TP,t} = -\sum_{c\epsilon(C \supset \{TP,USA\})} \omega_{c,t} \Delta TPC_{c,t}.$$

against the USD, our decomposition will correctly measure a TPC movement of 10%. In contrast, an approach based on the import-weighted exchange rate index would yield a TPC movement of 8.5% since the import-weighted exchange rate index itself moves by $10\% * 15\% = 1.5\%$.

Using an import-weighted exchange rate index instead of our USD measure would make it difficult to econometrically disentangle pass-through following USD movements as opposed to following TPC movements. Even worse, not controlling for the effect of large trade partners on the import-weighted exchange rate index would introduce a mechanical bias in the regressions estimated in Section 4 below that relates import shares to the rate of TPC pass-through, as large trade partners would by construction have a lower TPC volatility. Because both US imports and the BLS import price data are dominated by large trade partners such as China, Canada, and Mexico (overall import share in 2010: 19.2%, 14.5%, and 12.1% respectively), this problem is not trivial in the data.[9]

Our decomposition is closely related to Gopinath and Itskhoki (2011), who use the residuals from a regression of the trade-weighted exchange rate on the bilateral USD exchange rate as a measure of broad USD movements; that is, they use the element of the US trade-weighted exchange rate that is orthogonal to the bilateral one. While these two approaches of defining a broad USD movement are numerically not too different, we find it conceptually easier to work with the deterministic decomposition.[10]

More importantly, the main conceptual difference between Gopinath and Itskhoki (2011) and

[9]For the US, it is also common to estimate the pass-through rate of changes in the "Broad Exchange Rate" which is an rate index constructed by the Federal Reserve Board giving a 50% weight on import share, 25% on export share, and 25% on a measure of "third-market competitiveness" as described in Loretan (2005) "Indexes of the Foreign Exchange Value" Federal Reserve Board, Bulletin Winter 2005. While the broad exchange rate index may be a useful concept when evaluating the effect of the exchange rate on the current account or the macro economy in general, we consider using only import weights a more relevant statistic when estimating how the average exchange rate and average import prices commove.

[10]The difference between these two approaches is that we only net out each country's mechanical contribution to the trade-weighted exchange rate, whereas Gopinath and Itskhoki (2011) also include the covariance of the trade partner exchange rate with other exchange rates. For example, Iceland's import share is minuscule (around 0.0002), so that for the Icelandic kronor, the change in the ROW exchange rate we construct is nearly identical to the change in the US-trade-weighted exchange rate. However, since the kronor co-moves with other exchange rates, its regression coefficient on the US trade-weighted exchange rate is equal to 0.169. We note that despite what this example suggests, the difference between our approach and the one in Gopinath and Itskhoki (2011) is not too sizeable. The correlation between these two variables is equal to 0.79 and a regression yields a slope of 1.023 (which is significantly different from 1).

our approach is due to our focus on TPC movements: we are interested in the pass-through rate following the part of the bilateral exchange rate that is not driven by a general appreciation, that is our TPC movements are equal to the bilateral minus the ROW exchange rate. Gopinath and Itskhoki (2011), in contrast, use the bilateral exchange rate directly and control for the ROW exchange rate. While this difference is trivial for the analysis evaluating only the aggregate pass-through rate (since the pass-through coefficients are linear transformations of each other), it matters in sections 4 and 6, in which we interact TPC movements with each trade partner's market share and other sector-specific information.

We note that the USD exchange rate varies less than the TPC or bilateral movements. During 1994-2007 and in the group of OECD economies, the standard deviation of monthly exchange rate changes is 3% for the nominal bilateral exchange rate, 1.3% for the USD movements, and 2.6% for the TPC movements. However, persistence of these three time series is very similar: in this sample, the sum of AR coefficients up to 12-month lagged levels of the exchange rate is equal to 0.803, 0.794, and 0.814 for the nominal, USD movements, and TPC movements respectively.

## 3.2 Pass Through Following TPC and USD Movements

We measure pass-through by estimating a stacked regression where we regress monthly import price changes on monthly lags of the respective measure of the exchange rate. Following Gopinath and Rigobon (2008), our baseline estimation is

$$\Delta p_{i,c,t} = \alpha_c + \sum_{j=1}^{n} \beta_j \Delta e_{c,t-j+1} + \sum_{j=1}^{n} \gamma_j^{TP} \Delta \pi_{c,t-j+1}^{TP} + \epsilon_{i,c,t}, \tag{3}$$

where $i$ indexes goods, $c$ trade partners, $\alpha_c$ is a country fixed effect, $t$ a linear time trend, $n$ measures the length of the estimated pass-through horizon and varies from 1 to 25, and $\Delta e_{c,t-j+1}$ is the change in either the nominal, USD, or TPC exchange rate. $\Delta \pi_{c,t-j+1}^{TP}$ is the monthly inflation rate in the foreign country using the consumer price index. To obtain the $n$-months pass-through rate, we sum the coefficients up to the respective horizon. Alternatively, we also estimate a joint specification:

$$\Delta p_{i,c,t} = \alpha_c + \sum_{j=1}^{n} \beta_j^{USD} \Delta e_{c,t-j+1}^{USD} + \sum_{j=1}^{n} \beta_j^{ROW} \Delta e_{c,t-j+1}^{ROW} + \sum_{j=1}^{n} \gamma_j^{TP} \Delta \pi_{c,t-j+1}^{TP} + \epsilon_{i,c,t} \tag{4}$$

where $\Delta e_{c,t-j+1}^{ROW}$ corresponds to the TPC movement and $\Delta e_{c,t-j+1}^{USD}$ to the USD movements of the exchange rate.

Table 1 and Figures 1 and 2 present our results from the single pass-through estimations (3) and the joint estimation in (4). Column (1) in Table 1 presents these estimates for the Nominal Bilateral USD exchange rate. The rows list the cumulative pass-through coefficient equal to $\sum_{j=1}^{n} \beta_j$ for 1, 3, 6, 12, 18, and 24 month(s) and the corresponding standard error of this sum. All summed coefficients are significant at the 1% level. Columns (2) and (3) then repeat this specification using the USD-movement and the TPC movement respectively.

When we estimate pass-through for each component of the exchange rate, we find that USD movements are passed through at more than twice the rate of nominal movements. For example, at the six-month horizon, USD pass-through is estimated at 31%, while nominal exchange-rate pass-through is estimated at only 11% (see third row and columns (1) and (2), respectively). At the two-year horizon, USD pass-through is at 32% while the rate of pass-through conventionally estimated is at 15%. The result of high USD pass-through rate confirms the finding of higher trade weighted exchange rate pass-through of Gopinath and Itskhoki (2011) and also agree with them quantitatively.[11]

The striking novel result of our analysis comes from the estimation of TPC currency pass-through: for any horizon, TPC exchange rate pass-through is even lower than nominal exchange rate pass-through which is already less than USD pass-through. At the two-year horizon, TPC is only 7.34% compared to 32% USD pass-through as columns (2) and (3) show.

Figure 1 summarizes this finding graphically, based on the separate pass-through estimations

[11] Any residual differences between and our results and Gopinath and Itskhoki (2011) can be attributed to differences in the steps in data construction of the micro data and our exchange rate measures, which are derived as weighted sums and deviations thereof. Also, our sample selects out any time series with less than 72 months of data and drops BLS country codes below 1000 which are aggregates of more than one country.

of columns (1) to (3) in Table 1 and estimated for all horizons from 1 to 24 month(s). It shows the pass-through estimates that can be attributed to a movement of the USD against all partner currencies, a movement of the trade partner currency against the rest of the world or simply a nominal exchange rate movement. While USD pass-through is larger at all monthly horizons, it is at approximately 35% at horizons over one year. Trade-partner pass-through at that horizon is estimated at around only 5%, while nominal exchange rate pass-through is estimated at around 10%.

When we jointly estimate pass-through of our two components of the nominal exchange rate, that is broad USD and trade-partner specific currency movements, we find an even stronger impact of broad USD movements on U.S. import prices. Columns (4) and (5) in Table 1, as well as Figure 2 present the same comparison for the joint pass-through rates following USD and TPC movements, which is estimated using equation (4). Also in this joint estimation, the USD pass-through rate is estimated to be between three to over four times as large as the TPC pass-through rate. The TPC pass-through is low, topping out at 10.15% at the one-and-a-half years horizon. In this joint estimation, we can test whether USD pass-through is the same as TPC pass-through in a statistical sense, or not. They are so at the 1% significance level at all horizons except the 24 months one. This is also graphically demonstrated in Figure 2 using confidence bands.

Is the fact that TPC pass-through is low driven by specific trade partners? In Table 2, we estimate the pass-through rate jointly following USD and TPC movements for each of the countries in our sample separately and at the 6 and 12-months horizons. These estimations unveil a large degree in heterogeneity, with the TPC pass-through rate varying from 17% to 68% and the USD pass-through rate varying from 16% to 90%. However, it is both true that the median and the mean TPC rate are statistically lower than the mean and median of the USD rate. Moreover, it is also true that for 16 out of the 23 trade partners, TPC pass-through is estimated to be higher than USD pass-through.

Is the difference in pass-through rates following TPC and USD movements driven by specific sectors? We next estimate disaggregate pass-through regressions within three-digit NAICS sectors (we do not have enough data points for estimating pass-through rates within finer disaggregations).

Figure 3 displays the pass-through rates at the 1-24 month(s) horizons for two selected industries (NAICS 314 "Textileproduct mills", blue lines and 325 "Chemical Manufacturing", red lines). In both sectors, the TPC pass-through rate (dashed lines) is markedly below the USD pass-through rate (solid line).

To run the same robustness check for all three-digit NAICS industries, Figure 4 next present a scatter plot relating the USD pass-through rate to the TPC pass-through rate. In this diagram, the vertical axis displays the estimated sector-specific USD pass-through rate. The horizontal axis presents the TPC pass-through rate. In Figure 4, each datapoint then displays the TPC and the USD pass-through rate in one sector and at the $12-$month time horizon. Figure 4 also plots the 45 degree line. The majority of observations are above this line, hence indicating that USD pass-through is indeed higher on average than the TPC pass-through rate. Also a fitted line is estimated above the 45 degree line.

These robustness checks confirm that pass-through of broad USD movements is larger than trade-partner or nominal exchange rate pass-through also at the country and three-digit NAICS level, that is broad USD movements are passed through into U.S. import prices at a substantially higher rate than trade-partner movements.

Despite these results, a further important concern is that when estimating Equation (3), we are not properly controlling for changes in firms' production costs, as the exchange rate is endogenous to . A USD movement could be associated with a very high cost shock as it moves the world market prices for intermediate goods.

Despite these results, a further important concern is that when estimating Equation (3), is that any movement of the exchange rate – be it a TPC or USD one – could simply reflect productivity growth in either the US or the trade partner, which would also influence the prices of importers for reasons other than the exchange rate fluctuation. To address this concern, we proceed to utilizing the cross section of our dataset, that is variation in the import share of a specific country across the sectors. While the exchange rate is endogenous to average productivity growth, there is additional sectoral variation in the extent to which prices react to the exchange rate. We thus proceed to examine how sectoral import share correlates with the sector-specific TPC pass-through rate.[12]

## 4 Market Share and Pass Through

The above section demonstrates that pass-through is substantially larger following a general movement of the USD than when only the currency of a single trade partner moves against the USD. In this section, we show that the large USD pass-through rate is driven by the effect that a USD appreciation has on the general market environment. By the same token, we then show that TPC pass-through is increasing in the import share of the country from which the firm is exporting. This suggests that low TPC pass-through may be due to low individual trade-partner market shares.

Thus, we first show that pass-through following USD movements varies with the overall importance of imports in the sector. We identify the importance of imports with the total **sectoral import penetration** $1 - m_{US,k}$ in sector $k$ as

$$1 - m_{US,k} = 1 - \frac{Domestic\ Shipments_k}{Domestic\ Shipments_k + World\ Imports_k}$$

Using this measure, we estimate an augmented, reduced-form pass-through specification where we interact import penetration with USD movements:

$$\Delta p_{i,k,t} = \alpha_c + \sum_{j=1}^{n} \beta_j \Delta USD_{ROW-TP,t-j+1} + \sum_{j=1}^{n} \gamma_j \left( \left(1 - m_{US,k}\right) \Delta USD_{ROW-TP,t-j+1} \right) + m_{US,k} + \epsilon_{i,k,t} \quad (5)$$

The three lines displayed in Figure 5 reflect pass-through following a USD shock for three sectors in which where the foreign producers make up 0% (dotted line), 42.06% (which is equal to the median of $1 - m_{US,k}$ in our data, see solid line) and 100% (solid marked line). For each lag length $n$, the dotted line corresponds to the sum of the coefficients $\sum_{j=1}^{n} \beta_j$ in Equation (5). The difference between the solid marked line and the dotted line corresponds to the sum of the

[12] In a discussion of our paper, Landry (2011) re-estimates specification (3) using our exchange rate decomposition on the dataset of Baxter and Landry (2010). The latter dataset includes the prices of identical IKEA goods sold on different markets, with the advantage that one can control for changes in the cost of a good sold on other markets, yielding a much better cost control than in our specification. He finds a 2-year rate USD pass-through nearly identical to our specification. See also Baxter and Landry (2010).

interaction coefficients $\sum_{j=1}^{n} \gamma_j$ in Equation (5).

Figure 5 suggests the important conclusion that USD movements generate much pass-through exactly when import penetration is high.

Next, we show that also the response to TPC movements is dependent on the market share of the respective importers. We define the sector-specific import share of trade partner $c$ as

$$m_{c,k} = \frac{Imports_{c,k}}{World\ Imports_k}$$

Then, we run an augmented, reduced-form pass-through specification where we interact the sector-specific import share of the trade partner with TPC exchange rate movements:

$$\Delta p_{i,c,k,t} = \alpha_c + \sum_{j=1}^{n} \beta_j \Delta TPC_{c,t-j+1} + \sum_{j=1}^{n} \gamma_j m_{c,k} \Delta TP_{c,t-j+1} + m_{c,k} + \epsilon_{i,c,k,t}, \tag{6}$$

where $i$ denotes a good, $\alpha_c$ is a country fixed effect, $k$ a sector, $n$ varies from 1 to 25, and $TP_{c,t-j+1}$ is is the change in the trade-partner currency, and $m_{c,k}$ denotes the sector-specific import share measure of country $c$ in a given six-digit NAICS sector $k$ for the year 2002.

To obtain the $n$-months direct rate of pass-through, we sum the coefficients $\beta_j$ up to the respective horizon. To obtain the indirect effect working through the measure of market power, we sum the coefficients $\gamma_j$ up to the respective horizon. When we multiply the sum of $\gamma_j$ with the average respective market share from the data, this yields the effective interaction with the right economic magnitude.

The three lines displayed in Figure 6 reflect the pass through rate following a TPC shock for three sectors in which firms from the trade partners make up 0% (solid line), 31% (which is equal to the median of $m_{c,k}$ in our data, see dotted line) and 100% (solid marked line). For each lag length $n$, the solid line corresponds to the sum of the coefficients $\sum_{j=1}^{n} \beta_j$ in Equation (4). The difference between the solid marked line and the solid line corresponds to the sum of the interaction coefficients $\sum_{j=1}^{n} \gamma_j$ in Equation (4).

Again, we find that there is a sizeable impact of market share on the degree of exchange rate pass-through. In a sector in which a trade partner has around 0% of the import market, the TPC pass-through rate is around 13% at the 2 year horizon. In a sector where the trade partner supplies nearly 100% of imports, the TPC pass-through rate is equal to 38% at the same horizon, that is, it is 25 percentage points higher (0.25 is equal to the interaction term $\sum_{j=1}^{24} \gamma_j$ in the estimation of Equation (4)).

For a sector with median import share (the median of $m_{c,k}$ is equal to 31%), the average long-run pass-through rate is equal to 21%, of which $0.31 * 0.25 = 0.0775$ is attributed to the interaction term, that is, to the fact that the median sector has a nonnegligible import share. Thus, in economic terms, non-zero import shares explain more than a third of the long-run TPC pass-through rate for the typical firm.[13]

## 5 A Structural Relationship Between Pass-Through and Market Power

In the preceding analysis, we have shown that there is a strong reduced-form relationship between pass-through and the source of the exchange rate movement as well as the relevant market share. While these results are broadly consistent with pricing theories that argue for the importance of pricing-to-market and price complementarities, this section formalizes these statements, presenting a simple model of pricing-to-market that is based on Dornbusch (1987) and, in its log-linearized version, on Atkeson and Burstein (2008) (see also Yang (1997)).

The aim of this section to develop a framework that conceptualizes "market structure." Markets can be classified according to the number of firms active in the market and by the type of the commodity that is traded. In this paper, we focus on the first dimension and analyze how the number of firms and their size distribution matters for PTM. While there are four commonly recognized types of market structures (perfect competition, monopolistic competition, oligopoly,

[13]The finding that the total market share of all firms originating from a specific trade partner is related to Feenstra et al. (1996), who develop a differentiated products model in which firms compete a la Bertrand to show that the relationship between the pass-through rate and the trade partner market share is nonlinear. They find evidence for the theoretically predicted nonlinearity when they examine the relationship between exporter market share and pass through in the global car industry.

and monopoly), a realistic mapping of market structure into pass-through rates requires a more gradual definition. We use the Dornbusch (1987) and Atkeson and Burstein (2008) framework to guide our theoretical analysis.

As Atkeson and Burstein (2008), we do not view the proposed model as a general model of pricing to market, but rather as the simplest possible departure from the case of constant elasticity demand. Demonstrating how far the calibrated model is from the data can teach us whether more complex theories of pricing to market are necessary to reconcile theory and data.

We also show that the strong reduced-form relationships that we have estimated above can indeed be explained by a model of pricing to market, and under which conditions. We then explicitly discuss how other aspects of market structure influences pass-through. The next section present a calibration of the model.

### 5.1 The Dornbusch-Atkeson-Burstein Model

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

The preferences are given by a two-tiered "love of variety" utility/production function setup in which consumers consume the output of different sectors $k$ and the output of each sector is produced by combining varieties $n$ within each sector.

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

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

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

Each final producer's optimization yields

$$y_k = \left( \frac{P_k}{P} \right)^{-\eta} c, \tag{7}$$

where $P$ is the unit price of the final output and equal to $\left( \int_0^1 P_k^{(1-\eta)} \right)^{\frac{1}{1-\eta}} dk$. In each sector $k$, each input is produced by a set of $n \in N$ monopolists, but the sector itself is again competitive and produces using only the inputs with a production function given by

$$y_k = \left( \sum_{n=1}^{N} q_{n,k}^{(\rho_k-1)/\rho_k} \right)^{\rho_k/(\rho_k-1)}$$

We allow for the fact that $\rho_k$ may be sector-specific. Cost minimization yields the price of the sector-composite as $P_{i,k} = \left( \sum_{n=1}^{N} p_{n,k}^{(1-\rho_k)} \right)^{\frac{1}{1-\rho_k}}$ and demand for each individual input $y_{n,k}$ as

$$q_{n,k} = y_k \left( \frac{P_{n,k}}{P_k} \right)^{-\rho_k} \tag{8}$$

A key assumption of this preference framework is that

$$\rho_k > \eta,$$

that is, it is easier to substitute away from Reebok to Nike than to substitute from shoes to trousers.

**Price Setting by Variety Monopolists.** Dornbusch's main departure from Dixit and Stiglitz (1977) is that he assumes that firms are non-negligible in size within a sector, so that each firm has an impact on the aggregate price index of the sector, which it takes into account when setting its price.

Each variety producer faces a constant marginal cost $\omega_n$, which may include iceberg transportation costs and maximizes profits subject to demand derived from (8) and (7).

Given the two-tiered utility/production setup and the fact that the production elasticity $\rho_k$ differs from the demand elasticity over sector composites $\eta$, the first order condition of a firm with a non-negligible market share in sector $k$ implies a pricing rule of that is dependent on the firm's market share $s_{n,k}$:

$$\begin{aligned} P_{n,k} &= \frac{\varepsilon\left(s_{n,k}\right)}{\varepsilon\left(s_{n,k}\right)-\varepsilon\left(s_{n,k}\right)}\omega_{n,k} \\ \varepsilon\left(s\right) &= \left[\frac{1}{\rho_k}\left(1-s_{n,k}\right)+\frac{1}{\eta}s_{n,k}\right]^{-1} \end{aligned}$$

Since $\rho > \eta$, a firm's perceived demand elasticity is decreasing in its market share. Consequently, the equilibrium markup is increasing in the firm's market share.

This preference framework cannot easily be solved for analytically. Atkeson and Burstein (2008) show, however, that a loglinearization around the steady state results in a straightforward calibration of how cost changes translate into prices changes. This log-linearization yields

$$\begin{aligned} \widehat{P}_{n,k} &= \Gamma\left(s_{n,k}\right)\widehat{s}_{n,k}+\widehat{w}_{n,k} \\ \widehat{s}_{n,k} &= \left(\rho_k-1\right)\left(\widehat{P}_k-\widehat{P}_{n,k}\right) \end{aligned} \tag{9}$$

where a $\widehat{}$ denotes a deviation in logs from the steady state and where $\Gamma\left(s_{n,k}\right)$ measures the responsiveness of the markup to the market share, and is equal to $\Gamma\left(s_{n,k}\right)=\frac{s_{n,k}(1/\eta-1/\rho_k)}{1-\left(1-s_{n,k}\right)/\rho_k-s_{n,k}/\eta}>0$. We note that $\Gamma\left(s_{n,k}=0\right)=0$ and that $\Gamma\left(s_{n,k}=1\right)=\frac{1/\eta-1/\rho_k}{1-1/\eta}>0$. $\widehat{P}_k$ is the percentage change in the price index of sector $k$ and is equal to $\widehat{P}_k=\sum_{j\epsilon N_k}s_{j,k}\widehat{P}_j$. [14]

[14] As Atkeson and Burstein (2008), our approach abstracts from nominal price stickiness. Benigno and Faia (2010), who also use a variant of the Dornbusch (1987) preference setup and assume that firms are identical examine how trade integration affects the degree of exchange rate pass through in the presence of price stickyness. In their setup, an increase of globalization is modeled as an increase in the share of foreign firms that are active in the domestic economy; they document that such globalization unambigously increases the rate of pass through also when menu costs are present.

### 5.2 Market Structure and Pass Through

With the log-linearized recursive pricing formula (9), it is straightforward to show how market structure affects the rate of pass-through. Since

$$\widehat{P}_{n,k} = \Gamma\left(s_{n,k}\right)\left(\rho_k - 1\right)\left(\widehat{P}_k - \widehat{P}_{n,k}\right) + \widehat{w}_{n,k},$$

collecting $\widehat{P}_{n,k}$ terms yields a recursive pricing formula that relates each price change to a linear combination of all other price changes and the firm's cost change:

$$\widehat{P}_{n,k} = \gamma_{n,k}\widehat{P}_k + \alpha_{n,k}\widehat{w}_{n,k} \tag{10}$$

Here, $\gamma_{n,k} = \frac{\Gamma\left(s_{n,k}\right)(\rho_k - 1)}{1+\Gamma\left(s_{n,k}\right)(\rho_k-1)}$ is the rate at which firm $n$ responds to changes in the general price level for given own costs and $\alpha_{n,k} = \frac{1}{1+\Gamma\left(s_{n,k}\right)(\rho_k-1)}$ is the rate at which this firm reacts to its own cost for a given general price level.

**Proposition 1** *Equilibrium Price Effect*

$$\widehat{P}_{n,k} = \underbrace{\gamma_{n,k}}_{n's\ response\ to\ P_k} \underbrace{\frac{\sum_{j\epsilon N_k} s_j \alpha_{n,k}\widehat{w}_{n,k}}{\left(1-\sum_{j\epsilon N_k} s_j\gamma_{n,k}\right)}}_{Equilibrium\ Effect\ on\ P_k} + \underbrace{\alpha_{n,k}\widehat{w}_{n,k}}_{n's\ direct\ response\ to\ w_{n,k}} \tag{11}$$

**Proof.** The change in the sectoral price level $\widehat{P}_k$ can be solved for by acknowledging that $\widehat{P}_k$ itself is the sum of all individual prices changes (10) weighted by the firm's market share $s_{j,k}$:

$$\widehat{P}_k = \sum_{j\epsilon N_k} s_j\gamma_{n,k}\widehat{P}_k + \sum_{j\epsilon N_k} s_j\alpha_{n,k}\widehat{w}_{n,k} \tag{12}$$

That is, the change in the general price level $\widehat{P}_k$ depends on the total first round effect of how each firm responds to changing costs (reflected by the second summation in (12)) and on second-round effects: all prices depend on the general price level, which multiplies the first-round effect. Then, solving for the equilibrium price yields

$$\widehat{P}_k = \underbrace{\sum_{j \epsilon N_k} s_j \alpha_{n,k} \widehat{w}_{n,k}}_{1st \text{ Round Total Direct Cost Effect}} \Bigg/ \underbrace{\left(1 - \sum_{j \epsilon N_k} s_j \gamma_{n,k}\right)}_{\text{Higher Round Multiplier}} . \tag{13}$$

Substitution into (10) directly gives the rate of price changes as a function of the fundamental cost changes. ■

The solution to the recursive system of individual prices (10) is surprisingly simple. The reason for this simplicity is that the price of any firm $n$ reacts linearly to the linear composition of other prices $\widehat{P}_k = \sum_{j\epsilon N} s_j \widehat{P}_{j,k}$ as the preferences are additively linear (within nests).

In mathematical terms, there are two elements determining the rate of pass-through. The first element leading to pass-through is the fact that firms directly change their price in response to marginal cost changes. The price change resulting from this is equal to the change in the firm's marginal cost $\widehat{w}_{n,k}$ multiplied by the firm's sensitivity to its marginal costs $\alpha_{n,k}$. The second element is the effect of the exchange rate on the general price level, which is affected by market structure via three channels. The first channel is that if the exchange rate of a trade partner moves, any firm $n$ originating from this trade partner moves prices by $\alpha_{n,k}\widehat{w}_{n,k}$. Denoting the set of firms in sector $k$ that originates from the trade partner by $N_{k,TP}$, the total impact on $\widehat{P}_k$ is thus equal to $\sum_{j\epsilon N_{k,TP}} s_j \alpha_{n,k} \widehat{w}_{n,k}$. The first channel thus depends on the total impact of TP-firms on the general price level.

The second channel through which market structure affects pass-through works through second-round amplification because all firms in the industry react to the change in the general price level, thus multiplying the initial impact by $\left(1 - \sum_{j\epsilon N_k} s_j \gamma_{n,k}\right)^{-1}$. The third channel is that the firm, in turn, reacts to changes in the general price level with a rate of $\gamma_{n,k}$, which depends on its market share.

In economic terms, market structure matters via two effects: on the one hand, the market share of each individual firm affects its responsiveness to its costs and to the general price level. On the other hand, the combined market share of all firms from the trade partner determines the mass of firms that are affected by the exchange rate shock and the corresponding effect on the general price level. In order to highlight these two effects separately, we next proceed with a simplification of the equilibrium pricing equation (11), in which only the second channel matters: we assume that domestic firms and also firms from all trade partners are of equal size, so that only the number of firms originating from a certain country matters for pass-through.

**Assuming Equal-Sized Firms.** We first present the intuition for our model assuming equal-sized firms. We assume that in the steady state, all firms are of equal size so that with the total number of firms equal to $N_k$, $s_{n,k} = 1/N_k$ and $\Gamma\left(s_{n,k}\right) = \frac{1/N_k(1/\eta - 1/\rho)}{1-(1-1/N_k)/\rho - 1/(N_k\eta)} \equiv \overline{\Gamma}/\left(1-\rho\right)$ is equal for domestic and foreign firms.

We denote the fraction of firms from the US, a specific trade partner, and the ROW by $n_{US}$, $n_{TP}$, and $n_{ROW}$ where naturally $n_{US} + n_{TP} + n_{ROW} = 1$). Since firms are of equal size, the price change of any firm from the same country is identical. We therefore denote the price change of a US, TP, and ROW firm by $\widehat{P}_{US}$, $\widehat{P}_{TP}$, and $\widehat{P}_{ROW}$, respectively. Then, the change of the general price index is simply $\widehat{P}_k = n_{US}\widehat{P}_{US} + n_{TP}\widehat{P}_{TP} + n_{ROW}\widehat{P}_{ROW}$, and the price of a firm from country $c \in \{US, TP, ROW\}$ is equal to

$$\widehat{P}_{c,k} = \overline{\Gamma}\left(\widehat{P}_k - \widehat{P}_{c,k}\right) + \widehat{w}_{c,k}. \tag{14}$$

Since all prices are denominated in US Dollars and we only analyze cost shocks originating from exchange rate movements, we normalize $\widehat{w}_{US} = 0$. The key gain in simplification from our assumption of equally sized firms is that $\gamma_{n,k}$ and $\alpha_{n,k}$ are the same across firms:

$$\gamma_{n,k} = \frac{\frac{1/N(1/\eta-1/\rho)}{1-(1-1/N)/\rho-1/N\eta}\left(\rho_k - 1\right)}{1 + \frac{1/N(1/\eta-1/\rho)}{1-(1-1/N)/\rho-1/N\eta}\left(\rho_k - 1\right)} \equiv \overline{\gamma} \text{ and } \alpha_{n,k} = \frac{1}{1 + \frac{1/N(1/\eta-1/\rho)}{1-(1-1/N)/\rho-1/N\eta}\left(\rho_k - 1\right)} \equiv \overline{\alpha}$$

Solving the system of three pricing equations (11) for this special case yields the following optimal price response for a firm originating from country n:

$$\widehat{P}_{n,k} = \overline{\alpha\gamma}\frac{\sum_{j\epsilon N_k} s_j \widehat{w}_{n,k}}{(1-\overline{\gamma})} + \overline{\alpha}\widehat{w}_{n,k}.$$

Then, remembering our definitions of the exchange rate decomposition in (2), a TPC movement of a trade partner TP implies that $\widehat{w}_{ROW} = 0$ and $\widehat{w}_{TP} \neq 0$. To relate this to our empirical approach of identifying cost pass-through, we write $\widehat{w}_{USD} = \widehat{w}_{ROW}$ and $\widehat{w}'_{TPC} \equiv \widehat{w}_{TP} - \widehat{w}_{USD}$ yielding the TPC price change for the case of equally sized firms:

$$\widehat{P}_{TPC} = \underbrace{\overline{\gamma}\,\frac{1}{1-\overline{\gamma}} n_{TP}\overline{\alpha}\widehat{w}_{TP}}_{\text{Effect of TPC on } \widehat{P}_k} + \underbrace{\overline{\alpha}\widehat{w}_{TP}}_{\textit{Direct}\text{Cost Effect}} \tag{15}$$

where TPC pass-through is given by the sum of coefficients multiplying $\hat{\omega}_{TP}$.

Second, remembering the price response to broad USD shock defined as in Equation (1), as well as the fact that all prices are denominated in dollars so that the wage change of US firms is equal to 0 by definition, a USD movement implies that $\widehat{w}_{ROW} = \widehat{w}_{TP}$, while

$$\widehat{P}_{USD} = \underbrace{\overline{\gamma}\frac{1}{1-\overline{\gamma}}\left(n_{ROW} + n_{TP}\right)\overline{\alpha}\widehat{w}_{USD}}_{\text{Effect of USD on } \widehat{P}_k} + \underbrace{\overline{\alpha}\widehat{w}_{USD}}_{\textit{Direct}\text{Cost Effect}} \tag{16}$$

where USD pass-through is again given by the sum of coefficients multiplying $\hat{\omega}_{USD}$.

In the following proposition, we summarize how the model generates predictions for both price changes, pass-through and market structure. They also align exactly with the cases of your reduced-form estimations.

**Proposition 2**

1. *As long as the rest of the world is non-negligible, that is if $n_{ROW} > 0$, pass-through following a USD movement is larger than following a TPC movement of the same size:*

   $(\bar{\gamma}(n_{ROW} + n_{TP}) + 1 - \bar{\gamma}) > (\bar{\gamma}n_{TP} + 1 - \bar{\gamma})$

2. *Pass-through following a USD movement is increasing in import penetration:*
   $\frac{\partial \frac{\bar{\alpha}}{1-\bar{\gamma}}(\bar{\gamma}(n_{ROW}+n_{TP})+1-\bar{\gamma})}{\partial(1-n_{US})} > 0$

3. *Pass-through following a TPC movement is increasing in TP market share:*

$\frac{\partial \frac{\bar{\alpha}}{1-\gamma}(\bar{\gamma} n_{TP}+1-\bar{\gamma})}{\partial n_{TP}} > 0$

**Proof.** The proofs following directly from taking derivatives of the pass-through expressions. For 2., note that $1 - n_{US} = n_{TP} + n_{ROW}$. ■

**Allowing for Firm Heterogeneity.** Not only the mass of firms, but also the distribution of firm size matters for pass-through. For example, for the same set of total exports, pass-through is larger in less concentrated sectors. With the precise definition of price changes developed in (11) above, the TPC price change now becomes

$$\widehat{P}_{TPC} = \gamma_{n,k} \frac{\widehat{w}_{TP} \sum_{j \epsilon N_{k,TP}} s_j \alpha_{n,k}}{1 - \sum_{j \epsilon N_k} s_j \gamma_{n,k}} + \alpha_{n,k} \widehat{w}_{TP} \quad (17)$$

where again TPC pass-through is given by the coefficients multiplying $\hat{\omega}_{TP}$. Note that comparing the price change of the individual firm (17) following a TPC movement to the price change when all firms are of equal size is different in the following way:

- The firm's individual responses to price level change and changes in the marginal costs, $\gamma_{n,k}$ and $\alpha_{n,k}$, respectively, are now dependent on the market share of the firm

- The first-round impulse $\sum_{j \epsilon N_{k,TP}} s_j \alpha_{n,k}$ now depends on the distribution of sizes of all firms originating from TP. For example, if the TP has few large firms, $\alpha_{n,k}$ is small and so the total first round effect is small.

- The second round effects depend on the distribution of firms sizes of all firms in the industry. This is irrespective of the origin, that is, the entire market structure of the sector matters for pass-through.

## 6 Calibration Exercises

This section shows that we can match empirically observed price changes and estimated pass-through given our exchange rate decomposition, information on a sector's market structure, and the above-discussed preferences. We also show that the results are economically important in that they can explain a substantial part of the differences in pass-through rates across countries.

Our exercise maps the above-described theoretical pricing framework (17) to our approach of identifying TPC movements, making use of the aggregate information on import quantities and other sector-specific information. We exclusively focus on pass-through following TPC shocks. The reason for this is that we have more variation for the case of TPC movements than for USD movements: while the USD pass-through rate varies only across sectors, the TPC rates also varies across trade partners. We believe that this additional variation is important, as we examine only a limited aspect of how "market structure" affects pass-through rates: in this paper, market structure refers to the number and size distribution of the firms that are affected by a specific TPC movement. Obviously also other aspects of market structure influence pass-through rates, for example the characteristics of the traded product or the underlying production technology. Our analysis thus focuses on TPC pass-through rates, where we can focus on explaining differences in pass-through rates within rather than across sectors.[15]

We first test the predictions of the model in the BLS micro data. For this set of tests, we construct theoretical price change predictions following TPC shocks. We then relate the predicted to the actually observed price changes. Second, we aggregate information up to show that the developed theory is economically significant in explaining aggregate rates of pass-through. For example, we document that our models can explain around a third of the variation in TPC pass-through rates across countries.

Overall, we find that there is very strong evidence that we can match price changes and we also show that the results are economically important in that when they can explain a substantial part of the differences in pass-through rates across countries.

## 6.1 Inferring the Precise Market Structure from the BLS data

[15]In particular, we are also concerned that many sector characteristics that affect a sector's general openness are also directly influencing the rate of pass-through (see Campa and Goldberg (2005); Goldberg and Campa (2010), Goldberg and Tille (2009), and Gopinath and Itskhoki (2011)).

Here, we describe how we take the model to the data, matching actual price changes to the ones predicted by our model based on TPC movements, a firm's market share, the mass of competitors originating from the same country, and the entire market structure in an industry. We include monthly information on market shares at the firm level using information delivered by the structure of our model.

We overcome the limitation of the BLS data that there is no monthly data on quantities to construct market shares by using structural information contained in individual prices to infer market shares: it follows from the model that market shares are proportional to $\frac{p^{1-\rho}}{\sum p^{1-\rho}}$. We use this relationship to infer the distribution of firm size from prices in conjunction with available, already highly disaggregated data on bilateral imports and domestic production by sector. Thus, within each six-digit NAICS industry, the market share of a given firm $n\epsilon N_{TP,k}$ from country $TP$ is equal to

$$s_{n,k} = (1 - m_{US,k})\, m_{TP,k} \frac{p_{n,k}^{(1-\rho_k)}}{\sum\limits_{n\epsilon N_{k,TP}} p_{n,k}^{(1-\rho_k)}}, \tag{18}$$

where $m_{US,k}$ is the market share of all US domestic firms and $m_{TP,k}$ is the sectoral import share of country $TP$.[16]

In addition to its dependence on the market structure of all importers, the theoretical price response given by our model also depends on the market structure of domestic competitors. While information on domestic firms is not included in the BLS import price data, we do, however, have these prices available in a different dataset, the BLS domestic producer price data. For each sector, we therefore use in our estimation the aggregate weighted price changes of domestic firms computed from the BLS domestic producer price data at the six-digit level. Denoting the change in domestic

[16] It is important to note that our inference of market shares is robust to the presence of cross-country variation in good quality since we use the actual information on the trade partner's overall market share $(1 - m_{US,k})\, m_{TP,k}$. If the average quality of imports from a specific trade partner is high, this is reflected in $m_{TP,k}$. If US goods are of higher or worse quality than imports, this is reflected in $m_{US,k}$. Thus, adding measures of average country-specific quality such as the one developed in Hallak and Schott (2011) would not improve our results, as only average trade partner-specific qualities are reported in the literature. Our results would, however, be affected if there is systematic variation of good quality across different firms from the same trade partner and in the same NAICS six-digit industry. In a robustness exercise, we thus also construct a measure of market share that does not use the BLS prices.

prices by $\widehat{P}_{k,US} \equiv \sum_{j\epsilon N_{k,US}} s_j \widehat{P}_k$, the recursive pricing formula (12) can be shown to equal

$$\widehat{P}_k = m_{US,k}\widehat{P}_{k,US} + \sum_{j\epsilon N_{k,for}} s_j \gamma_{n,k} \widehat{P}_{k,j} + \sum_{j\epsilon N_{k,for}} s_j \alpha_{n,k} \widehat{w}_{n,k}$$

Further algebra directly leads to the following expression for TPC-induced price changes:

**Corollary 3**

$$\widehat{P}_{TPC} = \left( \gamma_{n,k} \frac{m_{US,k}\rho_{us,TP} + \sum_{j\epsilon N_{k,TP}} s_j \alpha_{n,k}}{1 - \sum_{j\epsilon N_{k,for}} s_j \gamma_{n,k}} + \alpha_{n,k} \right) \widehat{w}_{TP}, \tag{19}$$

*where* $\rho_{us,TP} \equiv \frac{\partial P_{k,US}}{\partial w_{TP}}$ *is the rate at which US domestic prices respond to the exchange rate of* $TP$ *and* $\rho_{us,TP}$ *is empirically estimated. Again, TPC pass-through is given by the coefficient multiplying* $\hat{\omega}_{TP}$.

**Corollary 4** *As a robustness check, we also estimate the model predictions under the alternative hypothesis that foreign firms and domestic firms do not compete directly within each industry, which yields:*

$$\widehat{P}_{TPC} = \left( \gamma_{n,k} \frac{m_{US,k}\rho_{us,TP} + \sum_{j\epsilon N_{k,TP}} \widetilde{s}_j \alpha_{n,k}}{1 - \sum_{j\epsilon N_{k,for}} \widetilde{s}_j \gamma_{n,k}} + \alpha_{n,k} \right) \widehat{w}_{TP} \tag{20}$$

*where the market shares* $\widetilde{s}_j$ *are constructed assuming that* $m_{US,k} = 0$ *, that is, that only the market structure of importers matters.*

This robustness check accounts for the possibility that domestic prices and the exchange rate could co-move for reasons other than the price complementarities examined in this paper.

With these important details of our procedure in mind, our calibration exercise is the following:

- We adopt one of the following definitions of a "sector"

  1. We define a sector to be a six-digit NAICS industry. We directly have the TP-six-digit NAICS market shares available and only need to allocate the TP-sector to the various firms from that TP according to (18).

2. We define a sector to be a ten-digit HS sector and assume that the TP's overall market share at the HS ten-digit level is the same as the one in the six-digit NAICS sector. We then allocate the total market share to the various firms from TP according to (18) with $m_{TP,6dNAICS}$ replaced by $m_{TP,10dHS}$.

- We calculate the theoretically predicted price changes and pass-through for each firm in the BLS sample using the constructed market shares, US domestic price changes, and the sectoral elasticity of substitution. We use either:

  1. The pricing formula (19) that does take into account domestic prices.
  2. The pricing formula (20) that does not take into account the price change of domestic firms

- We use $\rho = 34$ for the elasticity of substitution within sectors and $\eta = 1.01$ for the elasticity of substitutions across sectors.

  1. The value of 1.01 for $\eta$ is taken from Atkeson and Burstein (2008). It implies that a monopolist will have a high markup, but we note that the results presented below are robust to using a higher value of $\eta$.
  2. As a relevant estimate for $\rho$, the elasticity of substitution between varieties within a sector, we use a value of 34. Atkeson and Burstein (2008) use an estimate of 10 for their analysis, which is mostly at the *six*-digit level of aggregation. We need to use a higher estimate as we work with finer aggregations and goods are the more substitutable, the finer the definition of a sector. For example, Broda and Weinstein (2006) estimate elasticities to have a mean of 4 at the three-digit ISIC level, of 5.9 at the four-digit level, and of 12.5 at the five- digit level. At the seven-digit level of aggregation (using the TS-USA classification), the average estimated elasticity is equal to 17. Given that below we focus on the ten-digit level of disaggregation, this trend suggests using an even higher estimate of $\rho$. We use twice the seven-digit value, 34, as our estimate, which implies that firms with 0 market share have a markup of around 3%.

3. As a robustness check, we also use the sector-specific elasticity estimates from Broda and Weinstein (2006) directly. While Broda and Weinstein (2006) estimates are sector-specific thus adding more information, they are constructed assuming a preference structure that may conflict with the one used in this paper (see Feenstra (1994) for the details of this estimation). Therefore, our baseline assumption is to use a common $\rho$ across sectors.

- We then compare the actual price change of each good in our sample to the price change we predict, that is, the product of the cumulative TPC exchange rate movement and the predicted firm-specific pass-through rate (either (19) or (20)).

### 6.2 Calibration Results: The Response of Individual Prices

In this subsection, we show that our predicted price changes strongly and significantly correlate with the actual price changes. Since the large sample size allows us to condition on time and even time and trade partner-specific effects, we can precisely show that the variation in market structure that is behind the presented results. We present results in three tables: Table 3 discusses the fit of the predictions assuming that importers compete with other importers but not with domestic firms. Table 4 discusses the fit of the predictions assuming that importers also compete with domestic firms. Table 5 presents our robustness analysis.

First, we find that our model produces a good fit of predicted and actual price changes when we assume that importers compete with other importers but not with domestic firms. Table 3 summarizes this result in two sets of estimations: the predictions in columns (1) to (5) are calculated assuming that firms compete within NAICS six-digit sectors, while the predictions in columns (6) to (10) are calculated assuming that firms compete within HS ten-digit sectors. The dependent variable is the average $24-$months cumulative price change in the HS ten-digit trade partner pair. When constructing this average, we do not restrict the sample to the goods that actually experienced a price change, as it is likely that market structure also determines the frequency of price changes.

The fixed effects panel estimation in column (1) of Table 3 compares the predicted to the actual price change for individual goods in the BLS sample. This estimation is akin to an unconditional pass-through estimation, except that the predicted price change is the independent variable instead of the exchange rate change. The predicted price change is the 24-month predicted TPC-movements-induced price change; that is, we multiply the cumulative 24-month TPC exchange rate change with the rate of pass-through constructed in Equation (20).

The coefficient of this predicted price movement on the actual one is significant and estimated at 1.48. The high statistical significance – the t-score of the coefficient is equal to 5 – implies that our theory-based pricing formula (20) is qualitatively important to explain pricing changes. The fact that the estimated coefficient is not too different and statistically indiscernible from 1 implies that also quantitatively, this theory can explain pricing responses. Note that the coefficient of 1.48 implies that the pricing model (20) somewhat under predicts the importance of market structure for pass-through: when the predicted price change for example is +10%, the actual one is +14.8% on average.

To what extent is the correlation presented in column (1) driven by aggregate trends? In the fixed effects panel estimation of column (2), we add time dummies to the estimation to soak up all aggregate variation, resulting in a slightly higher coefficient of 1.51 that is still highly significant and statistically not discernible from 1.

While the estimation in column (2) shows that the correlation we pick up is not driven by broad aggregate patterns, it is still unclear whether we explain anything more than broad trade-partner specific shocks and the fact that our predicted pass-through rate is positive on average; for example, the estimation could pick up that in a given period, the Canadian Dollar (CAD) appreciated against the USD and Canadian Goods are becoming more expensive, while the Japanese Yen depreciated and, consequently, Japanese goods are cheaper. We address this concern in columns (3) to (5).

In order to highlight that market structure – which we have defined above as an aggregator of the distribution of firm sizes – is an important determinant of pass-through rates, we show that there is important variation in the degree to which our predicted price constructs can explain actual price changes also after we condition on the average covariation of prices with the exchange rate.

Column (3) thus adds the change in the TPC exchange rate to the estimation of column (1). The estimation shows that predicted price changes explain actual price changes conditional on the exchange rate, which absorbs the average covaration between prices and exchange rate movements. The addition of the TPC exchange rate leads to a slight increase in the estimated coefficient to 1.67. Nevertheless, in terms of statistical significance, the coefficient is still highly significant and not different from 1. Interestingly, the coefficient of the TPC-movement itself is far from significant, that is, conditional on our price change predictions, the TPC exchange rate change does not further explain actual price changes.

While column (3) documents that our price predictions add information to a regression explaining price changes with the exchange rate, it might still be the case that we are picking up mostly variation across countries instead of the effects of sector-specific market structure. It might be the case that pass-through rates are country-specific for reasons other than market structure but that these reasons are correlated with the country-specific average of market structure. For example, pass-through from Canada could be large in general and this might have nothing to do with the fact that Canada is a large U.S. trade partner.

This concern also regards the endogeneity of the exchange rate. As discussed above, we only use TPC movements in the specifications presented in this paper and are hence not concerned about the endogeneity of USD movements and prices on US markets. However, we are concerned about the endogeneity of TPC movements, where a TPC appreciation could simply reflect the fact that the trade partner improved its productivity vis-à-vis the rest of the world, which would obviously also influence the prices of importers for reasons other than the exchange rate fluctuation.

One solution for this problem would be to include further country-specific controls to the estimation. For example, trade partner-specific changes in unit labor costs or in producer prices could be added as further cost controls. However, since a controlling strategy is always incomplete, we prefer to add trade partner & time fixed effects ("TP-time dummies") to the estimation in column (4). Since this results in a large number of dummies, we cannot estimate a panel regression and instead estimate an absorption regression with standard errors clustered by HS ten-digit-trade partner pair (the panel identifier in columns (1) to (3)).

The addition of the TP-time dummies in column (4) is equivalent to comparing actual and predicted price changes within each TP-country pair and for each period. The variation that remains is that at each moment of time and for each trade partner, there are multiple HS ten-digit sectors and both actual and predicted price changes differ across these sectors. The coefficient on the predicted price change in column (4) then derives from the variation in market structure within each trade partner.[17]

However, the estimation with the TP-time dummies compares a more subtle (co)variation than the previous estimations, which compared also the absolute variation in market structure across countries, that is, does the Japanese car industry pass through the exchange rate differently than the Canadian one. This limited variation probably explains why the coefficient is estimated even higher (at 2.09).

Our predicted price changes are highly informative for actual price changes conditional on the exchange rate (column (3)) and also when considering variation within trade partners only (column (4)). However, going back to the discussion of the theoretical pricing model and with the reduced-form estimation results presented in Section 4 in mind, we are also interested in whether the effects of market structure are due to the simple "mass of firms" originating from a trade partner on the one side and, on the other side, in how much is added by knowing the precise distribution of firm-specific market shares. In column (5), we thus present the results of the absorption regression adding the interaction of the trade partner's sector-specific market share with the TPC exchange rate movement. As the specification includes TP-time dummies, the exchange rate itself is dropped from the estimation.

Even conditional on the trade partner's sector-specific market share, our predicted price changes are important for explaining actual price changes as column (5) shows. While the effect of market share itself is sizable and economically significant, this addition only has a small influence on the

[17] For example, assume that the market shares of Japanese firms are such that we predict the Japanese Yen to have a high pass-through rate in the car industry but a low one in the garment industry. As the TP-time dummies eliminate the average Japanese rate pass-through rate, the variation that is left is that the car industry price increase should be above while the garment industry price increase should be below the mean price increase following a Yen (TPC) appreciation. The estimation in column (4) then compares these demeaned price predictions to the demeaned actual price changes.

coefficient of the predicted price change. This provides strong evidence that also the variation in predicted price changes conditional on the pure mass of firms originating from a specific trade partner matters for pass through.[18] Overall, columns (1) to (5) present strong evidence that the above-discussed theory of pricing decisions combined with information on the market structure can explain pricing-to -market decisions.

However, despite its qualitatively good fit, our estimated coefficients are generally too high, and in particular, in the specification of columns (4) and (5), the estimated coefficient is about 2, implying that actual price changes move more than twice as much as do our predictions.

A reason for the predictions being too low in magnitude could be our assumption that firms compete within NAICS six-digit sectors, which might be too wide of a definition at least for some sectors. For example, this assumption seems realistic in the car industry (336111 - Automobile Manufacturing, which does not include heavy trucks) as nearly all type of cars for personal transport are more or less in direct competition. However, in other sectors, for example Laboratory Apparatus and Furniture (339111), very distinct goods that hardly ever directly compete are classified in the same NAICS six-digit industry. Therefore, we compare actual and predicted price changes assuming that competition happens within an HS ten-digit sector, the finest level of aggregation available in the BLS dataset.

When comparing actual and predicted price changes at this highly disaggregated level, we again find both in terms of statistical significance and robustness across the various specifications, a statistically highly significant fit, which is robust to the addition of time dummies (column (7)), to controlling for the TPC exchange rate (8), to the addition of TP-time dummies (9), and to the addition of TP-time dummies and the interaction of sector-specific TP market share and the TPC exchange rate change. Columns (6) to (10) respectively present the same specifications as do columns (1) to (5), but the predicted price change is constructed assuming that firms compete within a HS ten-digit sector.

In terms of quantitative fit, we find that whereas the predictions assuming that firms compete

[18]We also consider the estimation in column 5 an important comparison that can inform us on what is added by knowing the precise distribution of firms rather than only trade partner-specific market shares. From an empiricist's point of view, it implies that microeconomic dataset can vastly improve our understanding of pass-through.

within NAICS six-digit industries always under predict the actual pass-through rates, the coefficient in columns (6) to (10) are lower than 1, that is, we slightly over predict pricing responses. It is noteworthy that at the HS ten-digit level, good classifications are very fine (for example even Cinematographic projectors for large film (HS 8−digit code 9007.20.60) are classified as those with 16mm film and those with larger than 16mm film (HS ten-digit codes 9007.20.60.40 and 9007.20.60.80 respectively), whereas in reality these two types of projectors are quite substitutable.

The theoretical pricing model thus slightly under predicts actual price responses when assuming a coarse level of competition (within NAICS six-digit) and it slightly over predicts them when using the finest level of competition available (within HS ten-digit). We believe that one could further improve upon the statistical fit of the model by looking for the "correct" level of disaggregation or a slightly more complex approach with a nested estimation assuming that goods are very fine substitutes at the ten-digit level, less so at the 8−digit level, and even less so at the six-digit level. However, while such an approach might improve the statistical fit of the model it would also abstract from the simplicity of the Dornbusch-Atkeson-Burstein loglinearized pricing system, which we have chosen precisely to see by how much the simplest departure from the case of constantly elastic demand improves our understanding of prices.

A different shortcoming of the analysis presented in Table 3 is that we assume that importers only compete with domestic firms. As we explain above, the main reason for this is that we do not have information on the size distribution of domestic firms, and we thus cannot estimate the precise pricing formula. However, we do have information on the weighted price change of domestic firms at the sectoral level, which we can incorporate into the pricing formula (see equation (19)).

Table 4 presents the results when using the price predictions that also incorporate the pricing response of domestic firms. We note that we do interpret the results of these estimations with care as the prices of domestic and foreign firms might co-move for many other reasons than the exchange rate. Instead, we do believe that the estimated coefficients are of interest when contrasted with the ones in Table 3, that is, it makes sense to analyze the effect of adding the information contained in domestic prices to the price simulations that assume that importers compete only with other importers. With this in mind, the structure of Table 4 mirrors that of Table 3.

For the predictions assuming that firms compete within NAICS six-digit sectors, there are very sizeable differences between the result without and with the effect of domestic firms (compare columns (1) to (5) in Tables 3 to those in Table 4). In Table 4, the coefficient of the predicted price change is always estimated lower than 1 (between 0.42 to 0.77) and it is always significantly lower. The impact of the introduction of domestic firms is much smaller for the predictions assuming that firms compete within HS ten-digit sectors (compare columns (6) to (10) in Tables 3 to those in Table 4). In Table 4, estimates range from 0.54 to 0.63. On average in Table 4, coefficients are equal to around 0.6, implying that the introduction of the response of domestic firms to foreign firms is associated with a very limited pricing response, that is. There is evidence that the degree to which foreign firms and domestic firms compete is limited.[19]

We next examine the robustness of our results. As a first robustness exercise, we address the concern that there could be systematic variation of good quality across different firms from the same trade partner and in the same NAICS six-digit industry that would invalidate our allocation of market shares. We thus allocate the trade partner's market share equally to all the firms originating from the country in question. For example, if there are three Bangladeshi producers of Cotton Men's knitted shirts (HS 6105.10.00.10), and Bangladesh has an overall import share of 6% in this sector, we assume that each firm has a 2% market share. Columns (1) and (2) of Table 5 present estimation results with the price predictions constructed in this way. As in all specifications of Table 5, we assume that firms compete within HS 10 digit industries. Column (1) presents fixed effects panel regression that also include the TPC exchange rate change as a control. Column (2) presents an absorption regressions with TP-time dummies. Both columns (1) and (2) present estimations assuming that firms only compete with other importers.

When using this quality-robust allocation mechanism, we find that the predicted price change is quite informative for actual prices in the specification of column (1) presenting the fixed effects panel regression that also includes the TPC exchange rate change as a control. However, once we include the TP-time dummies in column (2), the predicted price change is no longer informative.

[19] We think that further research in the area of the competition structure between foreign and domestic prices is necessary, but this falls outside the scope of this paper.

We view this result as further evidence that knowing the precise distribution of firm sizes is important for explaining exchange rate pass through. The allocation mechanism that we use in Tables 3, and 4 differs from the alternative on in columns (1) and (2) of Table 5 not in how trade partner-specific market shares are constructed, but rather, in the way in which the combined market share of a trade partner is allocated to the various firms from that trade partner. Both types of allocation mechanisms can explain price changes on average, yet only the allocation mechanism used in the main part of the analysis can explain also the within-country variation in price changes. Thus, inferring market shares from the observed distribution of prices seems to make sense if it is done at a highly aggregated level and adjusted for across country difference in quality as in this paper.

As a second of robustness exercise, columns (3) and (4) incorporate more information using the sector-specific trade elasticities estimates from Broda and Weinstein (2006) instead of a constant elasticity. We do not find that this improves the results; instead, in the absorption regression in column (4), the predicted price change is insignificant.

As a third test, columns (5) and (6) analyze to what extent our results are dependent on the choice of the time horizon. Our prior is that our theory assuming fully flexible prices should work better over longer horizons. Indeed, when we present the absorption regression is 0.48 when assuming that importers compete only with importers and 0.38 when assuming that importers also compete with domestic firms. At the 24-month horizon the two rates are 0.94 and 0.54 (see in column (9) of Tables 3 and 4). Figure 7 extends the robustness check of column (5). Each data point in the figure represents the result of an absorption regression with TP-time dummies at horizon $n$, where $n$ varies from 1 to 24. All estimations assume that importers do not compete with domestic firms and that competition happens at the ten-digit HS level, that is, the 24 months data point is the same as the coefficient in column (9) of Table 3 while the 12 months data point is the same as the coefficient in column (5) of Table 5.

### 6.3 Calibration Results: Economic Significance

Here, we show that estimated and predicted pass-through are strongly and significantly correlated. Our sample in this section is much smaller than for price changes since the estimation of one pass-through rate requires many observations. However, the economic significance of our results comes out much more clearly as we can show how much of pass-through is explained by market structure.

Tables 3, 4, and 5 present strong evidence that the developed theory has significant implications for pass-through: all coefficients are significant at the 1% level, and this holds true when adding trade partner and time fixed effects and even when controlling for the sector-specific market share interacted with the exchange rate.

Still, these results are only indicative of the economic significance of our results as they do not directly show whether we can explain a substantial part of variation in pass-through rates across countries and sectors. To do the latter, we aggregate our predictions up to the sector and trade partner level and we analyze pass-through rates instead of price changes.

Overall, we want to show the extent to which market structure explains differences in pass-through rates, where "market structure" here only refers to the number and size distribution of the firms that are affected by a specific TPC movement and the size distribution of all other firms in the sector. Obviously also other aspects of market structure influence pass-through rates, for example the characteristics of the traded product or the underlying production technology. Our analysis in this subsection thus needs to account for the fact that we are only examining one aspect of market structure and we thus focus on whether we can explain differences in pass-through rates within rather than across sectors. For example, we examine how the number and size distribution of German machinery producers is different from the number and size distribution of South Korean machinery producers, how these differences translate into different predicted TPC pass-through rates, and finally, we examine how the differences in the predicted TPC pass-through rates correlate with differences in actual TPC pass-through rates.

As a first step, we estimate the trade partner-specific TPC pass-through rate at the sectoral level, that is, we estimate the TPC pass-through rate for each sector & TP combination. Because such estimation requires a minimum number of observations, we estimate pass-through rates at the three-digit NAICS level rather than at finer levels of disaggregation, resulting in 210 such three-digit NAICS-TPC pass-through rates. For each of these sector - trade partner combination, we also construct the theoretically prediction of the TPC pass-through rate. For these predictions, we use Equation (20) assuming that importers only compete with other importers and that competition happens at the HS ten-digit level.

As a second step, to account for the fact that pass-through rates might differ across sectors also for reasons other than the trade partner's firm size distribution, we next demean each of the sector & trade partner-specific pass-through rates by the sector-specific average (also at the three-digit level). For better comparability, we also demean the predicted TPC pass-through rate.[20]

Figure 8 shows that predicted pass-through rates can explain a sizeable part of the variation in actual pass-through rates across sectors and trade partners. The figure presents a scatter plot relating estimated to predicted pass-through rates. The vertical axis displays the estimated sector & trade partner-specific pass-through rate (as a deviation from the sector-specific average) and the horizontal axis displays the according predicted rate. Also a fitted line is displayed from a volume-weighted regression, which has a slope of 0.33 that is significant at the 1% level, while the $R^2$ associated with this regression is equal to 7.6%.

Figure 9 next provides strong evidence that the predicted pass-through rates can explain a sizeable part of the variation in actual pass-through rates across the trade partners. For this figure, we aggregate the pass-through rates at the country level using medians.[21] The vertical axis of Figure 9 presents the deviation of a country's actual average TPC pass-through rate from the TPC pass-through rate that is expected based on the country's sectoral composition of its exports. The horizontal axis measures, by the same token, whether we expect the TPC pass-through rate to

[20]Note that when we demean the predicted TPC pass-through rate, we demean by the overall average pass-through rate and not the sector-specific one. We do as in the construction of the predicted TPC pass-through, we use information on the market share distribution only but no other sector-specific information. Demeaning the TPC pass-through predictions at the sectoral level would thus eliminate information on the average market share distribution across trade partners. Nevertheless, it is noteworthy that for the conclusions drawn from the figures below, it is not of importance whether the predicted TPC pass-through rate are demeaned by the overall mean or the sector-specific mean (or for that matter whether they are demeaned at all).

[21]For this aggregation, it is important to note that since each estimated sectoral pass-through rate is demeaned at the sectoral level, the resulting aggregate country-specific average TPC pass-through rate is unaffected by the composition of the country's export basket. The latter fact is important as there are quite sizeable differences in the sectoral composition of exports across trade partners, which also explain some of the variation in pass-through rates across countries (see for example Campa and Goldberg (2005); Goldberg and Campa (2010)).

be higher or lower than average based on the size distribution of firms within all the sectors. For example, Denmark's TPC pass-through rate is estimated 18% higher than what is expected based on Denmark's export composition. The fitted line from a volume-weighted regression in Figure 9 suggests that around 16% of this is due to the size distribution of Danish firms.

While there are also outliers (in particular Greece), we find the overall fit of theory and data quite convincing. The slope of the fitted line is 0.62 (significant at the 1% level even with only 21 observations) and the $R^2$ is around 36%. We conclude that the theory presented in this paper, in combination with the relevant underlying micro-information from the BLS, can substantially improve our understanding of pricing decisions and exchange rate pass-through in import markets.

# 7 Conclusion

There is now ample notion in the literature that price complementarities and the way in which they affect the pricing decisions of importers are behind the low average long-run pass-through rates the empirical literature consistently finds.

We contribute to this literature by identifying how exchange rate shocks affect the market environment differently in different sectors depending on the mass and size distribution of firms that is affected by a particular exchange rate shock.

We also calibrate the preferences of Atkeson and Burstein (2008) to examine to which extent this simple model of price complementarities can match empirically observed price changes and pass-through rates when it is calibrated using decomposed exchange rate shocks and micro information on a sector's market structure.

Overall, we conclude that this theory is quite powerful in explaining how firms adjust prices in response to exchange rate movements. In the BLS micro data, our predictions are highly significant determinants of actual price changes and, depending on the specification, the estimated coefficients are close to one. Second, at the aggregate level, our calibrations can explain much of the heterogeneity in pass-through rates across countries that the exchange rate pass-through literature typically uncovers.

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# 8 Tables

**Table 1: Nominal vs USD or Trade Partner Pass Through Rates**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | NOM | USD | TPC | USD | TPC |
| Sample: | (1)-(3) All Observations, Single Estimation | | | (4)-(5) Full sample, joint estimation | |
| Horizon | | | | | |
| 1 | 5.75% | 18.92% | 3.44% | 19.81% | 4.09% |
| 3 | 8.63% | 23.72% | 5.58% | 25.28% | 6.55% |
| 6 | 10.91% | 31.16% | 7.23% | 32.96% | 8.06% |
| 12 | 14.18% | 39.94% | 8.63% | 40.69% | 9.16% |
| 18 | 16.33% | 41.58% | 10.21% | 41.39% | 10.15% |
| 24 | 15.11% | 31.59% | 7.34% | 29.67% | 9.73% |

**Table 2: Trade-Partner and USD Exchange Rate Pass-Through by Country**

| | Trade-Partner | USD | Trade-Partner | USD |
|---|---|---|---|---|
| Country/Horizon | 6 months | | 12 months | |
| Canada | 16% | 37% | 32% | 54% |
| Mexico | 2% | 18% | 5% | -1% |
| Sweden | 10% | 37% | 18% | 54% |
| Norway | 16% | 61% | 20% | 63% |
| Finland | 7% | 26% | 13% | 36% |
| Denmark | 18% | 43% | 23% | 39% |
| UK | 4% | 56% | -44% | 75% |
| Ireland | 1% | -9% | 16% | -9% |
| Netherlands | -4% | 87% | 14% | 90% |
| France | 17% | 12% | 18% | 5% |
| Germany | 51% | 31% | 56% | 34% |
| Austria | 24% | 34% | 30% | 62% |
| Czech | 8% | 17% | 10% | 77% |
| Hungary | -17% | 90% | 1% | 69% |
| Switzerland | 56% | 52% | 59% | 52% |
| China | 8% | -16% | 24% | -22% |
| Portugal | 25% | 47% | 43% | 72% |
| Italy | 27% | 32% | 37% | 36% |
| Greece | -1% | 10% | 7% | 21% |
| Singapore | 68% | 20% | 53% | 36% |
| Korea | 2% | 24% | 9% | 39% |
| Japan | 29% | 4% | 46% | -10% |
| New Zealand | 21% | 55% | 10% | 53% |
| Mean | 24% | 37% | 30% | 51% |
| Median | 25% | 34% | 29% | 50% |

**Table 3: Predicted and Actual Price Changes Assuming Importers do not Compete with Domestic Firms**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Estimation | XT reg (with F.E.) | (1) + Time Dummies | (1)+ control for for exchange rate | AREG w. TP- -time dummies | (4)+ interaction with market share |
| Prediction | Prediction Assumes Competition within **NAICS 6d** | | | | |
| | **Dependent Variable is the Avg. Actual Cum. Price Change over 24 Months** | | | | |
| **Predicted 24 months Price Change (TPC only)** | 1.48 | 1.51 | 1.67 | 2.09 | 1.99 |
| | (0.29) | (0.29) | (0.36) | (0.22) | (0.22) |
| **Change TPC Exchange Rate (24m)** | | | -0.01 | | |
| | | | (0.00) | | |
| **Market Share * Change TPC Exchange Rate** | | | | | 0.09 |
| | | | | | 0.03 |
| N | 98238 | 98238 | 82434 | 98238 | 59181 |
| $R^2$ | 0.43% | 0.58% | 1.24% | 3.16% | 4.19% |

| | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|
| Estimation | XT reg (with F.E.) | (6) + Time Dummies | (6)+ control for for exchange rate | AREG w. TP- -time dummies | (9)+ interaction with market share |
| Prediction | Prediction Assumes Competition within **HS 10d** | | | | |
| | **Dependent Variable is the Avg. Actual Cum. Price Change over 24 Months** | | | | |
| **Predicted 24 months Price Change (TPC only)** | 0.48 | 0.52 | 0.49 | 0.94 | 0.66 |
| | (0.22) | (0.22) | (0.28) | (0.18) | (0.26) |
| **Change TPC Exchange Rate (24m)** | | | 0.00 | | |
| | | | (0.01) | | |
| **Market Share * Change TPC Exchange Rate** | | | | | 0.17 |
| | | | | | 0.04 |
| N | 98238 | 98238 | 98238 | 82434 | 59181 |
| $R^2$ | 0.48% | 0.32% | 2.98% | 0.41% | 4.03% |

**Table 4: Predicted and Actual Price Changes Assuming That Importers Compete with Domestic Firms**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Estimation | XT reg (with F.E.) | (1) + Time Dummies | (1)+ contr. for for exrate | AREG w. TP- -time dummies | (4)+ interact. market sh. |
| Prediction | Prediction Assumes Competition within **NAICS 6d** | | | | |
| | **Dependent Variable is the Avg. Actual Cum. Price Change over 24 Months** | | | | |
| **Predicted 24 months Price Change (TPC only)** | 0.96<br>(0.06) | 0.96<br>(0.06) | 0.98<br>(0.06) | 0.51<br>(0.05) | 0.61<br>(0.07) |
| **Change TPC Exchange Rate (24m)** | | | -0.0021<br>(0.0011) | | |
| **Market Share * Change TPC Exchange Rate** | | | | | -0.037<br>(0.019) |
| N | 98238 | 98238 | 82434 | 98238 | 51112 |
| $R^2$ | 2.57% | 2.64% | 2.68% | 3.76% | 5.68% |

| | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|
| Estimation | XT reg (with F.E.) | (6) + Time Dummies | (6)+ contr. for for exrate | AREG w. TP- -time dummies | (9)+ interact. market sh. |
| Prediction | Prediction Assumes Competition within **HS 10d** | | | | |
| | **Dependent Variable is the Avg. Actual Cum. Price Change over 24 Months** | | | | |
| **Predicted 24 months Price Change (TPC only)** | 0.54<br>(0.06) | 0.54<br>(0.06) | 0.57<br>(0.06) | -0.036<br>(0.063) | 0.018<br>(0.07) |
| **Change TPC Exchange Rate (24m)** | | | -0.00064<br>(0.00094) | | |
| **Market Share * Change TPC Exchange Rate** | | | | | -0.023<br>(0.03) |
| N | 98238 | 98238 | 82434 | 98238 | 51112 |
| $R^2$ | 1.53% | 1.65% | 1.61% | 3.21% | 4.58% |

**Table 5: Simulation Robustness - All Simulations Assume Competition within HS 10d**

| | (1) | (2) | (5) | (6) | (9) | (10) |
|---|---|---|---|---|---|---|
| Type of Prediction | Quality-Robust Allocation Mechanism | | Broda and Weinstein Estimated $\rho$ | | 12m Horizon | |
| Estimation | XT contr. for exrate | AREG w. TP- -time dummies | XT contr. for exrate | AREG w. TP- -time dummies | AREG w. TP- -time dummies | AREG w. TP- -time dummies |
| Competition with domestic firms? | n | n | n | n | n | y |
| | **Dependent Variable is the Avg. Actual Cum. Price Change over 12 or 24 Months** | | | | | |
| **Predicted 24 months Price Change (TPC only)** | 1.47 | 0.26 | 2.71 | -0.72 | | |
| | (0.40) | (0.27) | (0.73) | (0.44) | | |
| **Predicted 12 months Price Change (TPC only)** | | | | | 0.48 | -0.037 |
| | | | | | (0.11) | (0.020) |
| **Ch. TPC Exchange Rate (24m)** | -0.02 | | -0.02 | | | |
| | (0.03) | | (0.02) | | | |
| N | 82434 | 98238 | 82434 | 98238 | 177269 | 177269 |
| $R^2$ | 1.51% | 7.15% | 4.97% | 8.08% | 2.36% | 1.59% |

# 9 Graphs

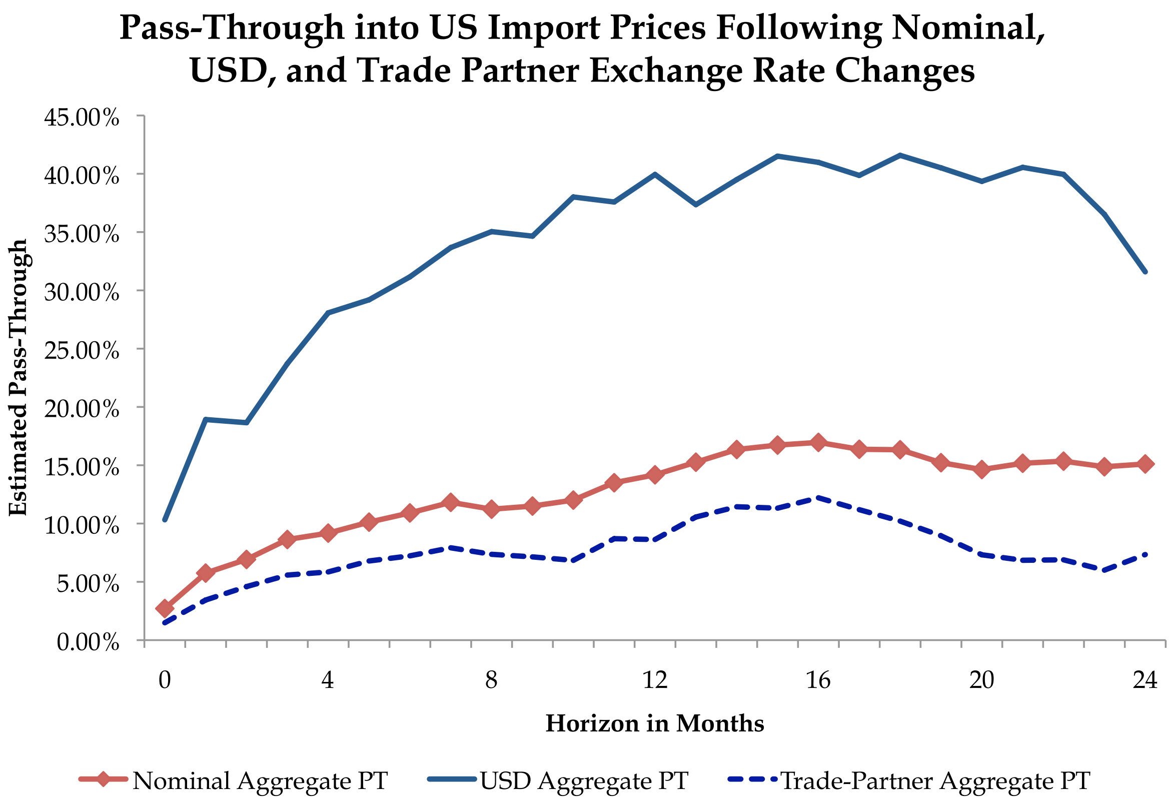


**Figure 1: Pass-Through of Different Exchange Measures into US Import Prices**

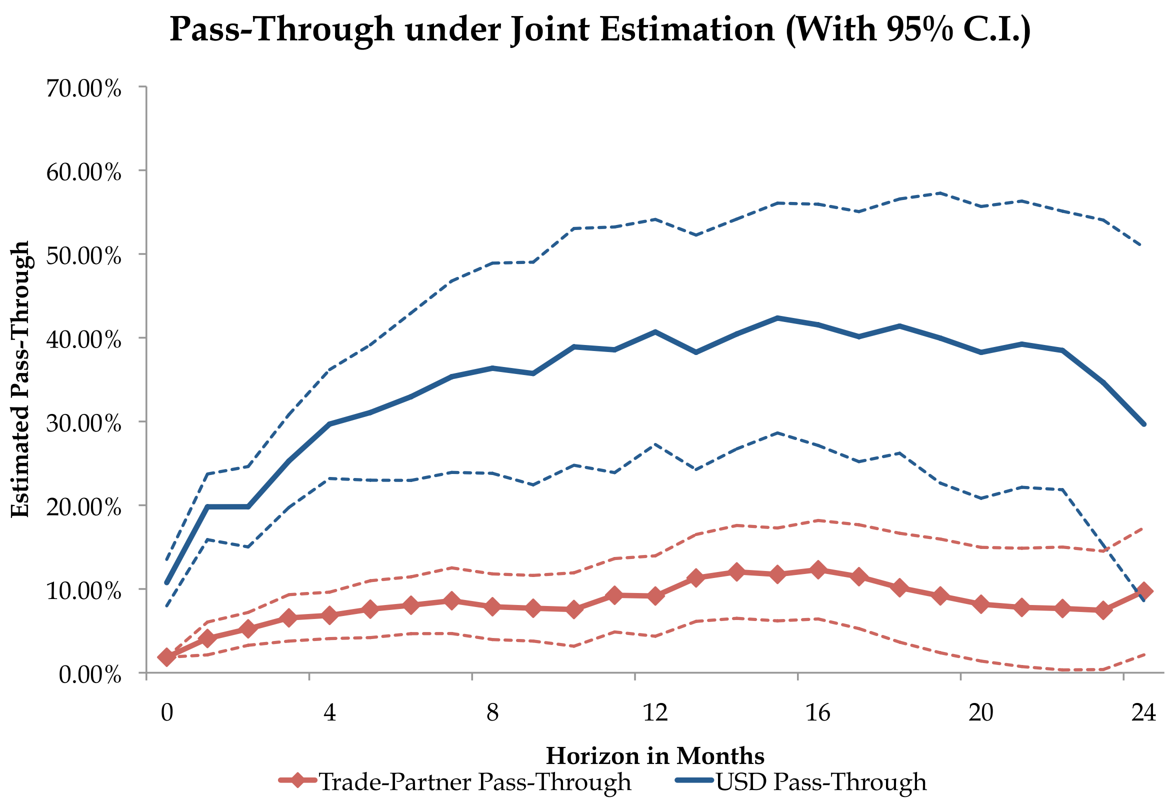


**Figure 2: Jointly Estimated Pass-Through of USD and Trade-Partner Exchange Rate Changes into US Import Prices**

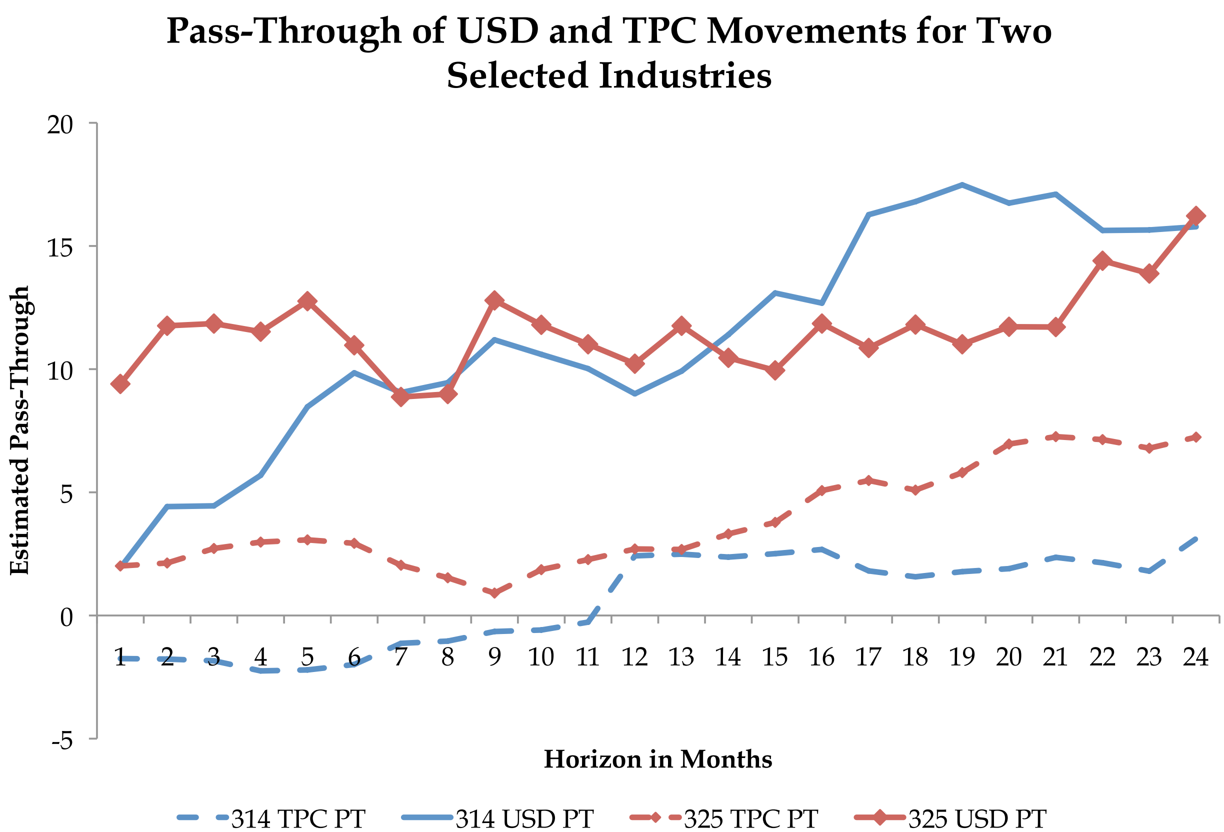


**Figure 3: Pass-Through for TP and USD Movements for NAICS Industries 314 and 325**

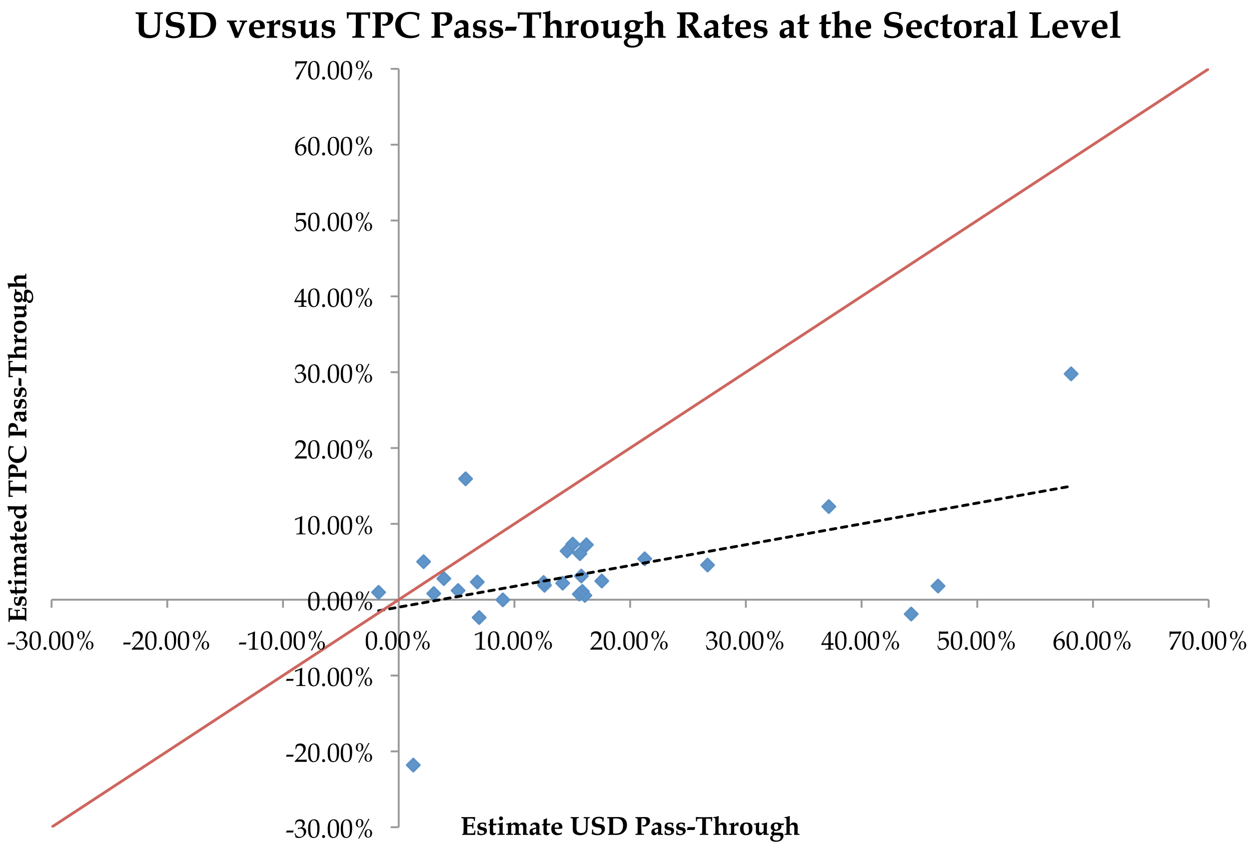


**Figure 4: USD versus TPC Pass-Through Rates at the Sectoral Level**

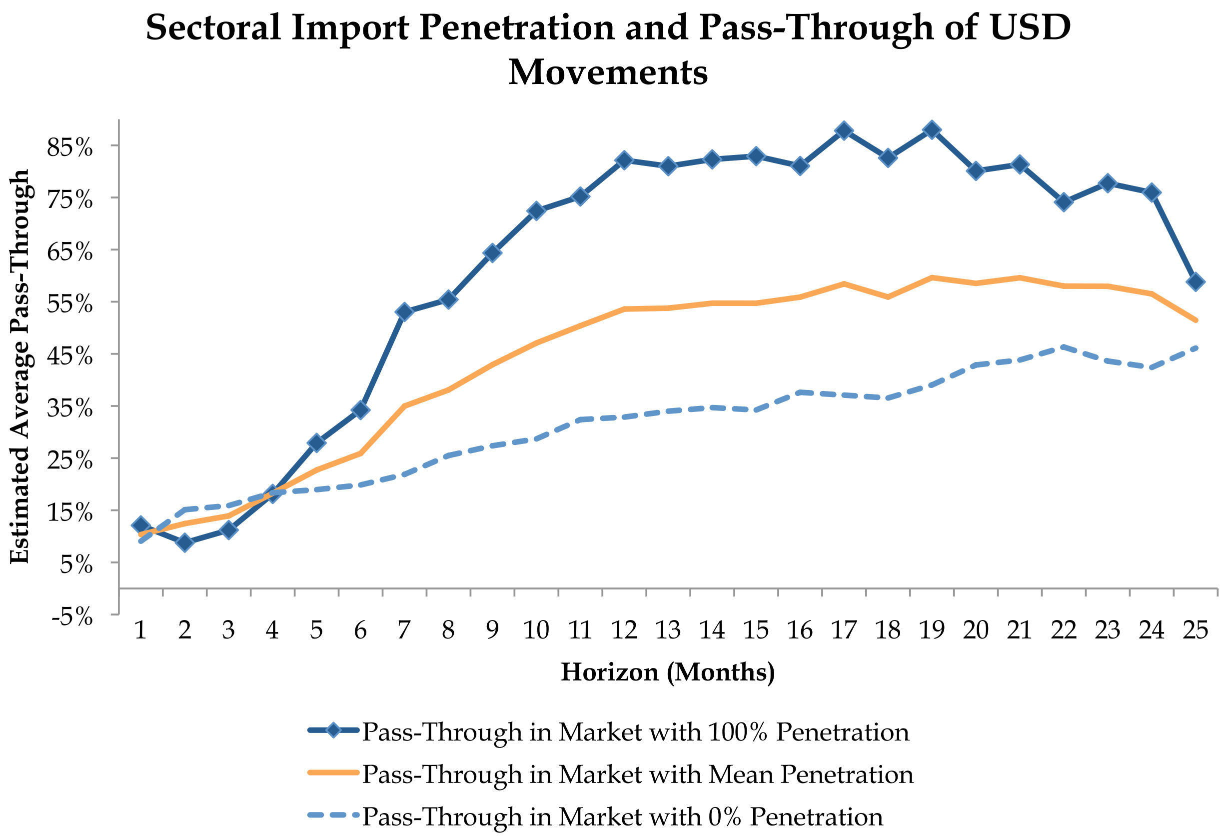


**Figure 5: Pass-Through and Sectoral Import Penetration**

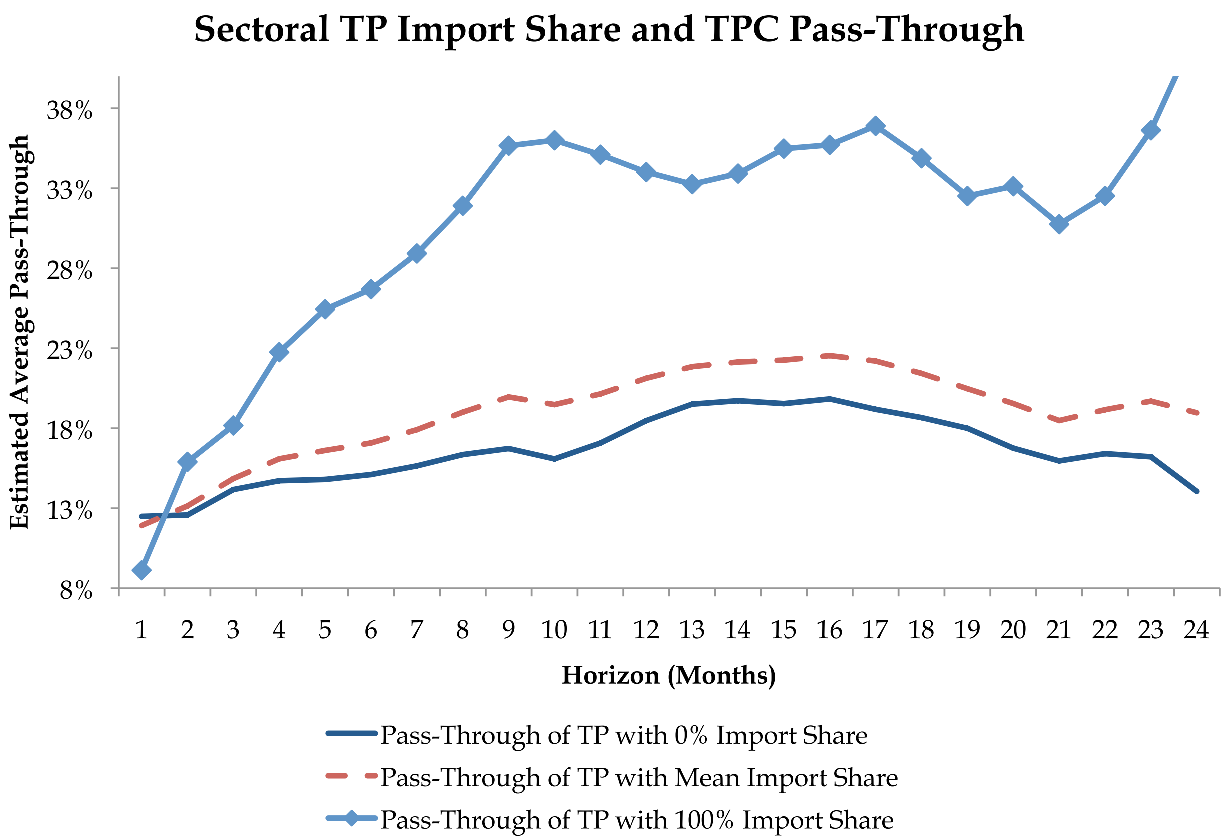


**Figure 6: Pass-Through and Trade-Partner Import Share**

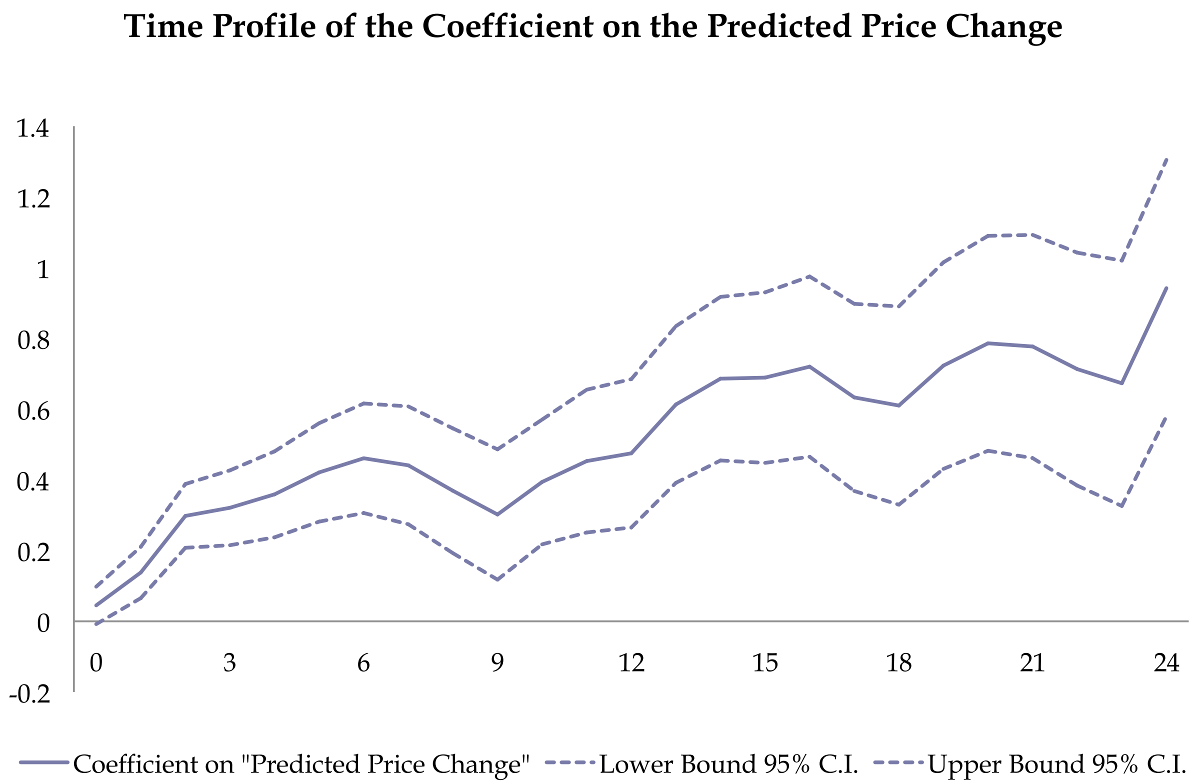


**Figure 7: Time Profile of the Coefficient on the Predicted Price Change**

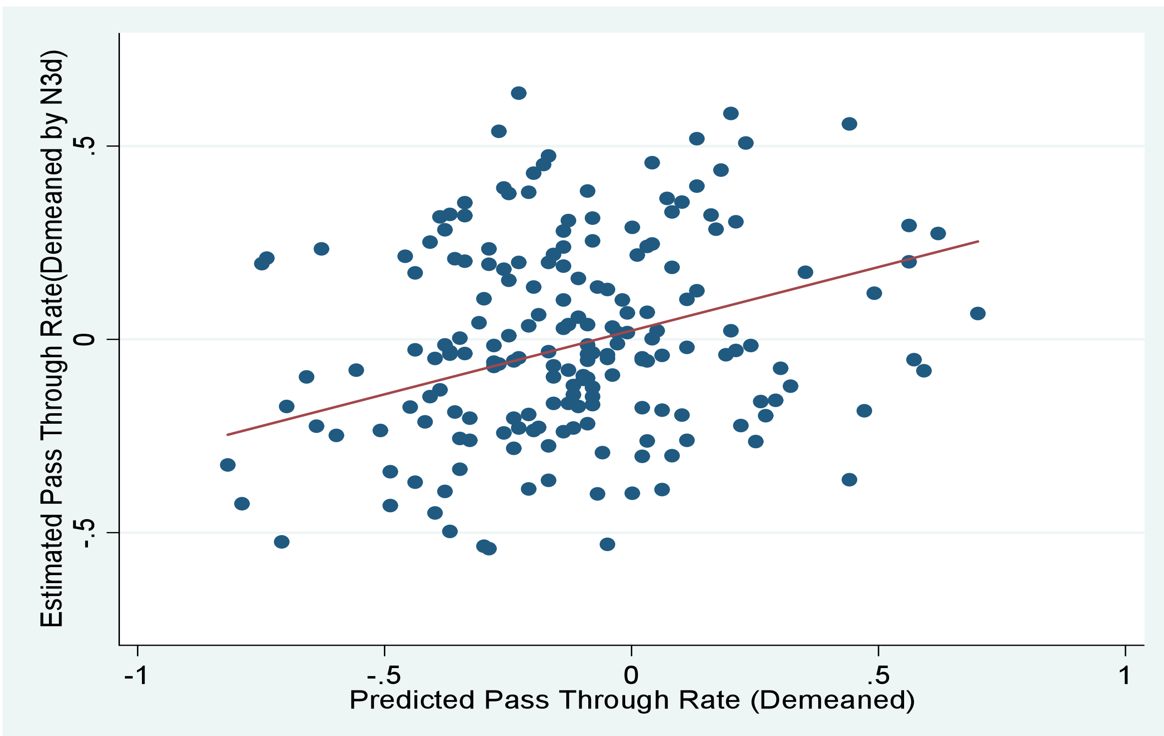


**Figure 8: Estimated and Predicted Pass-Through, Sector-Trade Partner Pairs**

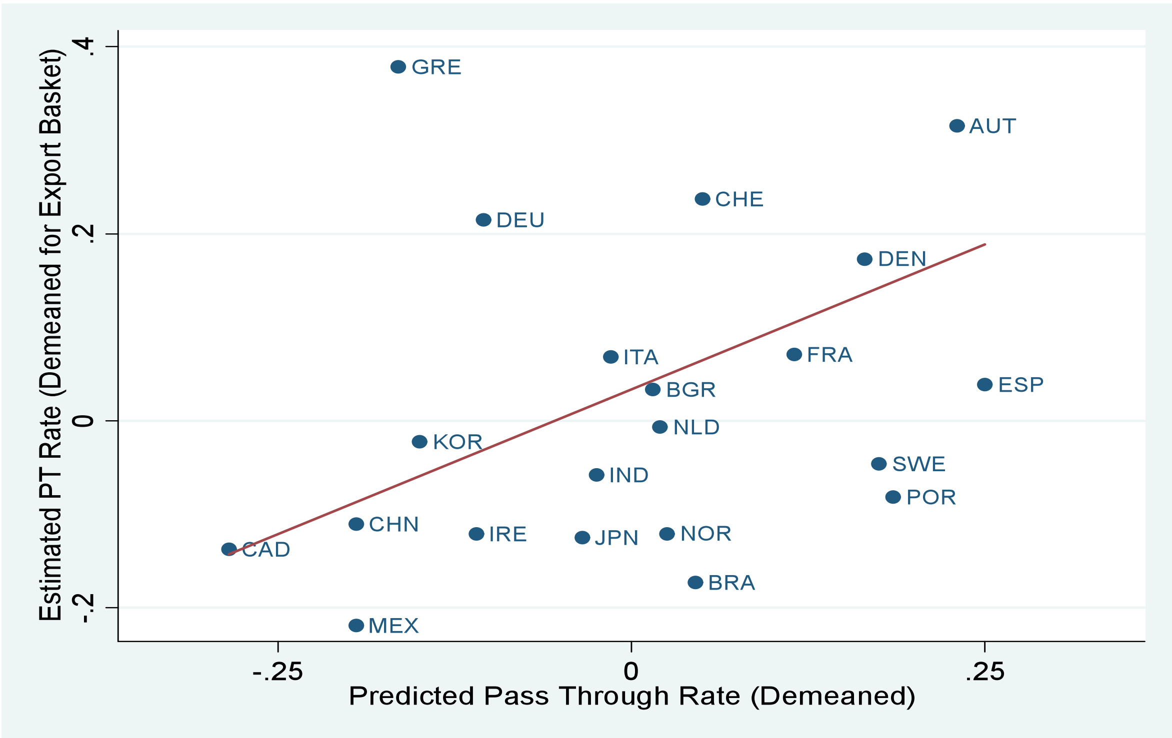


**Figure 9: Estimated and Predicted Pass-Through, Country-Level**