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Abstract

Large exporters are simultaneously large importers. In this paper, we show that this pattern is key to understanding low aggregate exchange rate pass-through as well as the variation in pass-through across exporters. First, we develop a theoretical framework that combines variable markups due to strategic complementarities and endogenous choice to import intermediate inputs. The model predicts that firms with high import shares and high market shares have low exchange rate pass-through. Second, we test and quantify the theoretical mechanisms using Belgian firm-product-level data with information on exports by destination and imports by source country. We confirm that import intensity and market share are the prime determinants of pass-through in the cross-section of firms. A small exporter with no imported inputs has a nearly complete pass-through of over 90 percent, while a firm at the 95th percentile of both import intensity and market share distributions has a pass-through of 56 percent, with the marginal cost and markup channels playing roughly equal roles. The largest exporters are simultaneously high-market-share and high-import-intensity firms, which helps explain the low aggregate pass-through and exchange rate disconnect observed in the data.

Key words: exchange rate pass-through, pricing-to-market, import intensity

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1 Introduction

One of the central puzzles in international macroeconomics is why large movements in exchange rates have small effects on the prices of internationally traded goods. This exchange rate disconnect has generated a vast literature, yet no empirical pass-through study has taken into account one of the most salient features of international trade, that is that the largest exporters are simultaneously the largest importers. In this paper, we show that this pattern is key to understanding the low aggregate pass-through, as well as the variation in pass-through across firms.

Using detailed Belgium micro data, we find that more import-intensive exporters have significantly lower exchange rate pass-through into their export prices, as they face offsetting exchange rate effects on their marginal costs. These data reveal that the distribution of import intensity among exporters is highly skewed, with the import-intensive firms being among the largest exporters, accounting for a major share of international trade. Consequently, the import-intensive firms also have high export market shares and hence set high markups and actively move them in response to changes in marginal cost, providing a second channel that limits the effect of exchange rate shocks on export prices. These two mechanisms reinforce each other and act to introduce a buffer between local costs and international prices of the major exporters, thus playing a central role in limiting the transmission of exchange rate shocks across countries. The availability of firm-level data with imports by source country and exports by destination, combined with domestic cost data, enables us to estimate the magnitude of these two channels.

To guide our empirical strategy, we develop a theoretical framework to study the forces that jointly determine a firm's decisions to source its intermediate inputs internationally and to set markups in each destination of its exports. The two building blocks of our theoretical framework are an oligopolistic competition model of variable markups following Atkeson and Burstein (2008) and a model of the firm's choice to import intermediate inputs following Halpern, Koren, and Szeidl (2011). These two ingredients allow us to capture the key patterns in the data that we focus on, and their interaction generates new insights on the determinants of exchange rate pass-through.[1]

More specifically, we allow for three forms of exogenous firm heterogeneity—in productivity, quality of their goods, and importing costs of their intermediate inputs—that jointly determine firms' import intensities and their market shares in each destination. With fixed

[1]The combination of these two mechanisms is central to our results, while the choice of a particular model of variable markups or of selection into importing is less important.

costs of importing, firms face the standard trade-off in choosing whether to import and how much to import, with larger-scale firms finding it optimal to import more varieties. In equilibrium, the more productive firms end up having greater market shares and choose to source a greater share of their inputs internationally, which in turn further amplifies the productivity advantage of these firms. Therefore, the two sources of incomplete pass-through—operating through the marginal cost and the markup—amplify and reinforce each other in the cross section of firms. The theory suggests a firm's import intensity and export market share are the two prime determinants of its exchange rate pass-through incompleteness in the cross-section of firms, with import intensity proxying for marginal cost sensitivity to the exchange rate and market shares proxying for markup elasticity.

We test the predictions of the theory with a rich data set of Belgian exporters for the period 2000 to 2008. A distinctive feature of these data is that they comprise firm-level imports by source country and exports by destination at the CN 8-digit product codes (close to 10,000 distinct product codes), which we match with firm-level characteristics, such as wages and expenditure on inputs. This allows us to construct a measure of imported inputs as a share of a firm's total costs and a measure of firm's market share for each export destination, which are the two key firm characteristic in our analysis. Further, with the information on imports by source country, we can separate inputs from Euro and non-Euro countries, which is an important distinction since imported inputs from within the Euro area are in the Belgium firms' currency.

We start our empirical analysis by documenting some new stylized facts related to the distribution of import intensity across firms, lending support to the assumptions and predictions of our theoretical framework. We show that in the already very select group of exporters relative to the overall population of manufacturing firms, there still exists a substantial heterogeneity in the share of imported inputs sourced internationally, in particular from the more distant source countries outside the Euro Zone. The import intensity is strongly correlated with firm size and other firm characteristics and is heavily skewed toward the largest exporters.

Our main empirical specification, as suggested by the theory, relates exchange rate pass-through with the firm's import intensity capturing the marginal cost channel and the destination-specific market shares capturing the markup channel. We estimate this relationship within industries and destinations. This allows us to estimate the cross-sectional relationship between pass-through and its determinants, holding constant the general equi-

librium forces common to all firms in a given industry and destination.[2]

The results provide strong support for the theory. First, we show that import intensity is an important correlate of a firm's pass-through, with each additional 10 percentage points of imports in total costs reducing pass-through by 5.3 percentage points. Second, we show that this effect is due to both the marginal cost channel, which import intensity affects directly, and the markup channel through the selection effect. Specifically, when we control for a firm's marginal cost, the effect of the import intensity on pass-through is reduced by half, and when we further control for market share proxying for the markup variability, it largely disappears. Last, including both import intensity and market share, we find these two variables jointly to be robust predictors of exchange rate pass-through across different sub-samples and with controls for other firm characteristics such as productivity and employment size.

Quantitatively, these results are large. A firm at the 5th percentile of both import intensity and market share (both approximately equal to zero) has a nearly complete pass-through of over 91%. In contrast, a firm at the 95th percentile of both import intensity and market share distributions has a pass-through of 56%, with import intensity and market share contributing nearly equally to this variation across firms. These results have important implications for aggregate pass through. Given that both import intensity and market share distributions are skewed toward the largest exporters, these findings imply an aggregate exchange rate pass-through of 64%.

We further explore the underlying mechanisms leading to incomplete pass-through with a number of extensions. We verify that our results hold non-parametrically when we sort the firms into bins of market share and import intensity. We also show that import-intensive exporters have lower pass-through due to greater sensitivity of their marginal costs to exchange rates, confirming the theoretical mechanism. Finally, we show that it is the share of imports from the non-Euro OECD countries that matters the most, while the share of imports from within the Euro Zone has no effect on pass-through and imports from the non-OECD countries have only a statistically marginal effect on exchange rate pass-through.[3]

Our paper is related to three strands of recent literature. First, it relates to the recent and growing literature on the interaction of importing and exporting decisions of firms. Earlier

[2]In particular, such common forces include the correlation between exchange rate and sector-destination specific price index, as well as sector-specific productivity and cost index.

[3]Indeed, we expect to find no effect of imports from within the Euro Zone since they are priced in the same currency and hence are not subject to exchange rate movements. The finding of little effect of imports from the non-OECD countries is consistent with low pass-through from these countries into import prices even when exchange rates move. We verify this hypothesis by estimating a pass-through regression of the exchange rate into import prices and finding a much larger coefficient from the OECD import-source countries.

work, for example, Bernard, Jensen, and Schott (2009), has documented a large overlap in the import and export activity of firms.[4] Indeed, major exporters are almost always major importers, and this is also true in our dataset. We focus exclusively on the already select group of exporters, most of whom are also importers from multiple source countries. We instead emphasize the strong selection that still operates within the group of exporters and in particular the heterogeneity in the intensity with which firms import their intermediate inputs. Our paper is also the first to empirically link the importing activity of the firms with the incomplete pass-through into export prices.

Second, our paper is related to the recent empirical and structural work on the relationship between firm import intensity and firm productivity. Although we base our model on Halpern, Koren, and Szeidl (2011), who estimate the effects of import use on total factor productivity for Hungarian firms, similar models were developed in Amiti and Davis (2012) to study the effects of import tariffs on firm wages and in Gopinath and Neiman (2012) to study the effects of the Argentine trade collapse following the currency devaluation of 2001 on the economy-wide productivity.[5] Amiti and Konings (2007) provided an early reduced-form empirical analysis of the micro-level effects of imports on firm productivity. In our study, the focus centers on the interplay between import intensity and markup variability, and the productivity effect of imported intermediate inputs contributes to the relationship of these two channels.

Third, our paper contributes to the vast literature studying exchange rate disconnect (see Obstfeld and Rogoff, 2001; Engel, 2001) and more specifically the incomplete pass-through of exchange rate shocks into international prices. In the past decade, substantial progress has been made in the study of this phenomenon, both theoretically and empirically.[6] This literature has explored three channels leading to incomplete pass-through. The first channel, as surveyed in Engel (2003), is short-run nominal rigidities with prices sticky in the local currency of the destination market, labeled in the literature as *local currency pricing* (LCP). Under LCP, the firms that do not adjust prices have zero short-run pass-through. Gopinath and Rigobon (2008) provide direct evidence on the extent of LCP in the US import and export prices. The second channel—*pricing-to-market* (PTM)—arises in models of variable markups in which firms optimally choose different prices for different destinations depending

[4]Other related papers include Kugler and Verhoogen (2009), Manova and Zhang (2009), Feng, Li, and Swenson (2012), and Damijan, Konings, and Polanec (2012).

[5]Blaum, Lelarge, and Peters (2010) document stylized facts about import behavior of French firms and provide another related model.

[6]For the survey of earlier work, see Goldberg and Knetter (1997), who in particular emphasize that "[l]ess is known about the relationship between costs and exchange rates..." (see p. 1244).

on local market conditions. Atkeson and Burstein (2008) provide an example of a recent quantitative investigation of the PTM channel and its implication for international aggregate prices.[7] Finally, the third channel of incomplete pass-through into consumer prices often considered in the literature is local distribution costs, as for example in Burstein, Neves, and Rebelo (2003) and Goldberg and Campa (2010). Our imported inputs channel is similar in spirit to the local distribution costs in that they make the costs of the firm more stable in the local currency of export destination.[8]

Our paper is closely related to Berman, Martin, and Mayer (2012) in that we also study the variation in pass-through across heterogeneous firms. While they focus on the role of firm productivity and size, we emphasize the role of imported inputs and destination-specific market shares.[9] Some previous studies have acknowledged the potential role of imported inputs in limiting exchange rate pass-through (e.g., see Gopinath, Itskhoki, and Rigobon, 2010), but none has empirically estimated its impact. Our paper is the first to incorporate the endogenous choice of importing within an exchange rate pass-through model, as well as to construct a theoretically consistent empirical measure of import intensity at the firm level and estimate its impact on pass-through. In addition, the focus of our paper is on the interaction between the imported inputs and the PTM channels, which, as we show, reinforce and amplify each other. We further build on the previous literature by quantitatively decomposing the contribution of the marginal cost and variable markup channels to

[7]Gopinath and Itskhoki (2011) show the importance of PTM in matching patterns in the international aggregate and micro price data. Fitzgerald and Haller (2012) provide the most direct evidence on PTM by comparing the exchange rate response of prices of the same item sold to both the domestic and the international market. Gopinath, Itskhoki, and Rigobon (2010) and Gopinath and Itskhoki (2010) show that the PTM and LCP channels of incomplete pass-through interact and reinforce each other, with highly variable-markup firms endogenously choosing to price in local currency as well as adopting longer price durations. Nakamura and Zerom (2010) and Goldberg and Hellerstein (2011) provide alternative decompositions of incomplete pass-through into the contribution of LCP and PTM components for the coffee and beer markets, respectively.

[8]The difference with the distribution cost channel is that the use of imported inputs results in incomplete pass-through not only into consumer prices, but also into the at-the-dock export prices of the producers. Corsetti and Dedola (2005) show how local distribution costs interacted with a monopolistic price setting also result in incomplete pass-through into at-the-dock export prices.

[9]A number of earlier papers have linked pass-through with market share of exporters. Feenstra, Gagnon, and Knetter (1996), Alessandria (2004), and Garetto (2012) emphasize the U-shape relationship between market share and pass-through. The Atkeson and Burstein (2008) model can in general produce such a non-monotonic relationship. However, when we hold the price index constant, consistent with our empirical strategy, pass-through monotonically decreases in market share. Empirically, we also find no evidence of a U-shape relationship between market share and pass-through. A recent paper by Auer and Schoenle (2012) shows that greater sector-level market share of exporters from a particular country contributes to higher pass-through. We instead focus on the firm-level interaction between market share and pass-through, and find a negative relationship. These seemingly contradictory findings are consistent with each other in a model of strategic complementarities due to counteracting general equilibrium effects operating at the sectoral level and held constant in our analysis (refer to Gopinath and Itskhoki, 2011, for further discussion).

incomplete exchange rate pass-through.[10]

The rest of the paper is structured as follows. Section 2 lays out the theoretical framework and provides the theoretical results that motivate the empirical analysis that follows. Section 3 describes our main empirical findings. Section 3 also reports information on the dataset, provides the stylized patterns of cross-sectional variation in the data, and reports the results of the robustness tests. Section 4 concludes.

2 Theoretical Framework

In this section, we develop a theoretical framework linking a firm's exchange rate pass-through to its import intensity and export market shares, all of which are endogenously determined. We use this framework to formulate testable implications and to derive an empirical specification, which we later take to the data. We start by laying out the two main ingredients of our framework—the Atkeson and Burstein (2008) model of strategic complementarities and variable markups and the Halpern, Koren, and Szeidl (2011) model of the firm's choice to import intermediate inputs. We then show how the interaction of these two mechanisms generates new theoretical insights on the determinants of exchange rate pass-through. The key predictions of this theory are that a firm's import intensity and market shares are positively correlated in the cross-section and together constitute prime determinants of incomplete exchange rate pass-through at the firm level, with import intensity proxying for marginal cost sensitivity to the exchange rate and market shares proxying for markup elasticity. All the technical derivations are omitted and provided in the appendix.

We develop the model in partial equilibrium and focus on the equilibrium cross-sectional variation between firms within industries and export destinations. This approach allows us to derive sharp predictions for cross-sectional variation, holding constant the general equilibrium environment of the firms within industry-destinations, without imposing any exogeneity assumptions for exchange rate shocks.

To focus our analysis on the relationship between import intensity and pass-through of the firms, we make a number of simplifying assumptions. First, we condition our analysis on the subset of exporting firms, and hence we do not model entry, exit, or selection into

[10] Burstein and Jaimovich (2008) emphasize the importance of discriminating between the marginal cost and the markup channels in order to assess the welfare implications of pass-through incompleteness. We return to this issue in the concluding section. De Loecker, Goldberg, Khandelwal, and Pavcnik (2012) propose an alternative structural method of decomposing prices into marginal costs and markups and apply it to estimate the pass-through from import tariffs into domestic prices, marginal costs and markups.

exporting (as, for example, in Melitz, 2003), but rather focus on the import decisions of the firms. Similarly, we do not model the decision to export to multiple destinations, but simply take this information as exogenously given. These additional sources of endogenous selection would only reinforce the cross-sectional patterns predicted by the model and leave the qualitative predictions for pass-through unchanged. Furthermore, we assume all firms are single-product, but as we explain below, within this framework one can think about multi-product firms in a similar way as multi-destination firms.

Second, we assume flexible price setting as in Atkeson and Burstein (2008) and hence do not need to characterize the currency choice (i.e., local versus producer currency pricing). This modeling choice is motivated by the nature of our dataset in which we use unit values as proxies for prices. Empirically, incomplete pass-through is at least in part due to price stickiness in local currency, and in light of this we provide a careful interpretation of our results in the discussion section (see Section 4).[11]

Last, while the marginal cost channel emphasized in the paper is inherently a mechanism of *real hedging*, in modeling firms' import decisions we abstract from the choice to peak or switch import source countries to better hedge firm's export exchange rate risk. Empirically, we find a moderate presence of real hedging, which, however does not vary with the firm variables that are the focus of our analysis (see Section 3).[12]

2.1 Demand and markups

Consider a firm producing a differentiated good i in sector s and supplying it to destination market k in period t. Consumers in each market have a nested CES demand over the varieties of goods, as in Atkeson and Burstein (2008). The elasticity of substitution across the varieties within sectors is ρ, while the elasticity of substitution across sectoral aggregates is η, and we assume $\rho > \eta \geq 1$.

[11] It is useful to keep in mind that, as shown in Gopinath, Itskhoki, and Rigobon (2010), the flexible-price pass-through forces shape the currency choice of the firms, i.e. firms with a low pass-through conditional on a price change choose to price in local currency, which further reduces the short-run pass-through of these firms. In this paper, we focus on the endogenous determinants of flexible-price (or long-run) pass-through in the cross-section of firms, which in the sticky price environment would also contribute to the prevalence of local currency pricing, yet the two forces work in the same direction.

[12] Note that under the assumption of risk neutrality of the firm and in the absence of liquidity constraints (for example, of the type modeled in Froot, Scharfstein, and Stein, 1993), financial hedging constitutes only a side bet to the firm and does not affect its import and pricing decisions. Fauceglia, Shingal, and Wermelinger (2012) provide evidence on the role of imported inputs in "natural" hedging of export exchange rate risk by Swiss firms and Martin and Méjean (2012) provide survey evidence on the role of currency hedging in international transactions of the Euro Zone firms.

Under these circumstances, a firm i faces the following demand for its product:

$$Q_{k,i} = \xi_{k,i} P_{k,i}^{-\rho} P_k^{\rho-\eta} D_k, \tag{1}$$

where $Q_{k,i}$ is quantity demanded, $\xi_{k,i}$ is a relative preference (quality) parameter of the firm, $P_{k,i}$ is the firm's price, P_k is the sectoral price index, and D_k is the sectoral demand shifter, which the firm takes as given. Index k emphasizes that all these variables are destination specific. For brevity, we drop the additional subscripts s and t for sector and time, since all of our analysis focuses on variation within a given sector.

The sectoral price index is given by $P_k \equiv \left[\sum_i \xi_{k,i} P_{k,i}^{1-\rho}\right]^{1/(1-\rho)}$, where the summation is across all firms in sector s serving market k in time period t, and we normalize $\sum_i \xi_{k,i} = 1$. As a convention, we quote all prices in the local currency of the destination market.

An important characteristic of the firm's competitive position in a market is its market share given by:

$$S_{k,i} \equiv \frac{P_{k,i} Q_{k,i}}{\sum_{i'} P_{k,i'} Q_{k,i'}} = \xi_{k,i} \left(\frac{P_{k,i}}{P_k}\right)^{1-\rho} \in [0,1], \tag{2}$$

where market share is sector-destination-time specific. The effective demand elasticity for the firm is then

$$\sigma_{k,i} \equiv -\frac{\mathrm{d} \log Q_{k,i}}{\mathrm{d} \log P_{k,i}} = \rho(1 - S_{k,i}) + \eta S_{k,i}, \tag{3}$$

since $\partial \log P_k / \partial \log P_{k,i} = S_{k,i}$. In words, the firm faces a demand elasticity that is a weighted average of the within-sector and the across-sector elasticities of substitution with the weight on the latter equal to the market share of the firm. Larger market share firms exert a stronger impact on the sectoral price index, making their demand less sensitive to their own price.

When firms compete in prices, they set a multiplicative markup $\mathcal{M}_{k,i} \equiv \sigma_{k,i}/(\sigma_{k,i} - 1)$ over their costs. Firms face a demand with elasticity decreasing in the market share, and hence high-market-share firms charge high markups. We now define a measure of the markup elasticity with respect to the price of the firm, *holding constant the sector price index*:[13]

$$\Gamma_{k,i} \equiv -\frac{\partial \log \mathcal{M}_{k,i}}{\partial \log P_{k,i}} = \frac{S_{k,i}}{\left(\frac{\rho}{\rho-\eta} - S_{k,i}\right)\left(1 - \frac{\rho-\eta}{\rho-1} S_{k,i}\right)} > 0. \tag{4}$$

A lower price set by the firm leads to an increase in the firm's market share, making optimal

[13] We choose this partial measure of markup elasticity (holding price index P_k constant) because in what follows we focus on the differences in price response across firms within sectors, hence facing the same sector-destination price index. Note that the monotonicity result in Proposition 1 does not in general apply to other measures of markup elasticity without further parameter restrictions.

a larger markup. Furthermore, the markup elasticity is also increasing in the market share of the firm. We summarize this discussion in:

Proposition 1 *Market share of the firm $S_{k,i}$ is a sufficient statistic for its markup; both markup $\mathcal{M}_{k,i}$ and markup elasticity $\Gamma_{k,i}$ are increasing in the market share of the firm.*

The monotonicity of markup and markup elasticity in market share is a sharp prediction of this framework. Although this prediction is not universal for other demand structures, it emerges in a wide class of models, as surveyed in Burstein and Gopinath (2012). In Section 3, we directly test this prediction and find no evidence of non-monotonicity in the data.

2.2 Production and imported inputs

We build on Halpern, Koren, and Szeidl (2011) to model the cost structure of the firm and its choice to import intermediate inputs. Consider a firm i, which uses labor L_i and intermediate inputs X_i to produce its output Y_i according to the production function:

$$Y_i = \Omega_i X_i^{\phi} L_i^{1-\phi}, \tag{5}$$

where Ω_i is firm productivity. Parameter $\phi \in [0,1]$ measures the share of intermediate inputs in firm expenditure and is sector specific but common to all firms in the sector.

Intermediate inputs consist of a bundle of intermediate goods indexed by $j \in [0,1]$ and aggregated according to a Cobb-Douglas technology:

$$X_i = \exp\left\{\int_0^1 \gamma_j \log X_{i,j} \mathrm{d}j\right\}. \tag{6}$$

The types of intermediate inputs vary in their importance in the production process as measured by γ_j, which satisfy $\int_0^1 \gamma_j \mathrm{d}j = 1$. Each type j of intermediate good comes in two varieties—a domestic and a foreign—which are imperfect substitutes:

$$X_{i,j} = \left[Z_{i,j}^{\frac{\zeta}{1+\zeta}} + a_j^{\frac{1}{1+\zeta}} M_{i,j}^{\frac{\zeta}{1+\zeta}}\right]^{\frac{1+\zeta}{\zeta}}, \tag{7}$$

where $Z_{i,j}$ and $M_{i,j}$ are respectively the quantities of domestic and imported varieties of the intermediate good j used in production. The elasticity of substitution between the domestic and the foreign varieties is $(1+\zeta) > 1$, and a_j measures the productivity advantage (when $a_j > 1$, and disadvantage otherwise) of the foreign variety. Note that since home and

foreign varieties are imperfect substitutes, production is possible without the use of imported inputs. At the same time, imported inputs are useful due both to their potential productivity advantage a_j and to the love-of-variety feature of the production technology (7).

A firm needs to pay a firm-specific sunk cost f_i in terms of labor in order to import each type of the intermediate good. The cost of labor is given by the wage rate W^*, and the prices of domestic intermediates are $\{V_j^*\}$, both denominated in units of producer currency (hence starred). The prices of foreign intermediates are $\{\mathcal{E}_m U_j\}$, where U_j is the price in foreign currency and $\mathcal{E}_m$ is the exchange rate measured as a unit of producer currency for one unit of foreign currency.[14] The total cost of the firm is therefore given by $W^* L_i + \int_0^1 V_j^* Z_{i,j} \mathrm{d}j + \int_{J_{0,i}} \left(\mathcal{E}_m U_j M_{i,j} + W^* f_i\right) \mathrm{d}j$, where $J_{0,i}$ denotes the set of intermediates imported by the firm.

With this production structure, we can derive the cost function of the firm. In particular, given output Y_i and the set of imported intermediates $J_{0,i}$, the firm chooses inputs to minimizes its total costs subject to the production technology in equations (5)–(7). This results in the following total variable cost function net of the fixed costs of importing:

$$TVC_i^*(Y_i|J_{0,i}) = \frac{C^*}{B_i^\phi \Omega_i} Y_i, \tag{8}$$

where C^* is the cost index for a non-importing firm.[15] The use of imported inputs leads to a cost-reduction factor $B_i \equiv B(J_{0,i}) = \exp\left\{\int_{J_{0,i}} \gamma_j \log b_j \mathrm{d}j\right\}$, where $b_j \equiv \left[1 + a_j (\mathcal{E}_m U_j / V_j^*)^{-\zeta}\right]^{1/\zeta}$ is the productivity-enhancing effect from importing type-j intermediate good, adjusted for the relative cost of the import variety.

We now describe the optimal choice of the set of imported intermediate goods, $J_{0,i}$, in the absence of uncertainty. First, we sort all intermediate goods j by $\gamma_j \log b_j$, from highest to lowest. Then, the optimal set of imported intermediate inputs is an interval $J_{0,i} = [0, j_{0,i}]$, with $j_{0,i} \in [0,1]$ denoting the cutoff intermediate good. The optimal choice of $j_{0,i}$ trades off the fixed cost of importing $W^* f_i$ for the reduction in total variable costs from the access to an additional imported input, which is proportional to the total material cost of the firm.[16] This reflects the standard trade-off that the fixed cost activity is undertaken provided that the scale of operation (here total spending on intermediate inputs) is sufficiently large.

With this cost structure, the fraction of total variable cost spent on imported intermediate

[14] We denote by m a generic source of imported intermediates, and hence $\mathcal{E}_m$ can be thought of as an import-weighted exchange rate faced by the firms.

[15] This cost index is given by $C^* = \left(V^*/\phi\right)^\phi \left(W^*/(1-\phi)\right)^{1-\phi}$ with $V^* = \exp\left\{\int_0^1 \gamma_j \log\left(V_j^*/\gamma_j\right) \mathrm{d}j\right\}$.

[16] The marginal imported input satisfies $\gamma_{j_{0,i}} \log b_{j_{0,i}} \cdot TMC_i = W^* f_i$, where the left-hand side is the incremental benefit proportional to the total material cost of the firm $TMC_i \equiv \phi C^* Y_i / \left[B_i^\phi \Omega_i\right]$ and the cost-saving impact of additional imports $\gamma_{j_{0,i}} \log b_{j_{0,i}}$.

inputs equals:

$$\varphi_i = \phi \int_0^{j_{0,i}} \gamma_j \big(1 - b_j^{-\zeta}\big) \mathrm{d}j, \tag{9}$$

where ϕ is the share of material cost in total variable cost and $\gamma_j(1 - b_j^{-\zeta})$ is the share of material cost spent on imports of type-j intermediate good for $j \in J_{0,i}$. We refer to φ_i as the *import intensity* of the firm, and it is one of the characteristics of the firm we measure directly in the data.

Finally, holding the set of imported varieties $J_{0,i}$ constant, this cost structure results in the following marginal cost:

$$MC_i^* = C^* / \big[B_i^{\phi} \Omega_i\big]. \tag{10}$$

The *partial* elasticity of this marginal cost with respect to the exchange rate $\mathcal{E}_m$ equals the expenditure share of the firm on imported intermediate inputs, $\varphi_i = \partial \log MC_i^* / \partial \log \mathcal{E}_m$, which emphasizes the role of import intensity in the analysis that follows.

We summarize these results in:

Proposition 2 (i) *Within sectors, firms with larger total material cost or smaller fixed cost of importing have a larger import intensity,* φ_i. (ii) *The partial elasticity of the marginal cost of the firm with respect to the (import-weighted) exchange rate equals* φ_i.

2.3 Equilibrium relationships

We now combine the ingredients introduced above to study the optimal price setting of the firm, as well as the equilibrium determinants of the market share and import intensity of the firm. Consider firm i supplying an exogenously given set K_i of destination markets k. The firm sets destination-specific prices by solving

$$\max_{Y_i, \{P_{k,i}, Q_{k,i}\}_k} \left\{ \sum_{k \in K_i} \mathcal{E}_k P_{k,i} Q_{k,i} - \frac{C^*}{B_i^{\phi} \Omega_i} Y_i \right\},$$

subject to $Y_i = \sum_{k \in K_i} Q_{k,i}$ and demand equations (1) in each destination k. We quote the destination-k price $P_{k,i}$ in the units of destination-k local currency and use the bilateral nominal exchange rate $\mathcal{E}_k$ to convert the price to the producer currency, denoting with $P_{k,i}^* \equiv \mathcal{E}_k P_{k,i}$ the producer-currency price of the firm for destination k. An increase in $\mathcal{E}_k$ corresponds to the depreciation of the producer currency. The total cost of the firm is quoted

in units of producer currency and hence is starred.[17] Note that we treat the choice of the set of imported goods $J_{0,i}$ and the associated fixed costs as sunk by the price setting stage. The problem of choosing $J_{0,i}$ before the realization of uncertainty is defined and characterized in the appendix and Section 3 provides empirical evidence supporting this assumption.

Taking the first order conditions with respect to $P_{k,i}$, we obtain the optimal price setting conditions:

$$P_{k,i}^* = \frac{\sigma_{k,i}}{\sigma_{k,i}-1} MC_i^* = \mathcal{M}_{k,i} \frac{C^*}{B_i^\phi \Omega_i}, \qquad k \in K_i, \tag{11}$$

where MC_i^* is the marginal cost as defined in (10) and $\mathcal{M}_{k,i} = \sigma_{k,i}/(\sigma_{k,i}-1)$ is the multiplicative markup with the effective demand elasticity $\sigma_{k,i}$ defined in (3). This set of first order conditions together with the constraints fully characterizes the allocation of the firm, given industry-level variables. In the appendix we exploit these equilibrium conditions to derive how relative market shares and import intensities are determined in equilibrium across firms, and since these results are very intuitive, here we provide only a brief summary.

We show that other things equal and under mild regularity conditions, a firm with higher productivity Ω_i, higher quality/demand $\xi_{k,i}$, lower fixed cost of importing f_i, and serving a larger set of destinations K_i has a larger market share $S_{k,i}$ and a higher import intensity φ_i. Intuitively, a more productive or higher-demand firm has a larger market share and hence operates on a larger scale which justifies paying the fixed cost for a more comprehensive access to the imported intermediate inputs. This leads the firm to become more import intensive, which through the cost-reduction effect of imports (larger B_i in (8)) enhances the productivity of the firm and, in turn, results in higher market shares. We refer to this feedback mechanism as the amplification effect of import intensity of the firm. This discussion implies that market shares and import intensities are likely to be positively correlated in the cross-section of firms, a pattern that we document in the data in Section 3.

2.4 Imported inputs, market share, and pass-through

We are now in a position to relate the firm's exchange rate pass-through into its export prices with its market share and import intensity. The starting point for this analysis is the optimal price setting equation (11), which we rewrite as a full log differential:

$$\mathrm{d}\log P_{k,i}^* = \mathrm{d}\log \mathcal{M}_{k,i} + \mathrm{d}\log MC_i^*. \tag{12}$$

[17] We do not explicitly model variable trade costs, but if they take an iceberg form, they are without loss of generality absorbed into the $\xi_{k,i} D_k$ term in the firm-i demand (1) in destination k.

Consider first the markup term. Using (2)–(4), we have:

$$\mathrm{d}\log \mathcal{M}_{k,i} = -\Gamma_{k,i}\big(\mathrm{d}\log P_{k,i} - \mathrm{d}\log P_{s,k}\big) + \frac{\Gamma_{k,i}}{\rho - 1}\mathrm{d}\log \xi_{k,i}, \tag{13}$$

where converting the export price to local currency yields $\mathrm{d}\log P_{k,i} = \mathrm{d}\log P^*_{k,i} - \mathrm{d}\log \mathcal{E}_k$, and we now made explicit the subscript s indicating that $P_{s,k}$ is the industry-destination-specific price index. The markup declines in the relative price of the firm and increases in the firm's demand shock. From Proposition 1, $\Gamma_{k,i}$ is increasing in the firm's market share, and hence price increases for larger market-share firms are associated with larger declines in the markup.

Next, the change in the marginal cost in equation (10) can be decomposed as follows:

$$\mathrm{d}\log MC^*_i = \varphi_i\,\mathrm{d}\log \frac{\mathcal{E}_m \bar{U}_s}{\bar{V}^*_s} + \mathrm{d}\log \frac{C^*_s}{\bar{\Omega}_s} + \epsilon^{MC}_i. \tag{14}$$

This expression generalizes the result of Proposition 2 on the role of import intensity φ_i by providing the full decomposition of the change in the log marginal cost. Here $\bar{U}_s$ and $\bar{V}^*_s$ are the price indexes for the imported intermediates (in foreign currency) and domestic intermediates (in producer currency), respectively. The subscript s emphasizes that these indexes can be specific to sector s in which firm i operates. Finally, $\mathrm{d}\log \bar{C}^*_s/\bar{\Omega}_s$ is the log change in the industry-average marginal cost for a firm that does not import any intermediates, and ϵ^{MC}_i is a firm-idiosyncratic residual term defined explicitly in the appendix and assumed orthogonal with the exchange rate. In deriving (14), we maintain the assumption that the set of imported intermediates $J_{0,i}$ is sunk, yet this can be relaxed without qualitative consequences for the results.

Combining and manipulating equations (12)–(14), we prove our key theoretical result:

Proposition 3 *The first order approximation to the exchange rate pass-through elasticity into producer-currency export prices of the firm is given by*

$$\Psi^*_{k,i} \equiv \mathbb{E}\left\{\frac{\mathrm{d}\log P^*_{k,i}}{\mathrm{d}\log \mathcal{E}_k}\right\} = \alpha_{s,k} + \beta_{s,k}\varphi_i + \gamma_{s,k}S_{k,i}, \tag{15}$$

where $(\alpha_{s,k}, \beta_{s,k}, \gamma_{s,k})$ are sector-destination specific and depend only on average moments of equilibrium co-movement between aggregate variables common to all firms.

We now provide the interpretation of this result. The pass-through elasticity $\Psi^*_{k,i}$ measures the equilibrium log changes of the destination-k producer-currency price of firm i

relative to the log change in the bilateral exchange rate, averaged across all possible states of the world and shocks that hit the economy. Under this definition, the pass-through elasticity is a measure of equilibrium co-movement between the price of the firm and the exchange, rate rather than a partial equilibrium response to an exogenous movement in the exchange rate.

Proposition 3 shows that, independently of a particular general equilibrium environment, we can relate firm-level pass-through to market share and import intensity of the firm, which form a sufficient statistic for cross-section variation in pass-through within sector-destination. Under mild assumptions on equilibrium co-movement between exchange rate and aggregate variables (price and cost indexes), we show that $\beta_{s,k}$ and $\gamma_{s,k}$ are positive. For example:

$$\beta_{s,k} = \frac{1}{1+\bar{\Gamma}_{s,k}} \mathbb{E}\left\{ \frac{\mathrm{d}\log \mathcal{E}_m}{\mathrm{d}\log \mathcal{E}_k} \cdot \frac{\mathrm{d}\log(\mathcal{E}_m \bar{U}_s/\bar{V}_s^*)}{\mathrm{d}\log \mathcal{E}_m} \right\}, \tag{16}$$

where $\bar{\Gamma}_{s,k}$ is the markup elasticity evaluated at some average measure of market share $\bar{S}_{s,k}$. Intuitively, $\beta_{s,k}$ depends on the co-movement between export and import exchange rates and the pass-through of import exchange rate into the relative price of imported intermediates, as can be see from (16). Empirically, we expect both of this elasticities to be positive, and hence $\beta_{s,k} > 0$.

When $\beta_{s,k}, \gamma_{s,k} > 0$, the firms with a higher import intensity (φ_i) and larger destination-specific market share ($S_{k,i}$) adjust their producer prices by more. This in turn implies that these firms have lower pass-through into destination-currency prices (equal to $1 - \Psi^*_{k,i}$). Intuitively, the high import intensity of a firm reflects its marginal cost sensitivity to exchange rate changes, other things equal. Firms with marginal costs strongly co-moving with devaluations against the destination currency respond with a bigger adjustment to their producer-currency prices and hence a lesser change in their destination-currency prices. The larger destination market share of the firm reflects its greater markup elasticity. Hence, these firms choose to absorb a larger portion of their marginal cost fluctuations into markups.[18] Consequently, larger market share firms have lower pass-through into destination-currency export prices (or, equivalently, higher $\Psi^*_{k,i}$).

In the next section we test these hypotheses, as well as estimate the average magnitudes of β and γ in (15) to quantify the extent of cross-sectional variation in pass-through.

[18]Consider the destination-currency price, $P_{k,i} = \mathcal{M}_{k,i} MC^*_i/\mathcal{E}_k$. Changes in $\mathcal{E}_k$ affect $MC^*_i/\mathcal{E}_k$, and firms partially pass them through into their destination-currency price $P_{k,i}$ and partially absorb them in their markups $\mathcal{M}_{k,i}$, with the relative strength of the markup adjustment increasing in $\Gamma_{k,i}$ (and hence in $S_{k,i}$).

3 Empirical Evidence

This section provides our empirical results starting with a description of the dataset and the basic stylized facts on exporters and importers, proceeding with our main empirical results, and concluding with a battery of robustness tests.

3.1 Data description and construction of variables

Our main data source is the National Bank of Belgium, which provided a comprehensive panel of Belgian trade flows by firm, product (CN 8-digit level), exports by destination, and imports by source country. We merge these data, using a unique firm identifier, with firm level characteristics from the Belgian Business Registry, comprising information on firms' inputs, which we use to construct total cost measures and total factor productivity estimates. Our sample includes annual data for the period 2000 to 2008, beginning the year after the euro was introduced. We focus on manufacturing exports to the OECD countries outside the euro area: Australia, Canada, Iceland, Israel, Japan, the Republic of Korea, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States, accounting for 58 percent of total non-Euro exports.[19] We also include a robustness test with the full set of non-Euro destinations. We provide a full description of all the data sources in the data appendix.

The left-hand side variable in our analysis is the log change in a firm f's export price of good i to destination country k at time t, proxied by the change in a firm's export unit value, defined as the ratio of export values to export quantities:

$$\Delta p^*_{f,i,k,t} \equiv \Delta \log \left(\frac{\text{Export value}_{f,i,k,t}}{\text{Export quantity}_{f,i,k,t}} \right), \tag{17}$$

where quantities are measured as weights or units. We use the ratio of value to weights, where available, and the ratio of value to units otherwise. We note that unit values are an imprecise proxy for prices because there may be more than one distinct product within a CN 8-digit code despite the high degree of disaggregation constituting close to 10,000 distinct manufacturing product categories over the sample period. Some price changes may be due to compositional changes within a product code or to errors in measuring quantities.[20] To

[19] The Euro Zone was formed on January 1, 1999, in Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Greece joined on January 1, 2001, Slovenia joined in 2007, Cyprus and Malta joined in 2008, and Slovakia joined in 2009. We also exclude Denmark from the set of export destinations because its exchange rate hardly moves relative to the Euro.

[20] This is the typical drawback of customs data (as, for exmaple, is also the case with the French dataset

try to minimize this problem, we drop all year-to-year unit value changes of plus or minus 200 percent.

A distinctive feature of these data that is critical for our analysis is that they contain firm-level import values and quantities for each CN 8-digit product code by source country. We include all 242 source countries and all 13,000 product codes in the sample. Studies that draw on price data have not been able to match import and export prices at the firm level. In general, many firms engaged in exporting also import their intermediate inputs. In Belgium, around 80 percent of manufacturing exporters import some of their inputs. We use these import data to construct two key variables—the import intensity from outside the Euro Zone $\varphi_{f,t}$ and the log change in the marginal cost $\Delta mc^*_{f,t}$. Specifically,

$$\varphi_{f,t} \equiv \frac{\text{Total non-euro import value}_{f,t}}{\text{Total costs}_{f,t}}, \tag{18}$$

where total costs comprise a firm's total wage bill and total material cost. We often average this measure over time to obtain a firm-level average import intensity denoted with φ_f.

The change in marginal cost is defined as the log change in unit values of firm imports from all source countries weighted by respective expenditure shares:

$$\Delta mc^*_{f,t} \equiv \sum_{j \in J_{f,t}} \sum_{m \in M_{f,t}} \omega_{f,j,m,t} \, \Delta \log U^*_{f,j,m,t}, \tag{19}$$

where $U^*_{f,j,m,t}$ is the euro price (unit value) of firm f imports of intermediate good j from country m at time t, the weights $\omega_{f,j,m,t}$ are the average of period t and $t-1$ shares of respective import values in the firm's total costs, and finally $J_{f,t}$ and $M_{f,t}$ denote the set of all imported goods and import source countries (including inside the Euro Zone) for the firm at a given time period. Note that this measure of the marginal cost is still a proxy since it does not reflect the costs of domestic inputs and firm productivity. We control for estimated firm productivity separately; however, data on the prices and values of domestic inputs are not available. Nonetheless, controlling for our measure of the firm-level marginal cost is a substantial improvement over previous pass-through studies that typically control

used in Berman, Martin, and Mayer, 2012), where despite the richness of firm-level variables, we do not observe trade prices of individual items. As a result, two potential concerns are, one, aggregation across heterogeneous goods even at the very fine level of disaggregation (firm-destination-CN 8-digit product code level) and, two, aggregation over time of sticky prices. In particular, we cannot condition our analysis on a price change of a good, as was done in Gopinath, Itskhoki, and Rigobon (2010) using BLS IPP item-level data, which however is limited in the available firm characteristics and hence not suitable for our analysis. We address these two caveats by conducting a number of robustness tests and providing a cautious interpretation of our findings in Section 4.

only for the the aggregate manufacturing wage rate or producer price level. Furthermore, our measure of marginal cost arguably captures the component of the marginal cost most sensitive to exchange rate movements.

Ideally, we would like to construct $\varphi_{f,t}$ and $\Delta mc^*_{f,t}$ for each of the products i a firm produces; however, this measure is available only at the firm-f level, which may not be the same for all of the products produced by multi-product firms. To address this multi-product issue, we keep only the firm's main export products which we identify using Belgium's input-output table for the year 2005, comprising 56 IO manufacturing codes. For each firm, we identify an IO code that accounts for its largest export value over the whole sample period and keep only the CN 8-digit product codes within this major-IO code. The objective is to keep only the set of products for each firm that have similar production technologies. This leaves us with 60 percent of the observations but 90 percent of the value of exports. We also present results with the full set of export products and experiment with defining the major product using more disaggregated product lines, such as HS 4-digit. Further, it is possible that some of the firm's imports might be final goods rather than intermediate inputs. We attempt to identify imported intermediate inputs using a number of different approaches. First, we omit any imports from the construction of $\varphi_{f,t}$ that is defined as a final product using Broad Economic Codes (BEC).[21] Second, we construct φ_f using only the intermediate inputs for a given industry according to the IO tables.

The last key variable in our analysis is a firm's market share, which we construct as follows:

$$S_{f,s,k,t} \equiv \frac{\text{Export value}_{f,s,k,t}}{\sum_{f' \in F_{s,k,t}} \text{Export value}_{f',s,k,t}}, \tag{20}$$

where s is the sector in which firm f sells product i and $F_{s,k,t}$ is the set of Belgian exporters to destination k, in sector s at time t. Therefore, $S_{f,s,k,t}$ measures a Belgium firm's market share in sector s, export destination k at time t relative to all other Belgium exporters. Note that, following the theory, this measure is destination specific. The theory also suggests that the relevant measure is the firm's market share relative to all firms supplying the destination market in a given sector, including exporters from other countries as well as domestic competitors in market k. But, since our analysis is across Belgian exporters within sector-destinations, the competitive stance in a particular sector-destination is common for all Belgian exporters, and hence our measure of $S_{f,s,k,t}$ captures all relevant variation for our analysis (see below).[22] We define sectors at the HS 4-digit level, at which we both obtain

[21] See `http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=10`. We define intermediate inputs as including codes 111, 121, 2, 42, 53, 41, and 521.

[22] In an extension of the theory (not provided due to space constraints), a multiproduct firm sets the same

Table 1: Exporter and importer incidence

	Exporters and/or importers	All exporters
Fraction of all firms	32.6%	23.7%
of them:		
— exporters and importers	57.0%	78.4%
— only exporters	15.8%	21.6%
— only importers	27.2%	—

Note: *Manufacturing firms sample. Average frequencies over the years 2000–2008.*

a nontrivial distribution of market shares and avoid having too many sector-destinations served by a single firm.[23]

3.2 Stylized facts about exporters and importers

A salient pattern in our data set is that most exporters are also importers, a pattern also present in many earlier studies cited in the introduction. As reported in Table 1, in the full sample of Belgian manufacturing firms, the fraction of firms that are either exporters or importers is 33%. Out of these firms, 57% both import and export, 28% only import and 16% only export. That is, 22% of manufacturing firms in Belgium export and 78% of exporters also import.[24] We show that this empirical regularity turns out to be important in understanding why there is incomplete exchange rate pass-through. This high correlation between exporting and importing reflects the fact that selection into both of these activities is driven by firm characteristics such as productivity and scale of operation.

Interestingly, the data reveal a lot of heterogeneity within exporting firms, which are an already very select subsample of firms. The large differences between exporters and non-exporters are already well-known and are also prevalent in our data. The new stylized facts we highlight here are the large differences within exporters between high and low import-intensity exporting firms. We show in Table 2 that these two groups of exporting firms

markup for all its varieties within a sector, as in (11), where its markup depends on the cumulative market share of all these varieties. Therefore, $S_{f,s,k,t}$ is indeed the appropriate measure of market power for all varieties i exported by firm f to destination k in sector s at time t.

[23]The median of $S_{f,s,k,t}$ is 7.8%, yet the 75th percentile is over 40% and the export-value-weighted median is 55%. 24% of $S_{f,s,k,t}$ observations are less than 1%, yet these observations account for only 1.4% of export sales. 3% of $S_{f,s,k,t}$ observations are unity, yet they account for less than 2.5%. Our results are robust (and, in fact, become marginally stronger) to the exclusion of observations with very small and very large market shares. We depict the cumulative distribution function of $S_{f,s,k,t}$ in Figure A1 in the appendix.

[24]These statistics are averaged over the sample length, but they are very stable year-to-year. In the subsample of exporters we use for our regression analysis in Section 3.3, the fraction of importing firms is somewhat higher at 85.5%, reflecting the fact that data availability is slightly biased toward larger firms.

Table 2: Exporting firms with high and low import intensity φ_f

	Exporters		Non-exporters
	Import intensive	Not import intensive	
Share of total imports in total cost	0.368	0.173	0.016
Share of non-Euro imports in total cost (φ_f)	0.166	0.012	0.003
Employment (# full-time equiv. workers)	270.9	112.1	20.7
Average wage bill (thousands of Euros)	48.8	42.3	34.9
Material cost (millions of Euros)	103.5	28.1	3.0
Total Factor Productivity (log)	0.36	0.07	—
Market share (firm–destination–HS-4)	0.19	0.12	—
Export value	49.6	9.4	
# of products exported	28.5	12.0	
# of non-Euro export destinations	18.8	9.4	
# of non-Euro export destinations by HS-8	8.1	5.0	
Import value	49.3	6.9	
# of import source countries	14.5	9.2	
# of import source countries by HS-8	2.7	2.0	
# of HS 8-digit products imported	79.8	53.4	
# of HS 8-digit-country products imported	131.0	75.1	
Import value outside EZ	20.8	0.5	
# of import source countries outside EZ	8.7	4.3	
Producer-price pass-through coefficient	0.25	0.14	

Note: *The exporter sub-sample is split at the median of non-Euro import intensity (share of non-Euro imports in total costs) equal to 4.3%. The non-exporter subsample is all non-exporting manufacturing firms with 5 or more employees. All import and export values are in millions of Euros. 33% of low import intensity firms do not import at all, and 48% of them do not import from outside the Euro Zone. The construction of the measured TFP follows standard procedure and is described in the data appendix.*

differ in fundamental ways. We report various firm-level characteristics for high and low import-intensity exporters, splitting exporters into two groups based on the median import intensity outside the Euro Zone (φ_f) equal to 4.3%.[25] For comparison, we also report the available analogous statistics for non-exporting firms with at least 5 employees.

From Table 2, we see that import-intensive exporters operate on a larger scale and are more productive. The share of imported inputs in total costs for import-intensive exporters is 37% compared to 17% for nonimport-intensive exporters, and similarly for imports sourced outside the Euro Zone it is 17% compared to 1.2%. And of course, these numbers are much lower for non-exporters at 1.6% for imports outside Belgium and 0.3% for imports outside the

[25]The unit of observation here is a firm-year. If we split our sample based on firm-product-destination-year (which is the unit of observation in our regression analysis), the median import intensity is higher at 8.2%, however, this has no material consequences for the patterns we document in Table 2.

Table 3: Distribution of import intensity φ_f among exporters

	# firms	fraction of firms	fraction of export value
$\varphi_f = 0$	716	24.9%	1.2%
$0 < \varphi_f \leq 0.1$	1,478	51.3%	38.5%
$0.1 < \varphi_f \leq 0.2$	348	12.1%	23.8%
$0.2 < \varphi_f \leq 0.3$	154	5.4%	8.9%
$0.3 < \varphi_f \leq 0.4$	95	3.3%	22.7%
$\varphi_f > 0.4$	89	3.1%	4.9%

Note: *Import intensity, φ_f, is the share of imported intermediate inputs from outside the Euro Zone in the total cost of the firm, averaged over the sample period.*

Euro Zone. Import-intensive exporters are 2.5 times larger in employment than nonimport-intensive exporters and 13 times larger than non-exporters; they pay a 15 percent wage premium relative to non-import-intensive firms and a 40 percent wage premium relative to non-exporters. Similarly, import-intensive exporters have much larger total material costs, total factor productivity, and market share. These firms also export and import on a much larger scale, in terms of export and import values, number of export destinations, and import source countries and in numbers of exported and imported varieties of goods. Specifically, import-intensive firms import on average a total of 80 varieties of intermediate inputs (at the CN-8-digit level) from 14 countries, of which 9 countries are outside the Euro Zone. Compare this with the lower numbers for nonimport-intensive firms that import 53 varieties from 9 countries, of which 4 countries are outside the Euro Zone. These numbers highlight that both types of exporting firms are active in importing from a range of countries both within and outside the Euro Zone but that the two types of firms differ substantially in import intensity, consistent with the predictions of our theoretical framework. We exploit the large differences between these two groups of exporters to show that import-intensive firms have a higher exchange rate pass-through into producer prices which we report in the last row of Table 2 and further explore in Section 3.3.

We now provide more details on the distribution of import intensity outside the Euro Zone (φ_f) among the exporting firms and its relationship with other firm-level variables. We see that the distribution of import intensity among exporters in Table 3, although somewhat skewed toward zero, has a wide support and substantial variation, which we exploit in our regression analysis in Section 3.3. Over 24% of exporters do not import from outside the Euro Zone; yet they account for only 1% of Belgian manufacturing exports. For the majority of firms, the share of imported inputs in total costs ranges between 0 and 10%. At the same time, the export-value-weighted median of import intensity is 12.7% and nearly 28% of export

Table 4: Correlation structure of import intensity

	Import intensity	TFP	Revenues	Empl't	Material cost
Market share	0.16	0.20	0.28	0.25	0.27
Material cost	0.23	0.70	0.99	0.83	
Employment	0.10	0.60	0.86		
Revenues	0.21	0.72			
TFP	0.15				

Note: *Cross-sectional correlations of firm-level variables averaged over time. Material costs, employment, revenues and TFP are in logs. Import intensity is the share of imported intermediate inputs from outside the Euro Zone in the total cost of the firm.*

sales are generated by the firms with import intensity in excess of 30%.[26] We further depict the cumulative distribution function of import intensity φ_f in Figure A1 in the appendix, which also provides a cumulative distribution function for our market share variable $S_{f,s,k,t}$.

Table 4 displays the correlations of import intensity with other firm-level variables in the cross-section of firms. Confirming the predictions of Proposition **??**, import intensity is positively correlated with market share, as well as with firm TFP, employment, and revenues. The strongest correlate of import intensity is the total material cost of the firm, consistent with the predictions of Proposition 2. Overall, the correlations in Table 4 broadly support the various predictions of our theoretical framework. At the same time, although import intensity and market share are positively correlated with productivity and other firm performance measures, there is sufficient independent variation to enable us to distinguish between the determinants of firm pass-through incompleteness in the following subsections.

We close this section with a brief discussion of the patterns of time-series variation in import intensity for a given firm. Import intensity appears to be a relatively stable characteristic of the firm, moving little over time and in response to exchange rate fluctuations. Specifically, the simple regression of $\varphi_{f,t}$ on firm fixed effects has an R^2 of over 85%, implying that the cross-sectional variation in time-averaged firm import intensity φ_f is nearly 6 times larger than the average time-series variation in $\varphi_{f,t}$ for a given firm. When we regress the change in $\varphi_{f,t}$ on firm fixed effects and the lags of the log change in firm-level import-weighted exchange rates, the contemporaneous effect is significant with the semi-elasticity of only 0.056, and with offsetting, albeit marginally significant, lag effects. That is, a 10% depreciation of the euro temporarily increases import intensity by 0.56 of a percentage point.

[26] While the unweighted distribution (firm count) has a single peak, the export-value-weighted distribution has two peaks. This is due to the fact that one exporter with $\varphi_f = 0.33$ accounts for almost 14% of export sales. Our results are not sensitive to the exclusion of this largest exporter, which accounts for only 134 observations out of a total of over 90,000 firm-destination-product-year observations in our sample.

Furthermore, we find that the firm hardly adjusts its imports on the extensive margin in response to changes in its import-weighted exchange rate.[27] All of this evidence provides support for our assumption in Section 2 that the set of imported goods is a sunk decision at the horizons we consider, and hence the extensive margin plays a very limited role in the response of a firm's marginal cost to exchange rate movements, justifying the use of φ_f as a time-invariant firm characteristic in the empirical regressions that follow.

To summarize, we find substantial variation in import intensity among exporters, and this heterogeneity follows patterns consistent with the predictions of our theoretical framework. Next, guided by the theoretical predictions, we explore the implications of this heterogeneity for the exchange rate pass-through patterns across Belgian firms.

3.3 Main empirical findings

Empirical specification We now empirically estimate the relationship between import intensity, market share and pass-through in the cross-section of exporters (Proposition 3). Theoretical regression equation (15) cannot be readily estimated since pass-through $\Psi^*_{k,i}$ is not a variable that can be measured in the data. Therefore, we step back to the decomposition of the log price change in (12)–(14), which we again linearize in import intensity and market share. After replacing differentials with changes over time Δ, we arrive at our main empirical specification, where we regress the annual change in log export price on the change in the exchange rate, interacted with import intensity and market share:

$$\Delta p^*_{f,i,k,t} = \left[\alpha_{s,k} + \beta\varphi_{f,t-1} + \tilde{\gamma} S_{f,s,k,t-1}\right]\Delta e_{k,t} + \left[\delta_{s,k} + b\varphi_{f,t-1} + cS_{f,s,k,t-1}\right] + \tilde{u}_{f,i,k,t}, \quad (21)$$

where $p^*_{f,i,k,t}$ is the log Euro *producer price* to destination k (as opposed to local-currency price) and an increase in the log exchange rate $e_{k,t}$ corresponds to the bilateral depreciation of the Euro relative to the destination-k currency.[28] In our analysis we focus on estimating parameters β and $\tilde{\gamma}$ with values pooled across sector-destinations. We emphasize that regression (21) is a structural relationship emerging from the theoretical model of Section 2, and $S_{f,s,k,t-1}$ corresponds to our measure of market share defined in (20). Under a mild assumption that $\Delta e_{k,t}$ is uncorrelated with $(\varphi_{f,t-1}, S_{f,s,k,t-1})$, we prove in the appendix:

[27] We measure the extensive margin as the change in firm imports due to adding a new variety or dropping an existing variety at CN 8-digit level.

[28] The exchange rates are average annual rates from the IMF. These are provided for each country relative to the US dollar, which we convert to be relative to the Euro.

Proposition 4 *The OLS estimates of β and $\tilde{\gamma}$ in* (21) *identify the weighted averages across sector-destinations of $\beta_{s,k}$ and $\gamma_{s,k} \cdot \mathbf{S}_{s,k,t-1}$ respectively, where $\mathbf{S}_{s,k,t-1}$ is the sector-destination-time-specific cumulative market share of all Belgian exporters and $(\beta_{s,k}, \gamma_{s,k})$ are the theoretical coefficient in the pass-through relationship* (15)*.*

This result shows that, despite the fact that we cannot directly estimate the theoretical regression (15), we can nonetheless identify the theoretical coefficients in the relationship between pass-through, import intensity and market share. Furthermore, it formally confirms the validity of our measure of the market share relative to other Belgian exporters.

Equation (21) is our benchmark empirical specification. Note that it is very demanding in that it requires including sector-destination dummies and their interactions with exchange rate changes at a very disaggregated level. Therefore, we start by estimating equation (21) with a common coefficient α for the group of non-Euro OECD countries within the manufacturing sector. Later we allow for α to be country-industry specific at a much higher degree of industry disaggregation, as well as estimate (21) for exports to a single destination (US) only. Furthermore, in our main regressions we replace $\varphi_{f,t-1}$ with a time-invariant φ_f to reduce the measurement error, and also replace $S_{f,s,k,t-1}$ with contemporaneous $S_{f,s,k,t}$ to maximize the size of the sample. Since these variables are very persistent over time, this has virtually no effects (qualitative or quantitative) on our results, as we show in the robustness section where we use lagged $\varphi_{f,t-1}$ and $S_{f,s,k,t-1}$.

Estimation results To explore the underlying mechanisms behind the equilibrium relationship between pass-through, import intensity, and market shares, we begin with a more simple specification and build up to the specification in equation (21). Table 5 reports the results. First, in column 1, we report that at the annual horizon the unweighted average exchange rate pass-through elasticity into producer prices in our sample is 0.21, or, equivalently, $0.79 (= 1 - 0.21)$ into destination prices. We refer to it as 79% pass-through.

In column 2, we include an interaction between exchange rates and a firm's import intensity. We see that the simple average coefficient reported in column 1 hides a considerable amount of heterogeneity, as firms with different import intensities have very different pass-through rates. Firms with a high share of intermediate inputs relative to total variable costs exhibit lower pass-through into destination-specific export prices—a 10 percentage point higher import intensity is associated with a 5.3 percentage point lower pass-through. A typical firm with zero import intensity has a pass-through of $85\% (= 1 - 0.15)$, while a firm with a 38% import intensity (in the 95th percentile of the distribution) has a pass-through

Table 5: Import intensity, market share, and pass-through

Dep. var.: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta e_{k,t}$	0.214***	0.149***	0.129***	0.136***	0.077***	0.088***
	(0.029)	(0.030)	(0.028)	(0.038)	(0.028)	(0.031)
$\Delta e_{k,t} \cdot \varphi_f$		0.526***	0.285***	0.375*	0.178	0.397***
		(0.097)	(0.104)	(0.202)	(0.108)	(0.091)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$					0.225***	0.262***
					(0.054)	(0.059)
$\Delta mc^*_{f,t}$			0.582***		0.577***	
			(0.034)		(0.033)	
FPY FE	no	no	no	yes	no	no

Note: *Observations unweighted at the firm-destination-product-year level; number of observations in each regression is 92,693.* Δ *corresponds to annual changes. All regressions include country fixed effects. FPY FE stands for firm-product-year fixed effects. Regressions (2)–(3) and (6) include a control for the level of* φ_f*, and regression (5)–(6) also include a control for the level of the market share,* $S_{f,s,k,t}$*.* * *and* *** *correspond to 10% and 1% significance levels respectively. Standard errors are clustered at the country-year level, reported in brackets. Alternative clustering at the firm level and at the country-HS 4-digit level yield the same conclusions.*

of only $65\%(= 1 - (0.15 + 0.53 \cdot 0.38))$.

Next, we explore whether import intensity operates through the marginal-cost channel or through selection and the markup channel. In columns 3 and 4, we add controls for the marginal cost of the firm to see whether the effect of import intensity on pass-through persists beyond the marginal cost channel. In column 3, we control for the change in marginal cost $\Delta mc^*_{f,t}$, measured as the import-weighted change in the firm's import prices of material inputs (see (19)), which is likely to be sensitive to exchange rate changes if the firm relies heavily on imported intermediate inputs. Comparing columns 2 and 3, we see that the coefficient on the import intensity interaction nearly halves in size once we control for marginal cost, dropping from 0.53 to 0.29, but still remains strongly significant with a t-stat of 2.74. We confirm this finding with an alternative control for marginal cost changes, by including firm-product-year fixed effects (FPY FE) in column 4. In this specification, the only variation that remains is across destinations for a given firm and hence, among other things, arguably controls for all components of the marginal cost of the firms. The coefficient on the import intensity interaction in column 4 is somewhat larger compared to column 3, but still about a third smaller compared to column 2 without the control for marginal cost. The coefficient in column 4 is much less precisely estimated, yet it remains marginally significant with a t-stat of 1.86. This result is impressive, given that this specification is saturated with fixed effects, and the similarity of the results in columns 3 and 4 provides confidence in our

measure of marginal cost.

The results in column 3 and 4 suggest that, although the marginal cost is an important channel through which import intensity affects pass-through (see Proposition 2), there is still a considerable residual effect after conditioning on the marginal cost that is operating through the markup channel. This effect is consistent with theoretical predictions, since import intensity correlates with market share in the cross-section of firms and market share determines the markup elasticity (hence, omitted variable bias). To test this, in column 5 we augment the specification of column 4 (controlling for $\Delta mc^*_{f,t}$) with a market share interaction with the log change in exchange rate to proxy for markup elasticity, as suggested by Proposition 3. Given that we now control for both marginal cost and markup, we expect import intensity to stop having predictive power. Indeed, the coefficient on import intensity interaction further nearly halves in size (from 0.29 to 0.18) and becomes statistically insignificant.[29]

Finally, column 6 implements our main specification in (21) by including the import intensity and market share interactions, without controlling for marginal cost. Proposition 3 suggests that import intensity and market share are two prime predictors of exchange rate pass-through, and indeed we find that the two interaction terms in column 6 are strongly statistically significant. Interpreting our results quantitatively, we find that a firm with a zero import intensity and a nearly zero market share (corresponding respectively to the 5th percentiles of both distributions) has a pass-through of $91.2\%(= 1 - 0.088)$. Although complete pass-through for such firms is statistically rejected, a 97% pass-through coefficient falls within a 95% confidence interval around our point estimate. A hypothetical non-importing firm with a 75% market share relative to other Belgian exporters (corresponding to the 95th percentile of the firm-level distribution of market shares) has a pass-through of 71.5%, that is 19.7 percentage points ($= 0.262 \cdot 0.75$) lower. Holding this market share constant and increasing the import intensity of the firm from zero to 38% (corresponding again to the 95th percentile of the respective distribution) reduces the pass-through by another 15.1 percentage points ($= 0.397 \cdot 0.38$), to 56.4%. Therefore, variation in market share and import intensity explains a vast range of variation in pass-through across firms.[30]

[29] Importantly, the coefficient $\Delta mc^*_{f,t}$ in both specifications of columns 3 and 5 is remarkably stable at 0.58. The theory suggests that this coefficient should be $1/(1+\bar{\Gamma})$, that is the average pass-through elasticity of idiosyncratic shocks into prices, corresponding to an average markups elasticity of $\bar{\Gamma} \approx 0.7$, close to the estimates provided in Gopinath and Itskhoki (2011) using very different data and methods.

[30] Additionally, we have also looked for possible non-monotonic effects of market share on pass-through by augmenting the main specification in column 6 of Table 5 with a quadratic term in market share and its interaction with the exchange rate change. The coefficient on squared market share interaction is negative, but insignificant and small, so even taking its point estimate, the estimated relationship between pass-

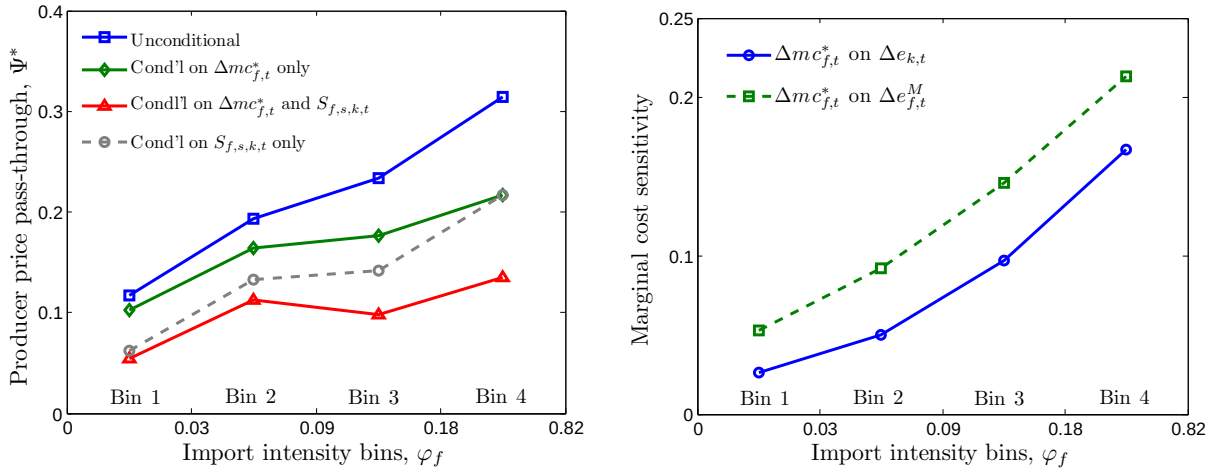

Figure 1: Pass-through by quartile of φ_f distribution

Note: *Equal-sized bins in terms of firm-product-year-destination observations. The means of φ_f in the four bins are 1.3%, 5.5%, 13.1% and 30.1% respectively. The left panel reports pass-through coefficients of $\Delta p^*_{f,i,k,t}$ on $\Delta e_{k,t}$ within each φ_f-quartile, where the regressions include additional controls in levels and interacted with $\Delta e_{k,t}$, as indicated in the legend of the figure. The right panel reports the pass-through coefficients from regressions of the log change in our measure of the marginal cost of the firm $\Delta mc^*_{f,t}$ on both bilateral export exchange rates $\Delta e_{k,t}$ and firm-level import-weighted exchange rate $\Delta e^M_{f,t}$, by quartiles of the φ_f-distribution. Additional information reported in Table A1 in the appendix.*

Deciphering the mechanism Our main empirical findings in Table 5 provide strong support for the theoretical predictions developed in Section 2. However, we want to ensure that these results are smooth and not driven by outliers, as well as to isolate the particular mechanism through which import intensity affects pass-through. We re-estimate the specifications in Table 5 nonparametrically, by splitting the distribution of import intensity φ_f into four quartiles. Specifically, we estimate a separate pass-through coefficient for each quartile of the import intensity distribution, including additional controls, and plot these coefficients in the left panel of Figure 1. All estimated coefficients, standard errors, and p-values are reported in Table A1 in the appendix. The graph shows that the coefficient is estimated to be monotonically higher (thus lower pass-through) as we move from low to higher import intensity bins when we do not include both marginal cost and market share controls. The steepest line corresponds to the unconditional regression (a counterpart to column 2 of Table 5), and is somewhat flatter with controls for marginal cost (column 3), and it is much flatter after controlling jointly for the change in the marginal cost and the market share interaction (column 5). The dashed line corresponds to our main specification (column 6), which controls for both market share and import intensity, but not marginal cost, and it also exhibits a considerable slope across the import intensity bins. Furthermore,

through and market share remains monotonically increasing throughout the whole range $[0, 1]$ of the market share variable. This confirms the theoretical prediction in Proposition 1.

in all of these cases the difference between the pass-through coefficient in the first and fourth quartiles is significant with a p-value of 1%, with the exception of when we control for both marginal cost and market share. Consistent with our findings in column 5 of Table 5, when controlling for market share and marginal costs, the profile of pass-through coefficients across the bins of the import intensity distribution becomes nearly flat with the differences between the pass-through values in different bins statistically insignificant.

A key mechanism that the theory highlights is that import intensity affects exchange rate pass-through by increasing the marginal cost sensitivity to exchange rates (Proposition 2). In the right panel of Figure 1, we test this by regressing our measure of the change in the marginal cost $\Delta mc^*_{f,t}$ on the change in the destination-specific exchange rate $\Delta e_{k,t}$ and separately on the change in the firm-level import-weighted exchange rate $\Delta e^M_{f,t}$, within each quartile of the import-intensity distribution.[31] Indeed, we find a very tight monotonically increasing pattern of marginal cost sensitivity to the destination-specific exchange rates across the bins with increasing import intensity. Quantitatively, an increase in import intensity from 1% on average in the first quartile to 30% on average in the fourth quartile leads to an increase in marginal cost sensitivity to the exchange rate from 0.03 to 0.17. Consistent with the theory, the response of the marginal cost to the import-weighted exchange rate is also monotonically increasing in φ_f and lies strictly above the response to the destination-specific exchange rate, ranging from 0.05 to 0.21. Table A1 reports the coefficients from these regressions in columns 6 and 7.

Column 8 of Table A1 also reports the projection coefficients of firm-level import-weighted exchange rates $\Delta e^M_{f,t}$ on destination-specific exchange rates $\Delta e_{k,t}$ across the quartiles of import-intensity distribution. This link is important for our mechanism since we expect import intensity to affect pass-through into export prices only to the extent that import and export exchange rates correlate with each other (see (16)). We find these projection coefficients to be stable at around 0.45, with no systematic and little overall variation across bins of import intensity. In particular, the coefficients across the range of import intensity cannot be distinguished statistically from each other. Furthermore, we find little evidence of *real hedging*, when firms may align their import sources and export destinations to hedge their exchange rate risks, which should be reflected in high coefficients in firm-level regression of import-weighted exchange rates on export-destination exchange rates.[32] Important

[31] The import-weighted exchange rate $\Delta e^M_{f,t}$ is a weighted average of bilateral exchange rates with weights equal to the import expenditure shares from outside the Euro Zone at the firm-level.

[32] Specifically, the median of the distribution of these firm-level regression coefficients is not substantially higher than the average of the regression coefficient of the manufacturing-wide import-weighted exchange rate on destination-specific exchange rates. At the same time, the distribution of firm-level regression coefficients

Table 6: Pass-through by import-intensity and market-share bins

	Low import intensity	High import intensity
Low market share	0.114***	0.146***
Fraction of observations	*30.0%*	*20.0%*
Share in export value	*8.8%*	*9.3%*
High market share	0.235***	0.388***
Fraction of observations	*19.9%*	*30.1%*
Share in export value	*21.2%*	*60.7%*

Note: *Coefficients from regression of $\Delta p^*_{f,i,k,t}$ on $\Delta e_{k,t}$ within respective bins. Firms are sorted by market share $S_{f,s,k}$ into below and above the median equal to 9.8%; and by import intensity φ_f into below and above median equal to 8.2%. All coefficients are significantly different from each other at least at a 5% level, with the exception of 0.114 and 0.146 which are statistically distinguishable only at 10.6% level. The reported fraction of observations is at the firm-product-destination level.*

for the interpretation of our results is the absence of systematic variation in our measure of real hedging across the bins of import intensity. To summarize, we conclude that the marginal cost channel through which import intensity affects pass-through, as emphasized in the theory, is indeed at play empirically and that import intensity does not appear to proxy for other omitted characteristics of the firm, such as the extent of real hedging.

Finally, given the importance of the interaction effects between import intensity and market share highlighted in the theory, we explore it further nonparametrically in Table 6 by creating four bins based on whether a firm's market share and import intensity are above or below their respective medians. Within each bin, we estimate a simple pass-through regression of the change in producer export prices on the change in the exchange rate. Consistent with results in column 6 of Table 5, we find that pass-through into destination-specific export prices decreases significantly either as we move toward the bin with a higher market share or toward the bin with a higher import intensity. The lowest pass-through of $61\%(= 1 - 0.388)$ is found in the bin with above median market share and above median import intensity, compared with the pass-through of $89\%(= 1 - 0.114)$ for firms with below median import intensity and market share, quantitatively consistent with the results in Table 5.

Furthermore, we report in Table 6 the fraction of observations and the share in total export value that fall within each of the four bins. Although we split the sample at the

exhibits a lot of variation, possibly due to imprecise measurement of the firm-level import-weighted exchange rate and the short estimation window. In addition, we find no evidence that firms switch the countries of their input sourcing in response to exchange rate fluctuations, at least at the horizons we consider in our pass-through estimation.

medians along both dimensions, we end up with more observations along the main diagonal (around 30% in each bin) relative to the inverse diagonal (around 20% in each bin). This finding reflects the positive correlation between the market share and the import intensity in the cross-section of firms. This notwithstanding, the share of export value in the first bin with both low market share and low import intensity is only 9%. The fourth bin with both above median import intensity and market share accounts for the majority of export values, namely, over 60%. Table 6 also suggests that the pass-through coefficient into destination prices from an unweighted regression as in column 1 of Table 5 should be substantially higher than from a regression in which observations are weighted by respective export values. Indeed, when weighting by export values, we find a pass-through coefficient of 64.5% as opposed to 78.6% in the unweighted specification, consistent with our earlier calculations.[33] Our evidence further shows that part of this difference is due to greater markup variability among the large exporters, but of a quantitatively similar importance is the higher import intensity of these firms.

3.4 Extensions and robustness

In this section we provide some additional evidence on the particular mechanism at play behind our main empirical findings, as well as report results from an extensive series of robustness tests.

Which imports matter? We first explore whether imports from all countries are equally important for exchange rate pass-through. Our main results in the previous section focused on the measure of imports from outside the Euro Zone as a share of total variable costs of the firm. Hence, although this measure fully excludes all imports of Belgian firms from other members of the common currency area, it treats symmetrically all source countries outside the currency union. We now ask whether imports from within the Euro Zone play a separate role in affecting pass-through, and whether imports from OECD and non-OECD countries outside the Euro Zone have different effects on pass-through. This is a possibility since what matters for marginal cost changes, beyond the exchange rate variation, is the pass-through of shocks into the prices of imported inputs, and this may well vary across import source countries.

Table 7 reports the results when we estimate our main empirical specifications with

[33]This difference also largely helps close the gap in the pass-through estimates between firm-level trade datasets finding larger pass-through (as, for example, in Berman, Martin, and Mayer, 2012) and product-level datasets finding substantially lower pass-through (as, for exmaple, in Gopinath and Itskhoki, 2010).

Table 7: Euro-area imports and imports from OECD vs non-OECD countries

	Euro Area imports		OECD vs non-OECD
Dep. var.: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)
$\Delta e_{k,t} \cdot \varphi_f$	0.534***	0.394**	
	(0.099)	(0.094)	
$\Delta e_{k,t} \cdot \varphi_f^{EZ}$	0.103	0.027	0.025
	(0.122)	(0.120)	(0.121)
$\Delta e_{k,t} \cdot \varphi_f^{OECD}$			0.485***
			(0.156)
$\Delta e_{k,t} \cdot \varphi_f^{non-OECD}$			0.272
			(0.193)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$		0.261***	0.261***
		(0.059)	(0.060)

Note: φ_f^{EZ} *is the share of firm's imports from within the Euro Zone in total variable costs, so that* $\varphi_f + \varphi_f^{EZ}$ *is the share of total imports in variable costs.* φ_f^{OECD} *and* $\varphi_f^{non-OECD}$ *are the cost shares of imports from non-Euro OECD and non-OECD countries respectively, so that* $\varphi_f^{OECD} + \varphi_f^{non-OECD} = \varphi_f$*. All regressions additionally include* $\Delta e_{k,t}$ *without interactions, as well as controls for levels of all variables included as interaction terms. The coefficients on* $\Delta e_{k,t}$ *range closely around 0.088 estimate in column 6 of Table 5 and hence are not reported for brevity. Other details as in Table 5.*

additional measures of import intensity. In columns 1–2, alongside our measure of import intensity from outside the Euro Area φ_f, we include φ_f^{EZ}—the share of imports from within the Euro Area in total variable costs. Column 1 has no additional controls, analogous to specification (2) in Table 5, while column 2 also controls for the market share interaction, as in our main specification (6) in Table 5. We find that imports from within the Euro Area have no additional effect on pass-through once we control for import intensity from outside the Euro Area. Indeed, we do not expect imports from within the Euro Zone to affect marginal costs differentially from inputs sourced inside Belgium. However, what is also interesting is that importing from within the Euro Zone does not appear to be a strong indicator of firm selection, since this variable does not have predictive ability even when we do not control for market share.

In column 3 of Table 5 we re-estimate our main empirical specification but partition the non-euro import intensity φ_f into import intensity from non-OECD and OECD countries outside the Euro Zone, as well as controlling for import intensity from within the Euro Zone, which still turns out inconsequential. We find that only imports from non-Euro OECD countries have a statistically significant effect on pass-through, while the effect of imports from non-OECD countries is half as big in its point estimate but is imprecisely

estimated. To gain further understanding of these results, we estimate pass-through regressions of import-country exchange rates into the price of imported inputs from each country, pooling separately the coefficients on all OECD and all non-OECD countries, and weighting the observations by their import shares. We find the import pass-through coefficient to be 48% from OECD countries and only 15% from non-OECD countries. Therefore, despite substantial fluctuations in Euro exchange rates with non-OECD countries, the pass-through from these countries into the prices of intermediate goods is very low, which explains why a high import intensity of a firm from these countries has little bearing on the firm's pass-through into export prices.[34] Finally, we find that larger importers in our sample import more from non-OECD countries, apparently another dimension of firm selection in the data. Specifically, the share of non-OECD imports monotonically increases from 24% to 45% as we go from the lowest to the highest quartile of import intensity. This pattern explains the somewhat moderated slope of the marginal cost pass-through across import-intensity quartiles reported in the right panel of Figure 1, and acts to diminish the strength of the export-price pass-through effects that we find, which are nonetheless large.

To ensure that our results are not sensitive to our definition of φ_f, we experimented extensively with alternative definitions. We report these robustness checks in Table A2 in the appendix, where we estimate our main empirical specification using different definitions of import intensity. First, in column 1, we verify that our results are unchanged when in specification (21) we use lagged time-varying $\varphi_{f,t-1}$ and $S_{f,s,k,t-1}$, as suggested by Proposition 4, instead of φ_f and $S_{f,s,k,t}$ respectively. Remarkably, the coefficient on the import-intensity interaction decreases only marginally, while the coefficient on market share interaction is completely unchanged.

Next, in columns 2 and 3 of Table A2, we respectively restrict the definition of imports to exclude consumer goods and capital goods. In the subsequent columns, we use IO tables to identify a firm's intermediate inputs. In column 4, we include only imports identified as intermediate inputs in the IO tables for all of the firm's exports, and in column 5 we only include IO inputs for a firm's IO major exports. Finally, in column 6, we exclude any import at the CN 8-digit industrial code if the firm simultaneously exports in this category to deal with the possibility of *carry-along trade* (Bernard, Blanchard, Van Beveren, and Vandenbussche, 2012). In all cases, the results are essentially unchanged, except that in

[34]This differential pass-through from rich and poor countries has been documented in many previous studies (e.g., see discussion in Gopinath and Itskhoki, 2011). One possible reason for this is low differentiation of products coming from poor countries. Another potential reason is volatile macroeconomic policies in the poor countries leading to swings in exchange rates, which do not affect foreign-currency prices of international transactions of these countries.

the last case the coefficient on the import intensity substantially increases, but it should be noted that the average import intensities here are much lower as we drop a large share of imports from the import intensity calculation.

Within destination-industry We now check whether the empirical relationship between pass-through, market share, and import intensity documented in Table 5 is driven largely by within industry-destination variation, as suggested by Propositions 3 and 4. Table A3 reports the results from estimating equation (21) with exchange rate changes interacted with industry-destination fixed effects (that is, allowing for sector-destination specific $\alpha_{s,k}$). Columns 1–4 of this table replicate the main specifications in Table 5 augmented with destination-industry (SITC 1-digit) fixed effects both in levels and interacted with exchange rate changes, hence identifying the pass-through relationship within destination and 1-digit manufacturing industries. The results are nearly identical to those in Table 5, in which we restricted $\alpha_{s,k}$ to be the same across 12 non-Euro OECD destinations and all manufacturing exports. This suggests that the relationship between pass-through, import intensity and market share that we uncover is almost entirely a within industry-destination relationship. We further confirm this in column 5 of Table A3 by controlling for industry interactions at a higher degree of disaggregation (specifically, 163 3-digit SITC manufacturing industries), but dropping the destination fixed effects.

Alternative samples We further check the robustness of our results within alternative subsamples of the dataset, both in the coverage of export destinations and in the types of products. Table A4 in the appendix provides the results from estimates of the main specification from column 6 of Table 5 in eight alternative subsamples. By and large, it reveals the same qualitative and quantitative patterns we find in our benchmark sample.

Columns 1–3 of Table A4 report the results for three alternative sets of export destinations—all non-Euro countries, non-Euro OECD countries excluding the US, and the US only. It is noteworthy that for the US subsample we estimate both a lower baseline pass-through (for firms with zero import intensity and market share) and a stronger effect of import intensity on pass-through, than for other countries. Specifically, small non-importing firms exporting to the US market pass-through on average only 80% of the Euro-Dollar exchange rate changes, while the largest firms with high import-intensity (at the 95th percentile) pass-through only 39%. This is consistent with previous work on low pass-through into the US and the prevalence of US dollar pricing in international transactions (which likely also affects the import prices of the Belgian firms).

The remaining columns in Table A4 consider a different set of products and firms. So far, all of the specifications have been restricted to the subsample of only manufacturing firms because our φ_f measure is likely to be a better proxy of import intensity in manufacturing than for wholesalers, who may purchase final goods within Belgium to export them or alternatively import final goods for distribution within Belgium.[35] In column 4, which adds in all wholesale firms to our baseline sample, we see that although the import intensity and market share interactions are still positive and significant, their magnitudes and t-stats are smaller. The wholesalers represent around 40 percent of the combined sample. Next, in column 5, we drop all intra-firm transactions from our baseline sample (around 15 percent of observations), and this has little effect on the estimated coefficients.[36]

Finally, our sample has included only the firm's major export products, based on its largest IO code, in order to address the issue of multi-product firms. In columns 6–8, we show that the results are not sensitive to this choice of "main products". In column 6, we include all of the firm's manufacturing exports rather than restricting it only to IO major products. In column 7, we adopt an alternative way to identify a firm's major products, using the HS 4-digit category, which is much more disaggregated than the IO categories. And in column 8, we only include a firm if its HS 4-digit major category accounts for at least 50 percent of its total exports. In all three cases, we find the magnitudes on the import intensity and market share interactions very close to our main specification.

Additional controls Our theory provides sharp predictions that market share is a sufficient statistic for markup variability and that import intensity is an important predictor of marginal cost sensitivity to exchange rate changes. Therefore, together they form a sufficient statistic for pass-through (Proposition 3). We test this prediction by including additional controls, which could be viewed as alternative proxies for markup elasticity and marginal cost sensitivity to exchange rates. Specifically, Table 8 re-estimates the main empirical specification in column 6 of Table 5 with additional controls—firm's employment size and measured TFP interactions with the exchange rate change. Consistent with theory and with the empirical correlations in Table 4, market share and import intensity are both positively

[35] Another related concern is that even some non-wholesale firms may import their intermediate inputs through other Belgian firms, which we cannot see in our data, and hence cannot adjust accordingly our measure of import intensity. Note, however, that this would work against our findings since some of the fundamentally import-intensive firms would be wrongly classified into low import-intensity. This measurement error should cause a downward bias in our estimates of the import-intensity effects on pass-through, which we find to be large nonetheless.

[36] Using data from the Belgium National Bank, we classify intra-firm trade as any export transaction from a Belgium firm to country k in which there is either inward or outward foreign direct investment to or from that country.

Table 8: Robustness with additional controls

Dep. var.: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)
$\Delta e_{k,t} \cdot \varphi_f$	0.326***	0.353***	0.387***
	(0.095)	(0.098)	(0.098)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$	0.199***	0.235***	0.265***
	(0.060)	(0.061)	(0.060)
$\Delta e_{k,t} \cdot \log L_{f,t}$	0.043***		
	(0.012)		
$\Delta e_{k,t} \cdot \log TFP_{f,t}$		0.054**	
		(0.023)	
$\Delta \log W^*_{f,t}$			-0.008
			(0.013)
$\Delta \log TFP_{f,t}$			0.037***
			(0.006)
# observations	91,891	91,424	86,958

Note: *The same specification as in column 6 of Table 5, augmented with additional controls.* $L_{f,t}$ *is firm employment,* $W^*_{f,t}$ *is firm average wage rate, and* $TFP_{f,t}$ *is the estimate of firm total factor productivity.*

correlated with employment and measured TFP in the cross-section of firms. As a result, it is possible that the market share or import intensity variables are picking up variation in one of these other variables.[37]

Columns 1 and 2 of Table 8 show that our empirical findings are robust to the inclusion of additional interaction terms. Controlling for employment and TFP interactions reduces slightly the estimated coefficients on import intensity and market share interactions, but they remain large and strongly statistically significant. The coefficients on employment and TFP interactions, although significant, are in turn quantitatively very moderate. Finally, column 3 of Table 8 controls for the local component of the marginal cost by including the change in the measure of the firm-level wage rate and the log change in firm TFP to isolate the effect of import intensity through the foreign-sourced component of the marginal cost of the firm. These controls have essentially no effect on the estimated coefficients of interest.

[37]In theories where productivity is the only source of heterogeneity, market share, employment, and productivity itself are all perfectly correlated. However, when there is more than one source of heterogeneity, these variables are correlated less than perfectly. The modeling framework that we use makes a sharp prediction that market share is the sufficient statistic for markup. Alternative theories may emphasize firm productivity as the sufficient statistic for markup variability, as for example in Berman, Martin, and Mayer (2012). Specifications in columns 1–2 of Table 8 are counterparts to some of their regressions with the exception that we include both the import intensity and market share interactions. Overall, our empirical results are consistent with their findings in that more productive firms have lower pass-through, but we split this effect into the markup and marginal cost effects by controlling separately for market share and import intensity, and show that these two controls are at least as strong as employment and productivity, consistent with our theoretical model.

4 Conclusion

In this paper, we show that taking into account that the largest exporting firms are also the largest importers is key to understanding the low aggregate exchange rate pass-through and the variation in pass-through across firms. We find that import intensity affects pass-through both directly, by inducing an offsetting change in the marginal cost when exchange rates change, and indirectly, through selection into importing of the largest exporters with the most variable markups. We use firms' import intensities and export market shares as proxies for the marginal cost and markup channels, respectively, and show that variation in these variables across firms explains a substantial range of variation in pass-through. A small firm using no imported intermediate inputs has a nearly complete pass-through, while a firm at the 95th percentile of both market share and import intensity distributions has a pass-through of only 56%. Around half of this incomplete pass-through is due to the marginal cost channel, as captured by our import intensity measure. Since import intensity is heavily skewed toward the largest exporters, our findings help explain the observed low aggregate pass-through elasticities, which play a central role in the study of exchange rate disconnect. Finally, we show that the patterns we document emerge naturally in a theoretical framework, which combines standard ingredients of oligopolistic competition and variable markups with endogenous selection into importing at the firm level.

Our findings suggest that the marginal cost channel contributes substantially—reinforcing and amplifying the markup channel—to low aggregate pass-through and pass-through variation across firms. The decomposition of incomplete pass-through into its marginal cost and markup components is necessary for the analysis of the welfare consequences of exchange rate volatility and the desirability to fix exchange rates, for example, by means of integration into a currency union. Furthermore, price sensitivity to exchange rates is central to the expenditure switching mechanism at the core of international adjustment and rebalancing. A sign of inefficiency is when exchange rate movements affect mostly the distribution of markups across exporters from different countries, leading to little expenditure switching. However, if the lack of pass-through is largely due to the complex international web of intermediate input sourcing, incomplete pass through of exchange rates into prices may well be an efficient response. A complete analysis of the welfare consequences requires a general equilibrium model disciplined with the evidence on the importance of marginal cost and markup channels of the type we provide, and we leave this important question for future research.

Finally, we briefly comment on the interpretation of our results in an environment with

sticky prices, where exporters choose to fix their prices temporarily either in local or in producer currency. Since we cannot condition our empirical analysis on a price change or split the sample by currency of pricing, our results confound together the change in the desired markup with the mechanical changes in markup induced by the exchange rate movements when prices are sticky in a given currency. Therefore, one should keep in mind that our results suggest that import intensity and market share contribute either to flexible-price pass-through incompleteness or to the probability of local currency pricing, which in turn leads to low pass-through before prices adjust. In reality, our results are likely to be driven partly by both these sources of incomplete pass-through.[38] Indeed, Gopinath, Itskhoki, and Rigobon (2010) show that the two share the same primitive determinants and provide evidence that the choice to price in local currency is closely correlated in the cross-section of firms with the pass-through incompleteness conditional on price adjustment. Nonetheless, we favor the flexible-price interpretation of our results, as we focus on a relatively long horizon using annual data.

[38] Our data do not allow us to do a decomposition into these two sources, but one can make such inference by taking a stand on a particular structural model of incomplete pass-through with sticky prices, and using outside information to calibrate its parameters related to price stickiness and currency of pricing. We do not attempt this exercise in the current paper.

A Appendix

A.1 Theoretical Appendix

A.1.1 Cost function and import intensity

For brevity, we drop the firm identifier i in this derivation. Given output Y and the set of imported intermediate goods J_0, the objective of the firm is

$$TC^*(Y|J_0) \equiv \min_{L,X,\{X_j,Z_j\},\{M_j\}} \left\{ W^*L + \int_0^1 V_j^* Z_j \mathrm{d}j + \int_{J_0} \left(\mathcal{E}_m U_j M_j + W^* f \right) \mathrm{d}j \right\},$$

Denote by λ, ψ and χ the Lagrange multiplier on constraints (5), (6) and (7) respectively. The first order conditions of cost minimization are respectively:

$$\begin{aligned}
W^* &= \lambda(1-\phi)Y/L, \\
\psi &= \lambda\phi Y/X, \\
\chi &= \psi\gamma_j X/X_j, && j \in [0,1], \\
V_j^* &= \chi(X_j/Z_j)^{1/(1+\zeta)}, && j \in [0,1], \\
\mathcal{E}_m U_j &= \chi(a_j X_j/M_j)^{1/(1+\zeta)}, && j \in J_0,
\end{aligned}$$

with $M_j = 0$ and $X_j = Z_j$ for $j \in \tilde{J}_0 \equiv [0,1]\backslash J_0$. Expressing out ψ and χ, taking the ratio of the last two conditions and rearranging, we can rewrite:

$$\begin{aligned}
W^*L &= \lambda(1-\phi)Y, \\
V_j^* X_j &= \lambda\phi\gamma_j Y (X_j/Z_j)^{1/(1+\zeta)}, \quad j \in [0,1], \\
\frac{\mathcal{E}_m U_j M_j}{V_j^* Z_j} &= a_j \left(\frac{\mathcal{E}_m U_j}{V_j^*} \right)^{-\zeta}, && j \in J_0,
\end{aligned}$$

Substituting the last expression into (7), we obtain $X_j = Z_j \left[1 + a_j(\mathcal{E}_m U_j/V_j^*)^{-\zeta}\right]^{\frac{1+\zeta}{\zeta}}$ for $j \in J_0$, which together with the expression for $V_j^* X_j$ above yields:

$$V_j^* X_j = \begin{cases} \lambda\phi\gamma_j Y b_j, & j \in J_0, \\ \lambda\phi\gamma_j Y, & j \in \tilde{J}_0, \end{cases}$$

where

$$b_j \equiv \left[1 + a_j(\mathcal{E}_m U_j/V_j^*)^{-\zeta}\right]^{1/\zeta}. \tag{A1}$$

Based on this, we express L and X_j for all $j \in [0,1]$ as functions of λY and parameters. Substituting these expressions into (5)–(6), we solve for

$$\lambda = \frac{1}{\Omega} \left(\frac{\exp\left\{ \int_0^1 \gamma_j \log\left(\frac{V_j^*}{\gamma_j} \right) \mathrm{d}j \right\}}{\phi \exp\left\{ \int_{J_0} \gamma_j \log b_j \mathrm{d}j \right\}} \right)^{\phi} \left(\frac{W^*}{1-\phi} \right)^{1-\phi} = \frac{C^*}{B^\phi \Omega}, \tag{A2}$$

where

$$B = \exp\left\{\int_{J_0} \gamma_j \log b_j \mathrm{d}j\right\} \tag{A3}$$

and C^* is defined in footnote 15. Finally, we substitute the expression for W^*L, $V_j^* Z_j = V_j^* X_j \cdot (Z_j/X_j)$ and $\mathcal{E}_m U_j M_j = V_j^* Z_j \cdot (\mathcal{E}_m U_j M_j/(V_j^* Z_j))$ into the cost function to obtain

$$TC^*(Y; J_0) = \lambda Y + \textstyle\int_{J_0} W^* f \mathrm{d}j. \tag{A4}$$

Choice of J_0 without uncertainty solves $\min_{J_0} TC^*(Y|J_0)$, given output Y. Consider adding an additional variety $j_0 \notin J_0$ to the set J_0. The net change in the total cost from this is given by

$$Y \frac{\partial \lambda}{\partial B} B \gamma_{j_0} \log b_{j_0} + W^* f = -\phi \lambda Y \cdot \gamma_{j_0} \log b_{j_0} + W^* f,$$

since $\gamma_{j_0} \log b_{j_0}$ is the increase in $\log B$ from adding j_0 to the set of imports J_0. Note that $\phi \lambda Y = \int_0^1 V_j^* Z_j \mathrm{d}j + \int_{J_0} \mathcal{E}_m U_j M_j \mathrm{d}j$ is the total material cost of the firm.

Therefore, the optimal choice of J_0 must satisfy the following fixed point:

$$J_0 = \left\{ j \in [0,1] : \phi \frac{C^*/\Omega}{\exp\left\{\phi \int_{J_0} \gamma_\ell \log b_\ell \mathrm{d}\ell\right\}} Y \cdot \gamma_j \log b_j \geq W^* f \right\}.$$

This immediately implies that once j's are sorted such that $\gamma_j \log b_j$ is decreasing in j, the set of imported inputs is an interval $J_0 = [0, j_0]$ for some $j_0 \in [0,1]$. Furthermore, the condition for j_0 can be written as:

$$j_0 = \max\left\{ j \in [0,1] : \phi \frac{C^*/\Omega}{\exp\left\{\phi \int_0^j \gamma_\ell \log b_\ell \mathrm{d}\ell\right\}} Y \cdot \gamma_j \log b_j \geq W^* f \right\}, \tag{A5}$$

and such j_0 is unique since the LHS of the inequality is decreasing in j. Figure A2 provides an illustration.

Proof of Proposition 2 The fraction of variable cost spent on imports is given by

$$\varphi = \frac{\int_{J_0} \mathcal{E}_m U_j M_j \mathrm{d}j}{\lambda Y} = \int_{J_0} \gamma_j (1 - b_j^\zeta) \mathrm{d}j,$$

where we used the first order conditions from the cost minimization above to substitute in for $\mathcal{E}_m U_j M_j$. Note that φ increases in J_0, and in particular when $J_0 = [0, j_0]$, φ increases in j_0. Therefore, from (A5) it follows that φ increases in total material cost $TMC = \phi \lambda Y = \phi [C^* Y]/[B^\phi \Omega]$ and decreases in fixed cost $W^* f$.

From definition of total cost (A4), holding J_0 constant, the marginal cost equals $MC^*(J_0) =$

λ defined in (A2). We have:

$$\frac{\partial \log MC^*(J_0)}{\partial \log \mathcal{E}_m} = \frac{\partial \log \lambda}{\partial \log B} \frac{\partial \log B}{\partial \log \mathcal{E}_m} = -\phi \cdot \int_{J_0} \gamma_j \frac{\partial \log b_j}{\partial \log \mathcal{E}_m} \mathrm{d}j = \varphi,$$

since from (A1) $\partial \log b_j / \partial \log \mathcal{E}_m = -(1 - b_j^{\zeta})$. ■

A.1.2 Price setting and *ex ante* choice of J_0

Under the assumption that J_0 is a sunk decision chosen before uncertainty is realized, we can write the full problem of the firm as (bring back the firm identifier i):

$$\max_{J_{0,i}} \mathbb{E} \left\{ \max_{Y_i, (P_{k,i}, Q_{k,i})} \left\{ \sum_{k \in K_i} \mathcal{E}_k P_{k,i} Q_{k,i} - TC_i^*(Y_i | J_{0,i}) \right\} \right\},$$

subject to $Y_i = \sum_{k \in K_i} Q_{k,i}$, with $(P_{k,i}, Q_{k,i})$ satisfying demand (1) in each market $k \in K_i$, and total cost given in (A4). We assume that $J_{0,i}$ is chosen just prior to the realization of uncertainty about aggregate variables, and for simplicity we omit a stochastic discount factor which can be added without any conceptual complications.

Substituting the constraints into the maximization problem and taking the first order condition (with respect to $P_{k,i}$), we obtain:

$$\mathcal{E}_k Q_{k,i} + \mathcal{E}_k P_{k,i} \frac{\partial Q_{k,i}}{\partial P_{k,i}} - \frac{\partial TC_i^*(Y | J_{0,i})}{\partial Y} \frac{\partial Q_{k,i}}{\partial P_{k,i}} = 0,$$

which we rewrite as

$$\mathcal{E}_k Q_{k,i} (1 - \sigma_{k,i}) + \sigma_{k,i} Q_{k,i} \frac{\lambda_i}{P_{k,i}} = 0,$$

where $\sigma_{k,i}$ is defined in (3) and $\lambda_i = MC_i^*(J_{0,i})$ is defined in (A2). Rearranging and using $P_{k,i}^* = \mathcal{E}_k P_{k,i}$, results in price setting equation (11).

Now consider the choice of $J_{0,i}$. By Envelope Theorem, it is equivalent to

$$\min_{J_{0,i}} \mathbb{E} \left\{ TC_i^*(Y_i | J_{0,i}) \right\},$$

where Y_i is the equilibrium output of the firm in each state of nature. Therefore, this problem is nearly identical to that of choosing $J_{0,i}$ without uncertainty, with the exception that now we have the expectation and Y_i varies across states of the world along with exogenous variables affecting TC_i^*. As a result, we can write the fixed point equation for $J_{0,i}$ in this case as:

$$J_{0,i} = \left\{ j \in [0,1] : \mathbb{E} \left\{ \phi \frac{C^* / \Omega_i}{\exp \left\{ \phi \int_{J_{0,i}} \gamma_\ell \log b_\ell \mathrm{d}\ell \right\}} Y_i \cdot \gamma_j \log b_j \right\} \geq \mathbb{E} \left\{ W^* f_i \right\} \right\}. \tag{A6}$$

Therefore, $J_{0,i}$ still has the structure $[0, j_{0,i}]$, but now we need to sort goods j in decreasing order by the value of the LHS in the inequality in (A6) (in expected terms).

A.1.3 Equilibrium Relationships

To illustrate the implications of the model for the equilibrium determinants of market share and import intensity, we study the following simple case. Consider two firms, i and i', in a given industry and both serving a single destination market k. The firms face the same industry-destination specific market conditions reflected in $\mathcal{E}_k$, P_k, D_k, C^* and ϕ. We allow the firms to be heterogeneous in terms of productivity Ω_i, demand/quality shifter $\xi_{k,i}$ and fixed cost of importing f_i. For a single-destination firm we have $Y_i = Q_{k,i}$, and we drop index k in what follows for brevity.

We want to characterize the relative market shares and import intensities of these two firms. In order to do so, we take the ratios of the equilibrium conditions (demand (1), market share (2) and price (11)) for these two firms:[39]

$$\frac{Y_i}{Y_{i'}} = \frac{\xi_i}{\xi_{i'}}\left(\frac{P_i}{P_{i'}}\right)^{-\rho}, \qquad \frac{S_i}{S_{i'}} = \frac{\xi_i}{\xi_{i'}}\left(\frac{P_i}{P_{i'}}\right)^{1-\rho} \quad \text{and} \quad \frac{P_i}{P_{i'}} = \frac{\mathcal{M}_i}{\mathcal{M}_{i'}}\frac{B_{i'}^{\phi}\Omega_{i'}}{B_i^{\phi}\Omega_i},$$

where $\mathcal{M}_i = \sigma_i/(\sigma_i - 1)$ and $\sigma_i = \rho(1 - S_i) + \eta S_i$. Log-linearizing relative markup, we have:

$$\log\frac{\mathcal{M}_i}{\mathcal{M}_{i'}} = \frac{\bar{\Gamma}}{\rho - 1}\log\frac{S_i}{S_{i'}},$$

where $\bar{\Gamma}$ is markup elasticity given in (4) evaluated at some average $\bar{S}$. Using this, we linearize the equilibrium system to solve for:

$$\log\frac{S_i}{S_{i'}} = \frac{1}{1+\bar{\Gamma}}\log\frac{\xi_i}{\xi_{i'}} + \frac{\rho - 1}{1+\bar{\Gamma}}\left(\log\frac{\Omega_i}{\Omega_{i'}} + \phi\log\frac{B_i}{B_{i'}}\right) \tag{A7}$$

and the interim variable (total material cost) which determines the import choice:

$$\log\frac{TMC_i}{TMC_{i'}} = \left[\log\frac{Y_i}{Y_{i'}} - \log\frac{\Omega_i}{\Omega_{i'}} - \phi\log\frac{B_i}{B_{i'}}\right] = \left(1 - \frac{\bar{\Gamma}}{\rho - 1}\right)\log\frac{S_i}{S_{i'}}. \tag{A8}$$

Assumption A1 $\bar{\Gamma} < (\rho - 1)$.

For a moderate value of $\rho = 4$, this only requires $\bar{S} < 0.8$ (given the definition of Γ in (4) and $\eta \geq 1$). This assumption requires that markups are not too variable, and hence high-market-share firms are simultaneously high-material-cost firms (as we document is the case in the data, see Table 4). Consequently, under A1, high-market-share firms choose to be more import intensive, as we discuss next.

Denote $\chi(j) \equiv \gamma_j \mathbb{E}\log b_j$, where expectation is over aggregate equilibrium variables (i.e., aggregate states of the world), and sort j so that $\chi'(\cdot) < 0$ on $[0, 1]$. Assuming the choice of

[39] Note that taking these ratio takes out the aggregate variables such as the price index. Intuitively, we characterize the relative standing of two firms in a given general equilibrium environment, and aggregate equilibrium variables such as price index affect outputs and market shares of firms proportionately.

the import set is internal for both firms, we can rewrite (A6) as a condition for a cutoff $j_0(i)$:

$$\mathbb{E}\left\{\gamma_{j_0(i)} \log b_{j_0(i)} \frac{\phi C^* Y_i}{B_i^\phi \Omega_i}\right\} = \mathbb{E}\{W^* f_i\},$$

and log-linearize it to yield:

$$\frac{-\chi'\big(\bar{j}_0\big)}{\chi\big(\bar{j}_0\big)} \cdot \big(j_0(i) - j_0(i')\big) = \mathbb{E}\left\{\log \frac{Y_i}{Y_{i'}} - \log \frac{\Omega_i}{\Omega_{i'}} - \phi \log \frac{B_i}{B_{i'}}\right\} - \log \frac{f_i}{f_{i'}},$$

where $\bar{j}_0$ is some average cutoff variety. Finally, using definition (A3), we have

$$\mathbb{E} \log \frac{B_i}{B_{i'}} = \chi\big(\bar{j}_0\big) \cdot \big(j_0(i) - j_0(i')\big). \tag{A9}$$

Combining the above two equations with (A8), we have:

$$\frac{-\chi'\big(\bar{j}_0\big)}{\phi \chi\big(\bar{j}_0\big)^2} \phi \mathbb{E} \log \frac{B_i}{B_{i'}} = \left(1 - \frac{\bar{\Gamma}}{\rho - 1}\right) \mathbb{E} \log \frac{S_i}{S_{i'}} - \log \frac{f_i}{f_{i'}}.$$

Combining with (A7), we solve for:

$$\phi \mathbb{E} \log \frac{B_i}{B_{i'}} = \frac{1}{\bar{\kappa}_0 - \left(\frac{\rho}{1+\bar{\Gamma}} - 1\right)} \left[\frac{1 - \frac{\bar{\Gamma}}{\rho - 1}}{1 + \bar{\Gamma}} \left(\log \frac{\xi_i}{\xi_{i'}} + (\rho - 1) \log \frac{\Omega_i}{\Omega_{i'}}\right) - \log \frac{f_i}{f_{i'}}\right], \tag{A10}$$

$$\mathbb{E} \log \frac{S_i}{S_{i'}} = \frac{1}{\bar{\kappa}_0 - \left(\frac{\rho}{1+\bar{\Gamma}} - 1\right)} \left[\frac{\bar{\kappa}_0}{1 + \bar{\Gamma}} \left(\log \frac{\xi_i}{\xi_{i'}} + (\rho - 1) \log \frac{\Omega_i}{\Omega_{i'}}\right) - \frac{\rho - 1}{1 + \bar{\Gamma}} \log \frac{f_i}{f_{i'}}\right], \tag{A11}$$

where $\bar{\kappa}_0 \equiv -\chi'\big(\bar{j}_0\big)/[\phi \chi\big(\bar{j}_0\big)^2] > 0$.

Assumption A2 $\bar{\kappa}_0 \equiv \dfrac{-\chi'\big(\bar{j}_0\big)}{\phi \chi\big(\bar{j}_0\big)^2} > \dfrac{\rho}{1 + \bar{\Gamma}} - 1.$

Parameter restriction in A2 is local stability condition: the function $\chi(j) = \mathbb{E}\gamma_j \log b_j$ must be decreasing in j fast enough, otherwise small changes in exogenous firm characteristics can have discontinuously large changes in the extensive margin of imports. We view it as a technical condition, and assume equilibrium is locally stable.

Finally, we relate import intensity of the firm φ_i to B_i. From definition (9) it follows that

$$\mathbb{E}\big\{\varphi_i - \varphi_{i'}\big\} = \nu\big(\bar{j}_0\big)\big(j_0(i) - j_0(i')\big) = \frac{\nu\big(\bar{j}_0\big)}{\chi\big(\bar{j}_0\big)} \mathbb{E} \log \frac{B_i}{B_{i'}}, \tag{A12}$$

where $\nu(j) = \gamma_j \mathbb{E}\{1 - b_j^\zeta\}$ and the second equality substitutes in (A9).

Equations (A10)–(A12) provide the log-linear characterization of (expected) relative market share and relative import intensities of the two firms as a function of their relative exoge-

nous characteristics. This approximations are nearly exact when the exogenous differences between firms are small. In other words, one can think of those relationships as describing elasticities of market share and semi-elasticities of import-intensity with respect to exogenous characteristics of the firm (productivity, demand/quality and fixed cost of importing), holding the general equilibrium environment constant. Therefore, we have:

Proposition A1 *Under Assumptions A1 and A2, (expected) market share and import intensity of the firm are both increasing in firm's productivity and firm's quality/demand shifter, and are both decreasing in firm's import fixed cost, in a given general equilibrium environment (that is, holding the composition of firms constant).*

A similar result can be proved for firms serving multiple and different number of destinations.

A.1.4 Pass-through relationship and proof of Proposition 3

Markup Given (2) and (3), we have the following full differentials:

$$\begin{aligned}\mathrm{d}\log\mathcal{M}_{k,i} \equiv \mathrm{d}\log\frac{\sigma_{k,i}}{\sigma_{k,i}-1} &= \frac{(\rho-\eta)S_{k,i}}{\sigma_{k,i}(\sigma_{k,i}-1)}\mathrm{d}\log S_{k,i} = \Gamma_{k,i}\frac{\mathrm{d}\log S_{k,i}}{\rho-1},\\ \mathrm{d}\log S_{k,i} &= \mathrm{d}\log\xi_{k,i} - (\rho-1)\big(\mathrm{d}\log P_{k,i} - \mathrm{d}\log P_k\big),\end{aligned}$$

where $\Gamma_{k,i}$ is as defined in (4). Combining these two expressions results in (13).

Marginal cost Taking the full differential of (10), we have:

$$\mathrm{d}\log MC_i^* = \mathrm{d}\log\frac{C^*}{\Omega_i} - \phi\mathrm{d}\log B_i.$$

Using definitions (A1) and (A3), and under the assumption that J_0 is a sunk decision (that is, the set of imported goods is held constant), we have:

$$\begin{aligned}\mathrm{d}\log b_j &= -(1-b_j^{\zeta})\mathrm{d}\log\frac{\mathcal{E}_m U_j}{V_j^*},\\ \phi\mathrm{d}\log B_i &= \phi\int_{J_{0,i}}\gamma_j\big(\mathrm{d}\log b_j\big)\mathrm{d}j\\ &= -\varphi_i\mathrm{d}\log\frac{\mathcal{E}_m\bar{U}}{\bar{V}^*} - \phi\int_{J_{0,i}}\gamma_j(1-b_j^{\zeta})\left[\mathrm{d}\log\frac{U_j}{\bar{U}} - \mathrm{d}\log\frac{V_j^*}{\bar{V}^*}\right]\mathrm{d}j,\end{aligned}$$

where φ_i is defined in (9), and $\mathrm{d}\log\bar{V}^* = \int_0^1\gamma_j\big(\mathrm{d}\log V_j^*\big)\mathrm{d}j\mathrm{d}j$ and similarly $\mathrm{d}\log\bar{U} = \int_0^1\gamma_j\big(\mathrm{d}\log U_j\big)\mathrm{d}j\mathrm{d}j$. Substituting this expression into the full differential of the marginal cost above results in (14), where the residual is given by:

$$\epsilon_i^{MC} = \int_{J_{0,i}}\gamma_j(1-b_j^{-\zeta})\left[\mathrm{d}\log\frac{U_j}{\bar{U}} - \mathrm{d}\log\frac{V_j^*}{\bar{V}^*}\right]\mathrm{d}j - \mathrm{d}\log\frac{\Omega_i}{\bar{\Omega}},$$

where $\mathrm{d}\log\bar{\Omega}$ is the sectoral average change in firm-level productivity.

Combining (13) and (14) with (12), we have:

$$\mathrm{d}\log P^*_{k,i} = -\Gamma_{k,i}\big(\mathrm{d}\log P_{k,i} - \mathrm{d}\log\tilde{P}_k\big) + \mathrm{d}\log\frac{C^*}{\bar{\Omega}} + \varphi_i \mathrm{d}\log\frac{\mathcal{E}_m\bar{U}}{\bar{V}^*} + \epsilon_{k,i}, \tag{A13}$$

where

$$\epsilon_{k,i} \equiv \epsilon^{MC}_i + \frac{\Gamma_{k,i}}{\rho-1}\epsilon^{\mathcal{M}}_{k,i}, \qquad \epsilon^{\mathcal{M}}_{k,i} \equiv \mathrm{d}\log\frac{\xi_{k,i}}{\bar{\xi}_k},$$

$\mathrm{d}\log\bar{\xi}_k$ is the sector-destination average change in demand/quality across firms, we denoted with $\tilde{P}_k \equiv \xi_k^{\frac{1}{\rho-1}} P_k$ the sector-destination price index adjusted for the average demand/quality shifter for Belgian firms. We make the following:

Assumption A3 $\big(\epsilon^{MC}_{k,i}, \epsilon^{\mathcal{M}}_{k,i}\big)$*, and hence* $\epsilon_{k,i}$*, are mean zero and independent from* $\mathrm{d}\log\mathcal{E}_m$ *and* $\mathrm{d}\log\mathcal{E}_k$*.*

Note that $\epsilon_{k,i}$ reflects the firm idiosyncratic differences in the change in input prices, productivity and demand/quality shifter, and therefore Assumption A3 is a natural one to make. Essentially, we assume that there is no systematic relationship between exchange rate movement and firm's idiosyncratic productivity or demand change relative to an average firm from the same country (Belgium) serving the same sector-destination. This nonetheless allows the exchange rates to be correlated with sector-destination average indexes for costs and productivity (that is, $\bar{\Omega}$, $\bar{U}$, $\bar{V}^*$, as well as $\tilde{P}_k$).

Substituting $\mathrm{d}\log P_{k,i} = \mathrm{d}\log P^*_{k,i} - \mathrm{d}\log\mathcal{E}_k$ into (A13) and rearranging, we arrive at:

$$\mathrm{d}\log P^*_{k,i} = \frac{\Gamma_{k,i}}{1+\Gamma_{k,i}}\mathrm{d}\log\mathcal{E}_k + \frac{\varphi_i}{1+\Gamma_{k,i}}\mathrm{d}\log\frac{\mathcal{E}_m\bar{U}_s}{\bar{V}^*_s} + \frac{\Gamma_{k,i}\mathrm{d}\log\tilde{P}_{s,k} + \mathrm{d}\log\frac{C^*_s}{\bar{\Omega}_{s,k}} + \epsilon_{k,i}}{1+\Gamma_{k,i}}, \tag{A14}$$

where we have now made the sector identifier s an explicit subscript (each i uniquely determines s, hence we do not carry s when i is present). Note that $\Gamma_{k,i}$ is increasing in $S_{k,i}$. We now linearize (A14) in φ_i and $S_{k,i}$:

Lemma A1 *Log price change expression* (A14) *linearized in* φ_i *and* $S_{k,i}$ *is*

$$\begin{aligned}\mathrm{d}\log P^*_{k,i} \approx{}& \frac{\bar{\Gamma}_{s,k}}{1+\bar{\Gamma}_{s,k}}\mathrm{d}\log\mathcal{E}_k + \frac{\bar{g}_{s,k}}{1+\bar{\Gamma}_{s,k}}\tilde{S}_{k,i}\mathrm{d}\log\mathcal{E}_k + \frac{1}{1+\bar{\Gamma}_{s,k}}\varphi_i\mathrm{d}\log\frac{\mathcal{E}_m\bar{U}_s}{\bar{V}^*_s} \\ &+ \left[\frac{\bar{\Gamma}_{s,k}\mathrm{d}\log\tilde{P}_{s,k} + \mathrm{d}\log\frac{C^*_s}{\bar{\Omega}_{s,k}} + \bar{\epsilon}'_{k,i}}{1+\bar{\Gamma}_{s,k}} + \frac{\bar{g}_{s,k}\left(\mathrm{d}\log\tilde{P}_{s,k} - \bar{\varphi}_s\mathrm{d}\log\frac{\mathcal{E}_m\bar{U}_s}{\bar{V}^*_s} - \mathrm{d}\log\frac{C^*_s}{\bar{\Omega}_{s,k}} + \bar{\epsilon}''_{k,i}\right)}{1+\bar{\Gamma}_{s,k}}\tilde{S}_{k,i}\right],\end{aligned} \tag{A15}$$

where $\bar{\Gamma}_{s,k} = \Gamma_{k,i}\big|_{\bar{S}_{s,k}}$*,* $\bar{g}_{s,k} \equiv \partial\log(1+\Gamma_{k,i})/\partial S_{k,i}\big|_{\bar{S}_{s,k}}$*,* $\bar{S}_{s,k}$ *is some average statistic of the* $S_{k,i}$ *distribution,* $\tilde{S}_{k,i} = S_{k,i} - \bar{S}_{k,i}$*, and* $\bar{\epsilon}'_{k,i} \equiv \epsilon^{MC}_i + \frac{\bar{\Gamma}_{s,k}}{\rho-1}\epsilon^{\mathcal{M}}_{k,i}$*,* $\bar{\epsilon}''_{k,i} \equiv \frac{\bar{\Gamma}_{s,k}}{\rho-1}\epsilon^{\mathcal{M}}_{k,i} - \epsilon^{MC}_i$*.*

Proof: Given the definitions of $\bar{\Gamma}_{s,k}$ and $\bar{g}_{s,k}$ in the lemma, we have the following first-order approximations:

$$\frac{1}{1+\Gamma_{k,i}} \approx \frac{1-\bar{g}_{s,k}\tilde{S}_{k,i}}{1+\bar{\Gamma}_{s,k}}, \qquad \frac{\Gamma_{k,i}}{1+\Gamma_{k,i}} \approx \frac{\bar{\Gamma}_{s,k}+\bar{g}_{s,k}\tilde{S}_{k,i}}{1+\bar{\Gamma}_{s,k}} \quad \text{and} \quad \frac{\varphi_i}{1+\Gamma_{k,i}} \approx \frac{\varphi_i-\bar{\varphi}_s\bar{g}_{s,k}\tilde{S}_{k,i}}{1+\bar{\Gamma}_{s,k}}.$$

Substitute these approximations into (A14) and rearrange to obtain (A15). ■

Proof of Proposition 3 Divide (A15) through by $\mathrm{d}\log\mathcal{E}_k$ and take expectations to characterize the pass-through elasticity:

$$\Psi^*_{k,i} \equiv \mathbb{E}\left\{\frac{\mathrm{d}\log P^*_{k,i}}{\mathrm{d}\log\mathcal{E}_k}\right\} \approx \alpha_{s,k} + \beta_{s,k}\cdot\varphi_i + \gamma_{s,k}\cdot S_{k,i},$$

where

$$\alpha_{s,k} = \frac{\bar{\Gamma}_{s,k}(1+\Psi^P_{s,k})+\Psi^C_{s,k}}{1+\bar{\Gamma}_{s,k}} - \gamma_{s,k}\bar{S}_{s,k},$$

$$\beta_{s,k} = \frac{\Psi^M_{s,k}}{1+\bar{\Gamma}_{s,k}} \qquad \text{and} \qquad \gamma_{s,k} = \frac{\bar{g}_{s,k}\left[(1-\bar{\varphi}_s\Psi^M_{s,k})+(\Psi^P_{s,k}-\Psi^C_{s,k})\right]}{1+\bar{\Gamma}_{s,k}},$$

and with

$$\Psi^P_{k,i} \equiv \mathbb{E}\left\{\frac{\mathrm{d}\log\tilde{P}_{s,k}}{\mathrm{d}\log\mathcal{E}_k}\right\}, \qquad \Psi^C_{s,k} \equiv \mathbb{E}\left\{\frac{\mathrm{d}\log(C^*_s/\tilde{\Omega}_{s,k})}{\mathrm{d}\log\mathcal{E}_k}\right\}, \qquad \Psi^M_{s,k} \equiv \mathbb{E}\left\{\frac{\mathrm{d}\log(\mathcal{E}_m\bar{U}_s/\bar{V}^*_s)}{\mathrm{d}\log\mathcal{E}_k}\right\}.$$

Note that the terms in $\epsilon_{k,i}$ drop out since, due to Assumption A3, $\mathbb{E}\{\epsilon_{k,i}/\mathrm{d}\log\mathcal{E}_k\} = 0$. Finally, note that $\Psi_{s,k} \approx \mathrm{cov}(\cdot,\mathrm{d}\log\mathcal{E}_k)/\mathrm{var}(\mathrm{d}\log\mathcal{E}_k)$, that is Ψ-terms are approximately projection coefficients. The expectations and in the definitions of Ψ-terms are unconditional, and hence average across all possible initial states and paths of the economy. ■

A.1.5 Empirical specification and proof of Proposition 4

We start from the linearized decomposition (A15) by replace differential d with a time lag operator Δ, making the time index t explicit, and rearranging:

$$\begin{aligned}\Delta p^*_{i,k,t} \approx{}& \frac{\bar{\Gamma}_{s,k}\Delta\tilde{p}_{s,k,t}+\Delta c_{s,t}+\bar{\epsilon}'_{k,i,t}}{1+\bar{\Gamma}_{s,k}} + \frac{\bar{g}_{s,k}\left(\Delta\tilde{p}_{s,k,t}-\Delta c_{s,t}+\bar{\epsilon}''_{k,i,t}\right)}{1+\bar{\Gamma}_{s,k}}\tilde{S}_{k,i,t-1} \\ &+ \frac{\bar{\Gamma}_{s,k}\Delta e_{k,t}}{1+\bar{\Gamma}_{s,k}} + \frac{\varphi_{i,t-1}}{1+\bar{\Gamma}_{s,k}}\Delta\log\frac{\mathcal{E}_{m,t}\bar{U}_{s,t}}{\bar{V}^*_{s,t}} + \frac{\bar{g}_{s,k}\tilde{S}_{k,i,t-1}}{1+\bar{\Gamma}_{s,k}}\left(\Delta e_{k,t}-\bar{\varphi}_{s,t-1}\Delta\log\frac{\mathcal{E}_{m,t}\bar{U}_{s,t}}{\bar{V}^*_{s,t}}\right),\end{aligned} \tag{A16}$$

where $\Delta p^*_{i,k,t} \equiv \log P^*_{k,i,t} - \log P^*_{k,i,t-1}$, $\Delta e_{k,t} \equiv \log\mathcal{E}_{k,t} - \log\mathcal{E}_{k,t-1}$, $\Delta c_{s,t} \equiv \log(C^*_{s,t}/\bar{\Omega}_{s,t}) - \log(C^*_{s,t-1}/\bar{\Omega}_{s,t-1})$, and $\Delta\tilde{p}_{s,k,t} \equiv \log\tilde{P}_{s,k,t} - \log\tilde{P}_{s,k,t-1}$. Note that we chose $t-1$ as the point of approximation for $\tilde{S}_{k,i,t-1}$ and $\varphi_{i,t-1}$. We also chose the approximation coefficients $\bar{\Gamma}_{s,k}$ and $\bar{g}_{s,k}$ not to depend on time by evaluating the respective functions (see Lemma A1) at a time-invariant average $\bar{S}_{s,k}$.

Next consider our main empirical specification (21) which we reproduce as:

$$\Delta p^*_{i,k,t} = \left[\alpha_{s,k} + \beta\varphi_{i,t-1} + \tilde{\gamma}\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}}\right]\Delta e_{k,t} + \delta_{s,k} + b\varphi_{i,t-1} + c\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}} + \tilde{u}_{k,i,t}, \tag{A17}$$

where $\mathbf{S}_{s,k,t}$ is the cumulative market share of all Belgian exporters. Our goal is to establish the properties of the OLS estimator of β and $\tilde{\gamma}$ in this regression, given approximate structural relationship (A16). To this end, we introduce two assumptions:

Assumption A4 *For every k, $\Delta \log e_{k,t}$ is mean zero, constant variance and independent from $(\varphi_{i,t-1}, S_{k,i,t-1}, \mathbf{S}_{s,k,t-1})$.*

Assumption A5 *The variance and covariance of $(\varphi_{i,t-1}, S_{k,i,t-1}/\mathbf{S}_{s,k,t-1})$ within $(s,k,t-1)$ is independent from $(\beta_{s,k}, \gamma_{s,k}\mathbf{S}_{s,k,t-1})$, where $\beta_{s,k}$ and $\gamma_{s,k}$ are defined in the proof of Proposition 3 above.*

Assumption A4 is a plausible martingale assumption for exchange rate which we require in the proof of Proposition 4. One interpretation of this assumption is that cross-section distribution of firm-level characteristics is not useful in predicting future exchange rate changes. Assumption A5, in turn, is only made for convenience of interpretation, and qualitatively the results of Proposition 4 do not require it. Essentially, we assume that the cross-section distribution of firm-characteristics within sector-destination does not depend on the aggregate comovement properties of sectoral variables which affect the values of $\beta_{s,k}$ and $\gamma_{s,k}$.

Before proving Proposition 4, we introduce the following three projections:

$$\begin{cases} \Delta \log \frac{\mathcal{E}_{m,t}\bar{U}_{s,t}}{\bar{V}^*_{s,t}} \equiv \rho^M_{s,k}\Delta e_{k,t} + v^M_{s,k,t}, & \rho^M_{s,k} = \frac{\mathrm{cov}\left(\Delta \log \frac{\mathcal{E}_{m,t}\bar{U}_{s,t}}{\bar{V}^*_{s,t}}, \Delta e_{k,t}\right)}{\mathrm{var}\left(\Delta e_{k,t}\right)}, \\ \Delta \tilde{p}_{s,k,t} \equiv \rho^P_{s,k}\Delta e_{k,t} + v^P_{s,k,t}, & \rho^P_{s,k} = \frac{\mathrm{cov}\left(\Delta \tilde{p}_{s,k,t}, \Delta e_{k,t}\right)}{\mathrm{var}\left(\Delta e_{k,t}\right)}, \\ \Delta c^*_{s,t} \equiv \rho^C_{s,k}\Delta e_{k,t} + v^C_{s,k,t}, & \rho^C_{s,k} = \frac{\mathrm{cov}\left(\Delta c_{s,k,t}, \Delta e_{k,t}\right)}{\mathrm{var}\left(\Delta e_{k,t}\right)} \end{cases} \tag{A18}$$

and therefore $(v^M_{s,k,t}, v^P_{s,k,t}, v^C_{s,k,t})$ are orthogonal with $\Delta e_{k,t}$. Note that $(\rho^M_{s,k}, \rho^P_{s,k}, \rho^C_{s,k})$ are the empirical counterparts to $(\Psi^M_{s,k}, \Psi^P_{s,k}, \Psi^C_{s,k})$ defined in the proof of Proposition 3.

Proof of Proposition 4 Substitute projections (A18) into (A16) and rearrange:

$$\begin{aligned} \Delta p^*_{i,k,t} \approx & \left[\underbrace{\frac{\bar{\Gamma}_{s,k}(1+\rho^P_{s,k}) + \rho^C_{s,k}}{1+\bar{\Gamma}_{s,k}}}_{\equiv\alpha_{s,k}} + \underbrace{\frac{\rho^M_{s,k}}{1+\bar{\Gamma}_{s,k}}}_{\equiv\beta_{s,k}}\cdot\varphi_{i,t-1} + \underbrace{\frac{[(1-\bar{\varphi}_s\rho^M_{s,k}) + (\rho^P_{s,k} - \rho^C_{s,k})]\bar{g}_{s,k}\mathbf{S}_{s,k,t-1}}{1+\bar{\Gamma}_{s,k}}}_{\equiv\tilde{\gamma}_{s,k,t}}\cdot\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}}\right]\Delta e_{k,t} \\ & + \underbrace{\frac{v^M_{s,k,t}}{1+\bar{\Gamma}_{s,k}}}_{\equiv b_{s,k}}\cdot\varphi_{i,t-1} + \underbrace{\frac{(v^P_{s,k,t} - v^C_{s,k,t} - \bar{\varphi}_{s,t-1}v_{m,k,t} + \bar{\epsilon}''_{k,i,t})\bar{g}_{s,k}\mathbf{S}_{s,k,t-1}}{(1+\bar{\Gamma}_{s,k})^2}}_{\equiv c_{s,k,t}}\cdot\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}} + \underbrace{\frac{\bar{\Gamma}_{s,k}v^P_{s,k,t} + v^C_{s,k,t} + \bar{\epsilon}'_{i,t}}{1+\bar{\Gamma}_{s,k}}}_{\equiv\delta_{s,k}+u_{k,i,t}}. \end{aligned}$$

Comparing this equation with the empirical specification (A17), the residual in the empirical specification is given by:

$$\tilde{u}_{k,i,t} = u_{k,i,t} + \left[(\beta_{s,k} - \beta)\varphi_{i,t-1} + (\tilde{\gamma}_{s,k,t} - \tilde{\gamma})\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}}\right]\Delta e_{k,t} + (b_{s,k} - b)\varphi_{i,t-1} + (c_{s,k,t} - c)\frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}},$$

where from the price decomposition above it follows that $u_{k,i,t} = \frac{\bar{\Gamma}_{s,k} v^P_{s,k,t} + v^C_{s,k,t} + \bar{\epsilon}'_{i,t}}{1+\bar{\Gamma}_{s,k}} - \delta_{s,k}$, where $\delta_{s,k}$ takes out the variation across sector-destination which is time-invariant.

Define $x_{k,i,t} = (\mathbf{1}'_{s,k}, \varphi_{i,t-1}, \tilde{S}_{k,i,t-1})'$, so that we can write our regressors as $z'_{k,i,t} = (x'_{k,i,t}, x'_{k,i,t}\Delta e_{k,t})$. From Assumptions A3 and A4 and properties of the projection (A18), it follows that $x'_{k,i,t}\Delta e_{k,t}$ is orthogonal with $x'_{k,i,t}$, and $x'_{k,i,t}\Delta e_{k,t}$ is uncorrelated with $u_{k,i,t}$. Therefore, the properties of the estimates of $(\alpha_{s,k}, \beta, \tilde{\gamma})$ are independent from the those of $(\delta_{s,k}, b, c)$. OLS identifies $(\alpha_{s,k}, \beta, \tilde{\gamma})$ from the following moment conditions:

$$0 = \mathbb{E}_{k,i,t}\left\{x_{k,i,t}\Delta e_{k,t}\tilde{u}_{k,i,t}\right\} = \mathbb{E}_{k,i,t}\left\{x_{k,i,t}\Delta e_{k,t}(\tilde{u}_{k,i,t} - u_{k,i,t})\right\},$$

where the second equality follows from $\mathbb{E}_{k,i,t}\{\Delta e_{k,t} x_{k,i,t} u_{k,i,t}\} = 0$ (due to Assumption A3 and projection (A18)). We now rewrite this moment condition in the form of summation (across the population of firms, sector-destinations, and time periods/states):

$$0 = \sum_{k,i,t} x_{k,i,t}\Delta e_{k,t}(\tilde{u}_{k,i,t} - u_{k,i,t}) = \sum_{k,i,t} \Delta e^2_{k,t} x_{k,i,t} x'_{k,i,t}\left(\mathbf{0}'_{s,k}, \beta_{s,k} - \beta, \tilde{\gamma}_{s,k,t} - \tilde{\gamma}\right)',$$

where the second equality substitutes in the expression for $\tilde{u}_{k,i,t} - u_{k,i,t}$ and uses the fact that $\Delta e_{k,t}$ is orthogonal with $x_{k,i,t}$ (Assumption A4). Using the same assumption further, we can rewrite the last expression as:

$$\sum_{s,k,t} \sigma^2_k n_{s,k,t} \Sigma_{s,k,t} \begin{pmatrix} \beta_{s,k} - \beta \\ \tilde{\gamma}_{s,k,t} - \tilde{\gamma} \end{pmatrix} = 0, \tag{A19}$$

where σ^2_k is the variance of $\Delta e_{k,t}$, $\Sigma_{s,k,t}$ is the covariance matrix for $(\varphi_{i,t-1}, S_{k,i,t-1}/\mathbf{S}_{s,k,t-1})$ within $(s, k, t-1)$, and $n_{s,k,t}$ is the respective number of observations.

(A19) already establishes the result of the proposition that β and $\tilde{\gamma}$ identify generalized weighted averages of the respective coefficients. Under additional Assumption A5, we have a particularly simple expressions for these weighted averages:

$$\beta = \sum_{s,k,t} \omega'_{s,k,t}\beta_{s,k} \qquad \text{and} \quad \tilde{\gamma} = \sum_{s,k,t} \omega''_{s,k,t}\tilde{\gamma}_{s,k,t},$$

$\omega'_{s,k,t} \propto \sigma^2_k n_{s,k,t} \operatorname{var}_{s,k,t-1}(\varphi_{i,t-1})$ and $\omega''_{s,k,t} \propto \sigma^2_k n_{s,k,t} \operatorname{var}_{s,k,t-1}(S_{k,i,t-1}/\mathbf{S}_{s,k,t-1})$ with $\operatorname{var}_{s,k,t-1}(\cdot)$ denoting the variance for observations within $(s, k, t-1)$.

Finally, $\beta_{s,k}$ and $\tilde{\gamma}_{s,k,t} = \gamma_{s,k}\mathbf{S}_{s,k,t-1}$ are defined above, and $(\beta_{s,k}, \gamma_{s,k})$ provide first order approximations to their analogs in Proposition 3 since $(\rho^M_{s,k}, \rho^P_{s,k}, \rho^C_{s,k}) \approx (\Psi^M_{s,k}, \Psi^P_{s,k}, \Psi^C_{s,k})$. ■

A.2 Data Appendix

A.2.1 Trade Data

The import and export data are from the National Bank of Belgium, with the extra-EU transactions reported by Customs and the intra-EU trade by the Intrastat Inquiry. These data are reported at the firm level for each product classified at the 8-digit combined nomenclature (CN) in values and weights or units. Note that the CN code is a Europe-based classification with the first 6-digits corresponding to the World Hamonized System (HS). We include all transactions that are considered as trade involving change of ownership with compensation (codes 1 and 11). These data are very comprehensive, covering all firms with a total extra-EU trade whose value is greater than 1,000 euros or whose weight is more than 1,000 kilograms. Since 2006, even smaller transactions are reported. However, for intra-EU trade, the thresholds are higher, with total intra-EU imports or exports above 250,000 euros in a year, and in 2006 this threshold was raised to 1,000,000 euros for exports and 400,000 for imports. Note that these thresholds result in changing cutoffs for countries that joined the EU during our sample period as their transactions move from being recorded by Customs to the Intrastat Inquiry.

A.2.2 Firm-level data

The firm-level data are from the Belgian Business Registry, covering all incorporated firms. These annual accounts report information from balance sheets, income statements, and annexes to the annual accounts. Only large firms are required to provide full annual accounts whereas small firms have to only provide short annual accounts so that some variables such as sales, turnover, employment, and material costs may not be provided for small firms. A large firm is defined as a company with an average annual workforce of at least 100 workers or when at least two of the followhing three thresholds are met: (i) annual average workforce of 50 workers, (ii) turnover (excluding VAT) amounts to at least 7,300,000 euros, or (iii) total assets exceeding 3,650,000 euros. Note that the last two thresholds are altered every four years to take account of inflation. Although less than 10 percent of the companies in Belgium report full annual accounts, for firms in the manufacturing sector these account for most of value added (89 percent) and employment (83 percent).

Each firm reports a 5-digit NACE code based on its main economic activity. The key variable of interest is the construction of φ defined as the ratio of total non-Euro imports to total costs (equal to wages plus total material costs). These total cost variables are reported by 58 percent of exporters in the manufacturing sector. Combining this information with the import data, we can set φ equal to zero when total non-Euro imports are zero even if total costs are not reported, giving us a φ for 77 percent of manufacturing exporters, which account for 98 percent of all manufacturing exports.

A.2.3 Product Concordances

We use SITC one-digit product codes (5 to 8) to identify a manuacturing export as it is not possible to do so directly from the CN 8-digit classifications nor from its corresponding HS 6-digit code. We construct a concordance between CN 8-digit codes and SITC Revision 3 by building on a concordance between HS 10-digit and SITC 5-digit from Peter Schott's website, which takes into account revisions to HS codes up to 2006.[40] We update this to take account of HS 6-digit revisions in 2007 using the concordance from the U.S. Foreign Census (see `http://www.census.gov/foreign-trade/reference/products/layouts/imhdb.html`). We begin by taking the first 6-digits of the 8-digit CN code, which is effectively an HS 6-digit code, and we include only the corresponding SITC code when it is a unique mapping. Some HS 6-digit codes map to multiple SITC codes, so that in those cases we do not include a corresponding SITC code. This happens mainly when we get to the more disaggregated SITC codes and rarely at the one-digit SITC code.

Second, we need to match the CN codes to input-output (IO) codes. We use a 2005 Belgium IO matrix with 74 IO codes of which 56 are within the manufacturing sector. The matching of the IO codes to the CN 8-digit was not straightforward as we had to deal with the many-to-many concordance issues. We included an IO code only when the match from the CN code was clear.

A.2.4 Sample

Our sample is for the years 2000 to 2008, beginning with the first year after the euro was formed. We keep all firms that report their main economic activity in manufacturing defined according to 2-digit NACE codes 15 to 36, thus excluding wholesalers, mining, and services. We restrict exports to those that are defined within the manufacturing sector (SITC one-digit codes 5 to 8). To address the multi-product firm issue, we keep only the set of CN 8-digit codes that falls within a firm's major IO export, which we identify as follows. We select an IO code for each firm that reflects the firm's largest export share over the sample period and then keep all CN codes that fall within that IO code. For most of the analysis, we focus on exports to noneuro OECD countries that are defined as advanced by the IMF or high-income by the World Bank.

We keep all import product codes and all import source countries. For some robustness checks, we limit the set of imports to intermediate inputs defined either according to Broad Economic Codes (BEC) by exluding any import that is classified as a consumer good or using the Belgium 2005 IO table to identify a firm's intermediate inputs.

A.2.5 Total Factor Productivity Measures

We measure total factor productivity (TFP) for each firm by first estimating production functions for each 2-digit NACE sector separately. We note that a key problem in the

[40] See Pierce and Schott (2012).

estimation of production functions is the correlation between inputs and unobservable productivity shocks. To address this endogeneity problem we estimate TFP using two different methodologies. The first approach is based on Levinsohn and Petrin (2003) (LP), who propose a modification of the Olley and Pakes (1996) (OP) estimator. OP uses investment as a proxy for unobservable productivity shocks. However, LP finds evidence suggesting that investment is lumpy and hence that investment may not respond smoothly to a productivity shock. As an alternative, LP uses intermediate inputs, such as materials, as a proxy for unobserved productivity. In particular, we assume a Cobb Douglas production function,

$$\nu_{f,t} = \beta_0 + \beta_l l_{f,t} + \beta_k k_{f,t} + \omega_{f,t} + \eta_{f,t}, \tag{A20}$$

where $\nu_{f,t}$ represents the log of value added, $l_{f,t}$ is the log of the freely available input, labor, and $k_{f,t}$ is the log of the state variable, capital. The error term consists of a component that reflects (unobserved) productivity shocks, $\omega_{f,t}$, and a white noise component, $\eta_{f,t}$, uncorrelated with the input factors. The former is a state variable, not observed by the econometrician but which can affect the choices of the input factors. This simultaneity problem can be solved by assuming that the demand for the intermediate inputs, $x_{f,t}$, depends on the state variables $k_{f,t}$ and $\omega_{f,t}$, and

$$x_{f,t} = x_{f,t}(k_{f,t}, \omega_{f,t}). \tag{A21}$$

LP shows that this demand function is monotonically increasing in $\omega_{f,t}$ and hence the intermediate demand function can be inverted such that the unobserved productivity shocks, $\omega_{f,t}$, can be written as a function of the observed inputs, $x_{f,t}$ and $k_{f,t}$, or $\omega_{f,t} = \omega(k_{f,t}, x_{f,t})$. A two-step estimation method is followed where in the first step semi-parametric methods are used to estimate the coefficient on the variable input, labor. In the second step, the coefficient on capital is estimated by using the assumption, as in OP, that productivity follows a first-order Markov process.

However, as pointed out by Ackerberg, Caves, and Frazer (2006), a potential problem with LP is related to the timing assumption of the freely available input, labor. If labor is chosen optimally by the firm, it is also a function of the unobserved productivity shock and capital. Then the coefficient on the variable input cannot be identified. Wooldridge (2009) shows how the two-step semi-parametric approach can be implemented using a unified one-step Generalized Methods of Moments (GMM) framework. This is the second methodology that we adopt for estimating TFP. In particular $\omega_{f,t} = \omega(k_{f,t}, x_{f,t})$ is proxied by a lagged polynomial in capital and materials, which controls for expected productivity in t. We use a third-order polynomial in capital and material in our estimation. To deal with the potential endogeneity of labor, we use its first lag as an instrument. A benefit of this method is that GMM uses the moment conditions implied by the LP assumptions more efficiently. The log of TFP measures are normalized relative to their 2-digit NACE sector mean to make them comparable across industries. The correlation between both measures is very high at 99 percent.

A.3 Additional Figures and Tables

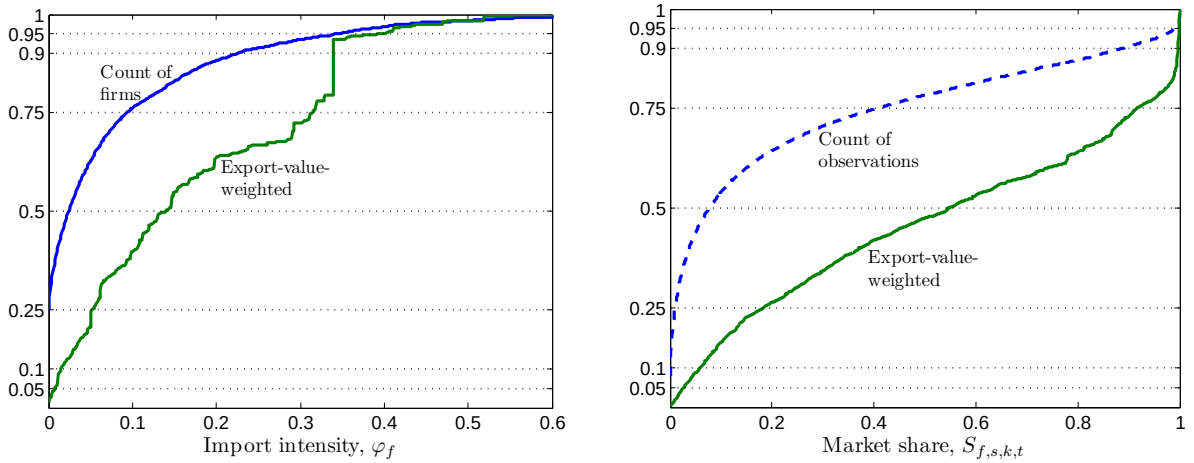

Figure A1: Cumulative distribution functions of import intensity φ_f and market share $S_{f,s,k,t}$

Note: *Estimated cumulative distribution functions. In the left panel, the upper cdf corresponds to the unweighted firm count, while the lower cdf weighs firm observations by their export values. The unweighted distribution of φ_f has a mass point of 24% at $\varphi_f = 0$, while this mass point largely disappears in the value-weighted distribution, which in turn has a step $\varphi_f = 0.33$ corresponding to the largest exporter in our sample with an export share of 14%. In the right panel, the upper cdf corresponds to the count of firm-sector-destination-year observations, and it has small mass points at both $S_{f,s,k,t} = 0$ and $S_{f,s,k,t} = 1$, which largely correspond to small sectors in remote destinations. The lower cdf weighs the observations by their export value, and this weighted distribution has no mass points, although the distribution becomes very steep at the very large market shares.*

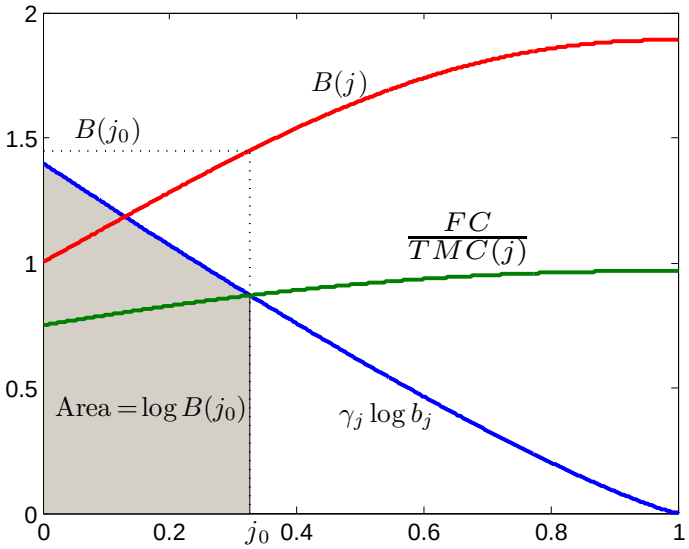

Figure A2: Import cutoff j_0 and cost-reduction factor $B(j_0)$

Note: *$FC = W^* f_i$ is the fixed cost of importing an additional type of intermediate input. $TMC(j) = C^* Y_i / [B(j)^\phi \Omega_i]$ is the total material cost of the firm, decreasing in j holding output fixed due to cost-saving effect of importing. The intersection between $\gamma_j \log b_j$ and $FC/TMC(j)$ defines the import cutoff j_0, and the exponent of the area under $\gamma_j \log b_j$ curve determines the cost-reduction factor from importing.*

Table A1: Pass-through into producer prices and marginal cost by quartiles of import intensity

Dep. variable:	$\Delta p^*_{f,i,k,t}$					$\Delta mc^*_{f,t}$		$\Delta e^M_{f,t}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta e_{\ell,t} \cdot \delta_{1,f}$	0.117***	0.102***	0.163***	0.054	0.062	0.026***	0.053***	0.415***
	(0.036)	(0.037)	(0.055)	(0.038)	(0.038)	(0.007)	(0.006)	(0.063)
$\Delta e_{\ell,t} \cdot \delta_{2,f}$	0.193***	0.164***	0.129***	0.113***	0.133***	0.050***	0.092***	0.449***
	(0.038)	(0.035)	(0.049)	(0.035)	(0.037)	(0.017)	(0.011)	(0.066)
$\Delta e_{\ell,t} \cdot \delta_{3,f}$	0.234***	0.177**	0.223***	0.098*	0.142**	0.097***	0.146***	0.480***
	(0.055)	(0.050)	(0.069)	(0.050)	(0.055)	(0.022)	(0.010)	(0.069)
$\Delta e_{\ell,t} \cdot \delta_{4,f}$	0.314***	0.217***	0.222***	0.135***	0.217***	0.167***	0.213***	0.438***
	(0.037)	(0.037)	(0.055)	(0.040)	(0.035)	(0.037)	(0.018)	(0.082)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$				0.350***	0.416***			
				(0.070)	(0.083)			
$\Delta mc^*_{f,t}$		0.580***		0.575***				
		(0.034)		(0.033)				
FPY FE			yes					
p-value Bin 1 vs 4	0.000***	0.012**	0.403	0.082*	0.000***	0.000***	0.000***	0.465

Note: *92,693 of firm-product-destination-year observations in each specification, unweighted, equally split into four bins according to the associated φ_f values; $\delta_{i,f}$ is a dummy for respective bins (corresponding to the quartiles of φ_f-distribution). All specifications control for country fixed effects. Specifications (4) and (5) also control for the level of the market share $S_{f,s,k,t}$. In columns (1)-(6), $\Delta e_{\ell,t} \equiv \Delta e_{k,t}$ is the destination-specific bilateral exchange rate; in column (7) $\Delta e_{\ell,t} \equiv \Delta e^M_{f,t}$ is the firm-level import-weighted exchange rate (excluding imports from the Euro Zone). column (8) reports the regression of firm-level import-weighted exchange rate $\Delta e^M_{f,t}$ on the destination-specific exchange rate $\Delta e_{k,t}$ by quartiles of φ_f-distribution. p-value for the F-test of equality of the coefficients for quartiles 1 and 4. *, ** and *** corresponds to 10%, 5% and 1% significance. Standard errors clustered at the destination-year level.*

Table A2: Robustness to the definition of import intensity

Dep. var.: $\Delta p^*_{f,i,k,t}$	Lagged time-varying $(\varphi_{f,t-1}, S_{f,s,k,t-1})$ (1)	Drop consumer imports (2)	Drop capital goods (3)	Only IO-table inputs (4)	Only IO-table inputs* (5)	Drop re-exports (6)
$\Delta e_{k,t} \cdot \varphi_{f,\cdot}$	0.332***	0.404***	0.377***	0.391***	0.403***	1.205***
	(0.142)	(0.115)	(0.129)	(0.097)	(0.095)	(0.385)
$\Delta e_{k,t} \cdot S_{f,s,k,\cdot}$	0.264***	0.265***	0.263***	0.265***	0.264***	0.257***
	(0.060)	(0.060)	(0.057)	(0.059)	(0.059)	(0.056)

Note: *The number of observations in column 1 is 87,173 and 92,693 in columns 2–6, with the difference due to the use of lagged market share. Column 1 estimates* (21) *with lagged import intensity and market share variables. Specifications in columns 2–6 are the same as in column 6 of Table 5, but with alternative measures of import intensity φ_f. The coefficient on $\Delta e_{k,t}$ varies very little with the alternative definitions of import intensity and is omitted. Columns 2–6 drop respective categories of imports from the definition of import intensity φ_f: column 2 and 3 exclude consumer and capital goods categories respectively according to the BEC classification; columns 4–5 keep only imports that correspond to intermediate input categories for the exports of the firm according to the input-output tables, where column 5 also focuses on the major export category of the firm; column 6 drops all imports in the same industrial codes as exports of the firm. Other details appear in the text and as in Table 5.*

Table A3: Robustness within destinations and industries

Dep. variable: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)	(4)	(5)
$\Delta e_{k,t} \cdot \varphi_f$	0.569***	0.306***	0.177	0.411***	0.477***
	(0.105)	(0.108)	(0.108)	(0.099)	(0.125)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$			0.252***	0.298***	0.138***
			(0.050)	(0.055)	(0.059)
$\Delta mc^*_{f,t}$		0.578***	0.572***		
		(0.034)	(0.034)		
Fixed effect interactions:					
$\Delta e_{k,t} \times$ country $\times$ SITC-1d	yes	yes	yes	yes	no
$\Delta e_{k,t} \times$ SITC-3d	no	no	no	no	yes
# of industries	4	4	4	4	163

Note: *92,693 observations. Columns 1–4 correspond to specifications in columns 2–3 and 5–6 of Table 5, and additionally include destination-industry fixed effect interacted with the change in the exchange rate. The number of destination is 12, and industries are defined at SITC 1-digit level (4 manufacturing industries). Column 5 repeats the specification in column 4, but replaces the destination-industry interactions with only industry interaction, but at a finer SITC 3-digit level (163 manufacturing industries). All specifications include respective destination-industry fixed effects in levels. Other details appear in the text and as in Table 5.*

Table A4: Robustness with different samples

	Countries			All firms	Dropping	Products		
	all countries	w/out US	only US	including wholesalers	intra-firm trade	all products	HS 4-digit major	HS 4-digit major*
Dep. var.: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta e_{k,t}$	0.065***	0.055*	0.203***	0.168***	0.096**	0.081***	0.128***	0.132***
	(0.014)	(0.033)	(0.059)	(0.032)	(0.037)	(0.030)	(0.041)	(0.042)
$\Delta e_{k,t} \cdot \varphi_f$	0.240***	0.352***	0.567*	0.217**	0.390***	0.529***	0.368**	0.492***
	(0.068)	(0.104)	(0.328)	(0.088)	(0.096)	(0.100)	(0.177)	(0.167)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$	0.081***	0.277***	0.262**	0.119*	0.188***	0.226***	0.184***	0.175**
	(0.027)	(0.059)	(0.120)	(0.061)	(0.067)	(0.051)	(0.057)	(0.071)
# countries	59	11	1	12	12	12	12	12
# observations	206,610	81,745	10,948	157,431	78,851	142,998	62,301	52,729

Note: *Main specification from column 6 of Table 5 estimated in alternative subsamples of the data. All the details are as in Table 5. column 5 excludes all transactions if the Belgian firm has either inward or outward FDI with that destination. columns 7 keeps only the major good reported by the firm at the HS 4-digit level, and column 8 keeps only this good if its market share in the firm's exports is above 50%.*

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