Online appendix to
Importers, Exporters, and Exchange Rate Disconnect

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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 key determinants of pass-through in the cross-section of firms. A small exporter with no imported inputs has a nearly complete pass-through, while a firm at the 95th percentile of both import intensity and market share distributions has a pass-through of just above 50%, 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
JEL classification: F14, F31, F41

A.1 Additional Figures and Tables

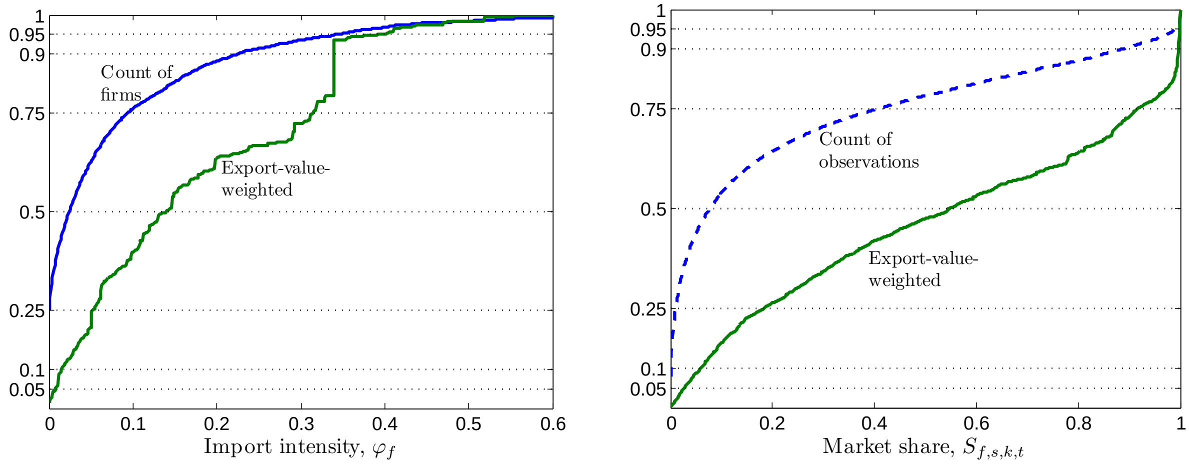

Figure A1: Cumulative distribution functions of import intensity φ_f and market share $S_{f,s,k,t}$

Note: *Estimated cumulative distribution functions. In the left panel, the upper cdf corresponds to the unweighted firm count, while the lower cdf weights 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 weights 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.*

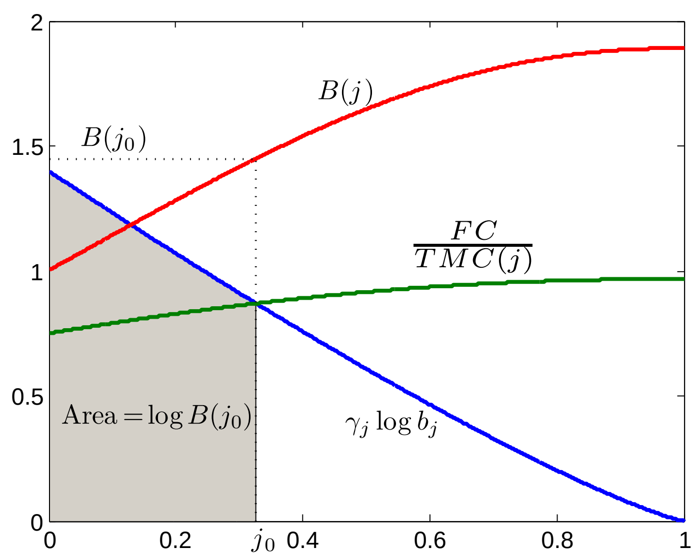

Figure A2: Import cutoff j_0 and cost-reduction factor $B(j_0)$

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)
$\Delta e_{\ell,t} \cdot \delta_{1,f}$	0.128***	0.115***	0.071**	0.077**	0.023***	0.054***	0.399***
	(0.034)	(0.034)	(0.035)	(0.035)	(0.007)	(0.006)	(0.065)
$\Delta e_{\ell,t} \cdot \delta_{2,f}$	0.203***	0.176***	0.130***	0.149***	0.047***	0.092***	0.434***
	(0.036)	(0.034)	(0.033)	(0.035)	(0.017)	(0.011)	(0.068)
$\Delta e_{\ell,t} \cdot \delta_{3,f}$	0.239***	0.185***	0.113**	0.154***	0.095***	0.145***	0.466***
	(0.053)	(0.049)	(0.048)	(0.052)	(0.022)	(0.010)	(0.070)
$\Delta e_{\ell,t} \cdot \delta_{4,f}$	0.321***	0.227***	0.152***	0.232***	0.165***	0.213***	0.421***
	(0.039)	(0.040)	(0.041)	(0.035)	(0.037)	(0.018)	(0.084)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$			0.205***	0.238***			
			(0.053)	(0.059)			
$\Delta mc^*_{f,t}$		0.569***	0.565***				
		(0.031)	(0.031)				
p-value Bin 1 vs 4	0.000***	0.014**	0.081*	0.000***	0.000***	0.000***	0.479
# obs.	93,395	93,395	93,395	93,395	93,395	89,504	89,504
R^2	0.003	0.010	0.010	0.003	0.025	0.045	0.214

Note: *Nonparametric regressions: firm-product-destination-year observations split into four equal-sized bins by value of import intensity* φ_f*, with* $\delta_{q,f}$ *denoting a dummy for respective bins (quartiles* $q = 1, 2, 3, 4$*). No fixed effects included in nonparametric specifications. Specifications (3) and (4) additionally control for the level of the market share* $S_{f,s,k,t}$*. In columns 1–5 and 7,* $\Delta e_{\ell,t} \equiv \Delta e_{k,t}$ *is the destination-specific bilateral exchange rate; in column 6,* $\Delta e_{\ell,t} \equiv \Delta e^M_{f,t}$ *is the firm-level import-weighted exchange rate (excluding imports from the Euro Zone). In column 7, firm-level import-weighted exchange rate* $\Delta e^M_{f,t}$ *is regressed on the destination-specific bilateral exchange rate* $\Delta e_{k,t}$*.* p*-value for the* F*-test of equality of the coefficients for quartiles 1 and 4. Standard errors clustered at the destination-year level.*

Table A2: High exchange rate correlation source-destination pairs

Destination	# of source countries		Share of imports from	
	pegs	corr $\geq$ 0.7	destination	corr $\geq$ 0.7
Australia	1	6	0.5%	5.2%
Canada	0	79	2.5%	58.7%
Iceland	0	6	0.1%	2.3%
Israel	0	77	0.5%	41.2%
Japan	0	22	5.1%	16.0%
Korea	0	24	1.6%	33.9%
New Zealand	0	3	0.3%	0.6%
Norway	0	1	1.2%	1.3%
Sweden	0	4	5.0%	6.8%
Switzerland	0	1	6.3%	6.7%
United Kingdom	0	12	23.0%	30.3%
United States	30	79	17.6%	38.0%

Note: *Total number of non-Euro source countries: 210. Number of countries in the first two columns excludes destination itself, while the share of imports in the last column includes imports from the destination country.*

Table A3: High and low pass-through import source countries

High pass-through ($\geq$ 0.50)			Low pass-through (< 0.50)		
Country	Pass-through	Import share	Country	Pass-through	Import share
Peru	1.20***	0.5%	Israel†	0.45***	0.2%
Bangladesh	0.93***	0.2%	India	0.42***	1.0%
Chile	0.75***	0.2%	Brazil	0.41***	3.1%
Taiwan	0.74***	0.5%	Thailand	0.41***	1.0%
Canada†	0.71***	1.8%	Sri Lanka	0.40**	0.2%
Australia†	0.69**	1.5%	Malaysia	0.40***	0.3%
Saudi Arabia	0.67**	1.3%	Egypt	0.39***	0.4%
China	0.67***	3.8%	Philippines	0.39*	0.5%
United States†	0.63***	16.6%	Venezuela	0.36**	0.4%
Russia	0.62***	3.8%	Singapore	0.31	0.2%
Hong Kong	0.61***	0.2%	Sweden†	0.31***	14.3%
Japan†	0.55***	5.4%	South Korea†	0.24***	0.9%
Colombia	0.55***	0.3%	United Kingdom†	0.19***	15.7%
Switzerland†	0.53***	1.5%	Indonesia	0.18**	0.6%
Mexico	0.50***	0.4%	Ukraine	0.15	0.2%
			Argentina	0.08**	0.3%
			Turkey	0.02	1.5%
			Pakistan	−0.02	0.2%
			Vietnam	−0.03	0.3%
			South Africa	−0.09	1.0%

Note: *Non-OECD import source countries with a share in Belgian imports above 0.2% and precisely estimated pass-through into import prices of Belgian firms, split into high and low pass-through bins with a threshold pass-through of 0.5. † marks high-income OECD countries. High-pass-through countries also include Guatemala, Macao, Uganda and United Arab Emirates; Low-pass-through countries also include Belarus, Congo, Dominican Republic, Ethiopia, Ghana, Honduras, Madagascar, New Zealand†, Paraguay, Uruguay, Zambia, Zimbabwe. For the remaining import source countries, which form the "Other" bin in Table 7, the pass-through estimates are too imprecise either because of too few observations or too little variation in the exchange rate against the euro (this latter group consists mainly of the non-Euro-Area European source countries which account for the majority of imports in the "Other" bin).*

Table A4: Robustness to the definition of import intensity

Dep. var.: $\Delta p^*_{f,i,k,t}$	Lagged time-varying $(\varphi_{f,t-1}, S_{\cdot,t-1})$ (1)	Only manuf. imports (2)	Drop consumer goods (3)	Drop capital goods (4)	Only IO-table inputs (5)	Only IO-table inputs* (6)	Drop inputs in export CN8 (7)
$\Delta e_{k,t}$	0.054*	0.062**	0.068**	0.065**	0.057*	0.056*	0.077**
	(0.032)	(0.030)	(0.030)	(0.032)	(0.031)	(0.031)	(0.033)
$\Delta e_{k,t} \cdot \varphi_{f,\cdot}$	0.452***	0.459***	0.429***	0.450***	0.471***	0.486***	1.062***
	(0.154)	(0.114)	(0.135)	(0.153)	(0.106)	(0.106)	(0.376)
$\Delta e_{k,t} \cdot S_{f,s,k,\cdot}$	0.278***	0.294***	0.292***	0.286***	0.287***	0.286***	0.288***
	(0.058)	(0.064)	(0.063)	(0.062)	(0.063)	(0.063)	(0.060)
FE: $\delta_{s,k} + \delta_t$	yes	yes	yes	yes	yes	yes	yes
# obs.	87,799	93,395	93,395	93,395	93,395	93,395	93,395
R^2	0.059	0.058	0.057	0.057	0.057	0.057	0.057

Note: *Column 1 estimates* (21) *with lagged import intensity and market share variables. Specifications in columns 2–7 are the same as in column 6 of Table 5, but with alternative measures of import intensity* φ_f*, dropping respective categories of imports from the definition of* φ_f*: Column 2 keeps only manufacturing products; Columns 3 and 4 exclude consumer and capital goods categories respectively according to the BEC classification; Columns 5 and 6 keep only imports that correspond to intermediate input categories for the exports of the firm according to the input-output tables, where column 6 additionally focuses on the major export category of the firm; Column 7 drops all imports in the same CN-8 industrial codes as exports of the firm. Other details appear in the text and as in Table 5.*

Table A5: Robustness with different samples

	Destinations			All firms	Dropping	Products		
	all	w/out	only	including	intra-firm	all	HS 4-digit	
	countries	US	US	wholesalers	trade	products	major	major*
Dep. var.: $\Delta p^*_{f,i,k,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta e_{k,t}$	−0.011	0.034	0.184**	0.094***	0.070**	0.062**	0.102**	0.090**
	(0.016)	(0.035)	(0.062)	(0.028)	(0.033)	(0.027)	(0.042)	(0.045)
$\Delta e_{k,t} \cdot \varphi_f$	0.263***	0.438***	0.652*	0.335***	0.479***	0.587***	0.400**	0.505***
	(0.064)	(0.122)	(0.385)	(0.079)	(0.120)	(0.107)	(0.175)	(0.165)
$\Delta e_{k,t} \cdot S_{f,s,k,t}$	0.097***	0.292***	0.312***	0.162***	0.211***	0.224***	0.195***	0.198**
	(0.029)	(0.062)	(0.110)	(0.057)	(0.071)	(0.051)	(0.070)	(0.087)
Fixed Effects:								
$\delta_{s,k} + \delta_t$	yes	yes	no	yes	yes	yes	yes	yes
δ_s	no	no	yes	no	no	no	no	no
# countries	55	11	1	12	12	12	12	12
# obs.	218,879	82,438	10,957	158,804	79,461	143,912	62,679	53,037
R^2	0.077	0.058	0.055	0.041	0.062	0.043	0.057	0.060

Note: *Main specification from column 6 of Table 5 estimated with alternative subsamples of the data. In column 3, δ_s are sector fixed effects at HS-4 digit level. All other details are as in Table 5. Column 5 excludes all firm-destination observations if the Belgian firm has either inward or outward FDI with that destination. Column 6 keeps all of the firms's manufacturing exports (i.e., not only its major products). Column 7 uses an alternative definition of the firm's major product and keeps only the major good reported by the firm at the HS 4-digit level, and column 8 keeps only these HS 4-digit major goods if its market share in the firm's exports is above 50%.*

A.2 Theoretical Appendix

A.2.1 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:

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

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 13. 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

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

Choice of J_0 without uncertainty solves $\min_{J_0} TC^*(Y|J_0)$, given output Y.[1] 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 the definition of total cost (A4), holding J_0 constant, the marginal cost equals $MC^*(J_0) = \lambda$ defined in (A2). We have:

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

[1] We first consider the case without uncertainty to establish the fundamental determinants of import intensity in a simpler setup, and next generalize the results to the case with uncertainty (*cf.* (A5) and (A6)).

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

A.2.2 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 (bringing back the firm identifier i) as:

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

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 the price setting equation (11).

Now consider the choice of $J_{0,i}$. By the 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.2.3 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 the 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:[2]

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

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

This assumption implies that the (level of) markup does not vary too much with the productivity of the firm, so that high-market-share firms are simultaneously high-material-cost firms (as we document is the case in the data, see Table 4).[3] 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 the 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 the import set is internal for both firms, we can rewrite (A6) as a condition for a cutoff $j_0(i)$:

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

[2]Note that taking these ratios 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 the price index, which affect outputs and market shares of firms proportionately, drop out.

[3]This assumption is not very restrictive for the parameters of the model, as for a moderate value of $\rho = 4$, it only requires $\bar{S} < 0.8$ (given the definition of Γ in (4) and $\eta \geq 1$).

and log-linearize it to yield:

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

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

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

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

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

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

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

The parameter restriction in A2 is a 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

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

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 exogenous characteristics. These 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, the (expected) market share and import intensity of the firm are both increasing in its productivity and quality/demand shifter, and are both decreasing in the firm's fixed cost of importing, 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 numbers of destinations.

A.2.4 Pass-through relationship and proof of Proposition 3

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

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

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:

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

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:

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

where

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

$\mathrm{d}\log\bar{\xi}_k$ is the sector-destination average change in demand/quality across firms, and we denote 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 $\left(\epsilon_{k,i}^{MC}, \epsilon_{k,i}^{\mathcal{M}}\right)$, *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:

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

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*

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

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* $\bar{\epsilon}'_{k,i} \equiv \epsilon_i^{MC} + \frac{\bar{\Gamma}_{s,k}}{\rho-1}\epsilon_{k,i}^{\mathcal{M}}$, $\bar{\epsilon}''_{k,i} \equiv \frac{\bar{\Gamma}_{s,k}}{\rho-1}\epsilon_{k,i}^{\mathcal{M}} - \epsilon_i^{MC}$.

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

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

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

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, $\mathbb{E}\big\{\epsilon_{k,i}/\mathrm{d}\log\mathcal{E}_k\big\} = 0$. Finally, note that $\Psi^{\cdot}_{s,k} \approx \mathrm{cov}(\cdot,\mathrm{d}\log\mathcal{E}_k)/\mathrm{var}(\mathrm{d}\log\mathcal{E}_k)$, that is Ψ-terms are approximately projection coefficients. The expectations and the definitions of Ψ-terms are unconditional, and hence average across all possible initial states and paths of the economy. ■

A.2.5 Empirical specification and proof of Proposition 4

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

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

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 $(s,k,t-1)$ are 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 the exchange rate, which we require in the proof of Proposition 4. One interpretation of this assumption is that the 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:

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

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:

$$\Delta p^*_{i,k,t} \approx \left[\underbrace{\frac{\bar{\Gamma}_{s,k}(1+\rho^P_{s,k}) + \rho^C_{s,k}}{1+\bar{\Gamma}_{s,k}}}_{\equiv \alpha_{s,k}} + \underbrace{\frac{\rho^M_{s,k}}{1+\bar{\Gamma}_{s,k}}}_{\equiv \beta_{s,k}} \cdot \varphi_{i,t-1} + \underbrace{\frac{[(1-\bar{\varphi}_s\rho^M_{s,k}) + (\rho^P_{s,k} - \rho^C_{s,k})]\bar{g}_{s,k}\mathbf{S}_{s,k,t-1}}{1+\bar{\Gamma}_{s,k}}}_{\equiv \tilde{\gamma}_{s,k,t}} \cdot \frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}} \right] \Delta e_{k,t}$$

$$+ \underbrace{\frac{v^M_{s,k,t}}{1+\bar{\Gamma}_{s,k}}}_{\equiv b_{s,k}} \cdot \varphi_{i,t-1} + \underbrace{\frac{\left(v^P_{s,k,t} - v^C_{s,k,t} - \bar{\varphi}_{s,t-1}v^M_{s,k,t}\right)\bar{g}_{s,k}\mathbf{S}_{s,k,t-1}}{(1+\bar{\Gamma}_{s,k})^2}}_{\equiv c_{s,k,t}} \cdot \frac{S_{k,i,t-1}}{\mathbf{S}_{s,k,t-1}} + u_{k,i,t},$$

$$u_{k,i,t} = \frac{\bar{\Gamma}_{s,k}v^P_{s,k,t} + v^C_{s,k,t} + \bar{\epsilon}'_{i,t}}{1+\bar{\Gamma}_{s,k}} + + \frac{\bar{g}_{s,k}S_{k,i,t-1}}{(1+\bar{\Gamma}_{s,k})^2}\bar{\epsilon}''_{k,i,t}.$$

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

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

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 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):

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

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:

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

where σ_k^2 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.

Equation (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:

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

$\omega'_{s,k,t} \propto \sigma_k^2 n_{s,k,t}\, \mathrm{var}_{s,k,t-1}(\varphi_{i,t-1})$ and $\omega''_{s,k,t} \propto \sigma_k^2 n_{s,k,t}\, \mathrm{var}_{s,k,t-1}(S_{k,i,t-1}/\mathbf{S}_{s,k,t-1})$ with $\mathrm{var}_{s,k,t-1}(\cdot)$ 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.2.6 Selection bias

In this appendix we provide a brief exposition of the theoretical arguments for the direction of the potential bias of the coefficient estimates in equation (21) due to sample selection. We also provide corroborating empirical evidence.

For simplicity, imagine an environment with no sunk cost and only fixed cost $F_{k,i}$ of supplying each market k for firm i, and denote with $\Pi_{k,i}$ the operating profit of firm i from serving market k. Then the selection equation is $\Pi_{k,i} \geq F_{k,i}$, or equivalently $\log\left(\Pi_{k,i}/F_{k,i}\right) \geq 0$. A general approximation to the profit function, which can also be derived from the structure of the profit maximization problem introduced in Section 2.3, results in the following selection condition:

$$\log \frac{\Pi_{k,i,t}}{F_{k,i,t}} \approx \delta_{s,k} + \delta_t + \Delta_{k,i,t-1} + \theta \Delta e_{k,t} + v_{k,i,t} \geq 0, \tag{A20}$$

where $\delta_{s,k}$ and δ_t are sector-destination and year dummies, $\Delta_{k,i,t-1}$ is a combination of firm-destination characteristics (such as productivity Ω_i and demand shifter $\xi_{k,i}$) and $v_{k,i,t}$ is an idiosyncratic firm-destination shock in period t. In words, approximation (A20) implies that firms are more likely to stay in the sample under favorable industry-destination-year conditions (high $\delta_{s,k} + \delta_t$), when the domestic exchange rate depreciates (high $\Delta e_{k,t}$), when firms have strong fundamentals (large $\Delta_{k,i,t-1}$), and when firms face a favorable idiosyncratic shock (large $v_{k,i,t}$). For our purposes we project $\Delta_{k,i,t-1} = a\varphi_{i,t-1} + bS_{k,i,t-1} + \xi_{k,i,t-1}$.

Next consider our empirical specification:

$$\Delta p^*_{k,i,t} = \delta_q + \alpha_q \Delta e_{k,t} + u_{k,i,t}, \tag{A21}$$

estimated within bins q of import intensity and market share (analogous to Table 6). We assume that $u_{k,i,t}$ is negatively correlated with $v_{k,i,t}$. Intuitively, this implies that an adverse marginal cost shock (e.g., negative productivity shock) both reduces $v_{k,i,t}$ and increases $u_{k,i,t}$. This assumption can be formally derived from the structure of our model: we can decompose $v_{k,i,t} = z_{k,i,t} - \rho u_{k,i,t}$, where $\rho > 0$ and $u_{k,i,t}$ and $z_{k,i,t}$ are uncorrelated. Then the selection equation (A20) can be rewritten as:

$$u_{k,i,t} \leq \gamma_{k,i,t} + \frac{\theta}{\rho}\Delta e_{k,t}, \qquad \text{where} \qquad \gamma_{k,i,t} \equiv \frac{1}{\rho}\left[\delta_{s,k} + \delta_t + a\varphi_{i,t-1} + bS_{k,i,t-1} + \xi_{k,i,t} + z_{k,i,t}\right].$$

We directly verify in the data that $a, b, \theta > 0$ (see the table below).

Given this econometric model, we can directly evaluate the magnitude of the bias of an OLS estimate of α_q. First, for each bin q we calculate:

$$\mathbb{E}\left\{\Delta p^*_{k,i,t} | \Delta e_{k,t}\right\} = \delta_q + \alpha_q \Delta e_{k,t} + f_q(\Delta e_{k,t}),$$

where

$$f_q(\Delta e_{k,t}) = \mathbb{E}\left\{ u_{k,i,t} \middle| \Delta e_{k,t}, u_{k,i,t} \leq \gamma_{k,i,t} + \frac{\theta}{\rho}\Delta e_{k,t} \right\}.$$

With $u_{k,i,t}$ unconditionally mean zero, we have the following properties (provided $\theta \geq 0$):

$$f_q(\cdot) \leq 0, \quad f_q(\infty) = 0, \quad f'_q(\cdot) \geq 0, \quad f_{q'}(\cdot) \geq f_q(\cdot), \quad f'_{q'}(\cdot) \leq f'_q(\cdot).$$

The last two properties come from the fact that in bin q' with higher $\varphi_{i,t-1}$ and/or $S_{k,i,t-1}$ the distribution of $\gamma_{k,i,t}$ is shifted to the right (first order stochastically dominates), relative to that for bin q. In the special case of $\theta = 0$, we have $f_q(\cdot) \equiv f_q$, a q-specific constant.

Given this calculation, we can evaluate the bias in the OLS estimate of α_q as the standard omitted variable bias:

$$bias(\hat{\alpha}_q) = p\lim\big(\hat{\alpha}_q - \alpha_q\big) = \frac{\mathrm{cov}\big(\Delta p^*_{k,i,t}, \Delta e_{k,t}\big)}{\mathrm{var}\big(\Delta e_{k,t}\big)} - \alpha_q = \frac{\mathrm{cov}\big(f_q(\Delta e_{k,t}), \Delta e_{k,t}\big)}{\mathrm{var}\big(\Delta e_{k,t}\big)} \geq 0,$$

since $f_q'(\cdot) \geq 0$ whenever $\theta > 0$. For $\theta = 0$, the bias equals zero. Furthermore, the bias is (weakly) smaller (closer to zero) for bin q' than for bin q, if $\varphi_{i,t-1}$ and/or $S_{k,i,t-1}$ are higher in bin q' than in bin q.

To summarize, whenever $a, b, \theta > 0$, the OLS estimates have an upward bias in α (downward bias in the level of pass-through), which diminishes with import intensity and market share. This in turn implies a downward bias in β and γ.

The table below estimates a Probit regression for the probability of staying in the sample ($\iota_{f,t} = 1$):

$\mathbb{P}\{\iota_{f,t} = 1 \vert \iota_{f,t-1} = 1\}$	(1)	(2)	(3)	(4)
φ_f	0.066***	0.084***	0.025	0.284***
	(0.025)	(0.025)	(0.026)	(0.027)
$S_{f,s,k,t-1}$	0.564***	0.558***	0.710***	0.777***
	(0.011)	(0.011)	(0.011)	(0.013)
$\Delta e_{k,t}$	0.745***	0.354***	0.090	0.094
	(0.048)	(0.065)	(0.067)	(0.068)
Fixed Effects	—	δ_t	$\delta_t + \delta_k$	$\delta_t + \delta_k + \delta_s$
# obs.	172,988	172,988	172,988	172,988

Note: $\delta_t, \delta_k, \delta_s$ are year, country and industry (HS 2-digit) fixed effects respectively. The dependent variable equals 1 in 67.6% of the observations.

This confirms that firms with high import intensity and market share are less likely to drop out of the sample ($a, b > 0$). Further, this table provides evidence that exit is more likely in response to exchange rate appreciation ($\Delta e_{k,t} < 0$), that is $\theta > 0$.

A.3 Data Appendix

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.

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, 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. Note that in less than half a percent of the observations, total imports were greater than material costs in which case we treated φ as missing.

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 (see Pierce and Schott, 2012). 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 IO codes are based on the Statistical Classifications of Product by Activity, abbreviated as CPA, which in turn are linked to the CN 8-digit codes using the Eurostat correspondence tables.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.

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 multiproduct 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 and 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 using the Belgium 2005 IO table or according to Broad Economic Codes (BEC). See `http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=10`, where we define intermediate inputs as including codes 111, 121, 2, 42, 53, 41, and 521.

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 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,

$$\nu_{f,t} = \beta_0 + \beta_l l_{f,t} + \beta_k k_{f,t} + \omega_{f,t} + \eta_{f,t}, \tag{A22}$$

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

$$x_{f,t} = x_{f,t}(k_{f,t}, \omega_{f,t}). \tag{A23}$$

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.

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